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FRONTIERS IN WOOD AND BIOMASS SUPPLY CHAIN OPTIMISATION

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In many parts of the wood products markets are becoming increasingly competitive and complex. The increased competition from a globalised wood and biomass industry will require that increased efficiency from producers who seek to gain access to new markets or hold existing markets from new competitive pressures. Buyers are demanding, and suppliers are offering, wood and biomass products for very specific end-uses and which may be specified in terms of internal as well as external properties. Optimally matching these products to markets requires good measurements and/or predictions of the wood and biomass properties. Thus, improved and optimised management of the forestry supply chain is a cornerstone for modern timber management to remain a viable enterprise.

In this presentation, the state-of-the-art optimisation techniques and technologies for efficient biomass supply chains are presented. Supply chain optimisation is the application of processes and tools to ensure the optimal operation of a manufacturing and distribution supply chain. In wood and biomass supply chains this includes the optimal placement of inventory within the supply chain, minimising operating costs (including manufacturing costs, transportation costs, and distribution costs). This often involves the application of mathematical modelling techniques using computer software aiming to produce and to deliver the right product at the right time and for the right customer with the goal of maximising revenue and/or product margins.

Analytics, defined as the scientific process of transforming data into insight for making better decisions, is one of the pillars of state-of-the-art business and supply chain optimisation. Thus, analytics, and specifically prescriptive analytics (PA), defined as the area of business analytics (BA) dedicated to finding the best course of action for a given situation, are presented and discussed. The goal of prescriptive analytics is to enable quality improvements, service enhancements, cost reductions, and productivity increases. Optimisation is a type of prescriptive analytics that finds a "best" solution from a set of "feasible" solutions, using a mathematical algorithm that maximises or minimises a specified objective function subject to constraints". Mathematical optimisation is one of the most important and widely used techniques in operations research (OR), a scientific method that arose after World War II, as a "scientific method of providing executive departments with a quantitative basis for decisions regarding the operations under their control".

The four steps for the implementation of a prescriptive (optimisation) model are discussed. This includes the Objective function (What do I want to achieve?), Decisions, (What do I need to decide on?), Restrictions (What do I have to adhere to?) and Inputs (What do I know?). Ultimately, an optimisation model allows finding the best combination(s) possible, understand the effect of decisions, and explore what-ifs. An optimisation model is implemented through a set of mathematical equations representing the objective function and the constraints of the supply chain problem to be solved. Modern commercial platforms (e.g AIMMS and IBM Ilog CPLEX Optimization Studio) have been developed for such purpose. These platforms enable rapid development and deployment of decision optimisation models using mathematical and constraint programming. They combine a fully featured integrated development environment that supports an optimisation programming language and the high-performance optimiser solvers.

Supply chain optimisation models at a strategical, tactical, an operational level are also shown, including practical examples of the implementation of these models, and a discussion of the problems to be solved, the mathematical solution techniques, and the software technology to solve the models. Examples will include practical tools developed by AFORA-USC in Australia, such FastPLAN (tactical planning), MCPlan (wood and biomass supply chain optimisation), and FastTRUCK (truck scheduling systems).

The presentation will also discuss opportunities for improvements in the wood and biomass supply chain including improved characterisation of the resources, log tracking and collaborative planning. In addition, the presentation will expose concepts and technologies around "Industry 4.0", name given to the current trend of automation and data exchange in manufacturing technologies, and the potential use of the technologies to optimise wood and biomass supply chains. Thus, some of the technologies supporting real-time data collection, internet of things, automation and robotics, and data analytics will be presented and discussed. These include mobile technologies, machine to machine technologies, artificial intelligence and big data analytics (deep learning, machine learning), and virtual and augmented reality, among others.

The presentation will finalise discussing the challenges and opportunities of state-of-the-art supply chain optimisation for practitioners and researchers, and presenting future initiatives in supply chain optimisation for research and education.

Keywords: biomass supply chain, optimisation, operations research, data and prescriptive analytics, Industry 4.0

FORESTS, FOREST OPERATIONS AND CLIMATE CHANGE

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Keywords: climate change, forest operations, forest disturbances

1. Introduction

Changing climate affects forestry and forest operations in two main ways: It changes the physical conditions, where forest operations are performed. Depending on the geographic area in Europe, it can, for example, increase or decrease the growth and yield of forests and subsequently availability of wood for forest industries. Today, especially the northern part of Europe gains already from an elevated forest productivity due to climate change (Kellomäki et al. 2017). However, harvesting conditions have already changed in the northern parts of Europe and winters are becoming shorter and shorter. Thus, the period when heavy machines can operate on sensitive and wet soils becomes shorter. In addition, the forest disturbances cause unplanned large scale salvage loggings in southern Europe and Canada due to forest fires and in Central Europe and Canada due to massive insect outbreaks.

The political attempts to mitigate the climate change are growing. The Paris Agreement sets out a long-term goal in line with the objective to keep the global temperature increase well below 2°C above pre-industrial levels and to pursue efforts to keep it to 1.5°C above pre-industrial levels. Earlier the climate policy and agreements were focusing on the reduction of fossil emissions and mechanisms such as emission trading were developed. Later transport sector, agriculture, housing and waste management have been brought in the climate policy. Last year also the LULUCF (Land use, land use change and forestry) sector became an integral part of EU's climate policy. LULUCF sector can contribute to climate change mitigation in several ways, in particular by reducing emissions, and maintaining and enhancing sinks and carbon stocks. In order for measures aiming in particular at increasing carbon sequestration to be effective, the long-term stability and adaptability of carbon pools is essential (Regulation…2018). Because member countries can use their forests and part of their carbon binding capacity to compensate the fossil carbon emissions, the ratio between the growth and drain (fellings + natural dying) will be of interest. Simultaneously, forest and their wood sources are the feedstock for the growing forest and energy industry that is an essential part of growing bioeconomy.

The bioeconomy encompasses the utilisation of renewable biological resources and the conversion of these resources (including side- and waste streams) into value-added products, technology and services (Nordic bioeconomy...2018). The bioeconomy has the potential to replace many of the fossil-based products (energy, materials and chemicals) upon which we are so heavily reliant, and to reduce the carbon footprint of food and feed by increasing resource efficiency and upgrading side-streams. In this way, the bioeconomy can contribute significantly to the United Nations COP process and to reaching the 17 Sustainable Development Goals for 2030 (Nordic bioeconomy…2018).

Because of its dual role as a source of carbon neutral raw material and a biological engine capable to bind and store carbon, the balancing of these two functions can have significant impacts on forestry, forest industry and their sourcing or raw materials.

This paper presents examples of the impacts of changing climate on the forests and forest operations. The direct impacts related with the changes in the forests, terrain, precipitation and temperature are discussed. In addition, indirect impacts due to natural disturbances and their effects on wood sourcing are presented. Finally, the potential impacts of climate change mitigation related policies are discussed.

2. Climate change and forests

2.1 Historical development of the climate in Europe

Long term changes in the climate have been researched using many indirect sources of weather data. In this paper I present a proxy that is close to forestry and foresters: The dendro-chronology series that are based on the analysis of the variation of the widths of annual rings. These time series stretches over 8000 years to the history. Longest European annual-ring based series are over 7600 years long (Figure 1). Time series show, how temperature has been varying over millennia and that we are now experiencing a very warm period. According to weather statistics the temperature has already risen over 2°C in Nordic countries.

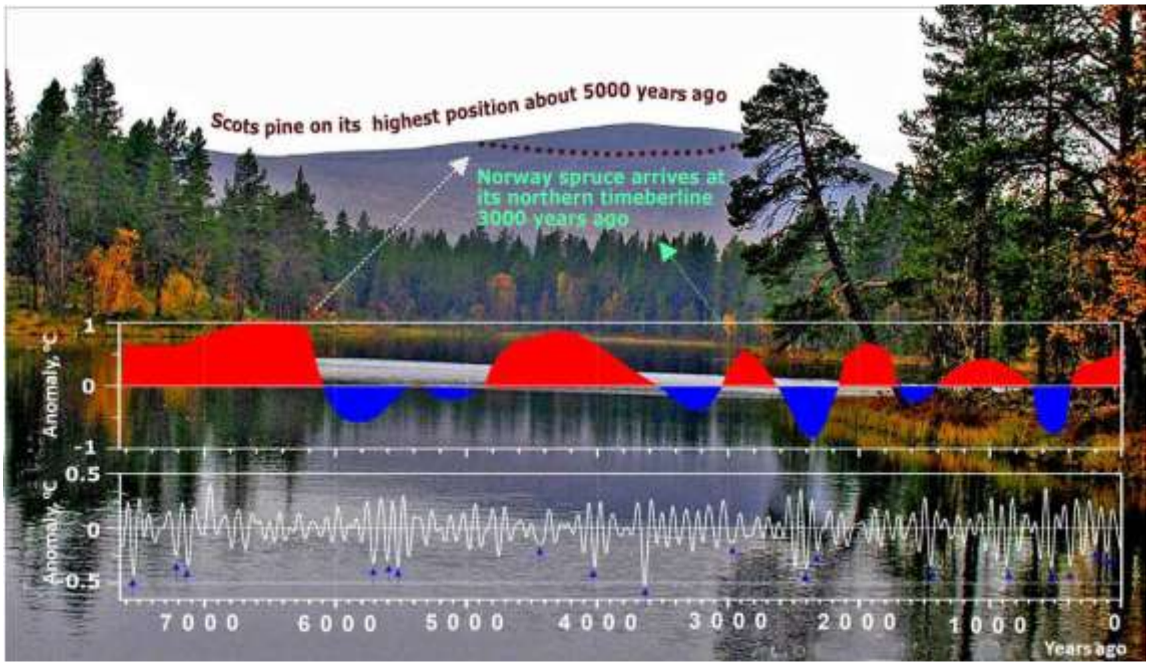

Figure 1 Deviations from the average climate according to the dendro-chronological time series (Mielikäinen et al 2012).

2.2 Changes in the climatic conditions and their impacts on the forests

Changing climate and have impacts on the risks associated with forests and forest disturbances. The risk of forest fires has a rather direct link to the temperature and rainfall variation. Several weather models show, how the dry periods are evolving in Europe. Mediterranean parts of Europe will experience severe droughts in the future. Same trend can be seen across Europe. Although the development is not as evident as in Southern parts, the absolute temperature changes has many impacts on forests: The droughts are more frequent, rising temperatures favor number of insects and fungi and the bearing capacity of terrain will change.

By now, the positive impact of rising temperatures has been most visible in the Nordic countries. In Europe, the growth of forests has increased substantially in recent decades. This is mainly resulting from the intensified silviculture and tree breeding. However, in the boreal forests the temperature is the factor that reduces growth of trees. In a recent study it was estimated that about 1/3 of the growth improvement in the Finnish forests is associated with the climate change and other changes in the growth environment (Henttonen et al. 2017). Figure 2 shows how probability of threshold degree days (1500 dd) of Spruce bark beetle to produce two generations in a summer evolves across Europe. Mass infestations can invoke large salvage cuttings. Warming winters has been identified to have been one of key factors that triggered one of the largest insect outbreaks in British Columbia, Canada, where Mountain bark beetle has killed c.s. 1 billion m^3 pine forest and subsequently, forest fires have reached the scale of 1.2 million ha in 2017 (Asikainen et al 2018).

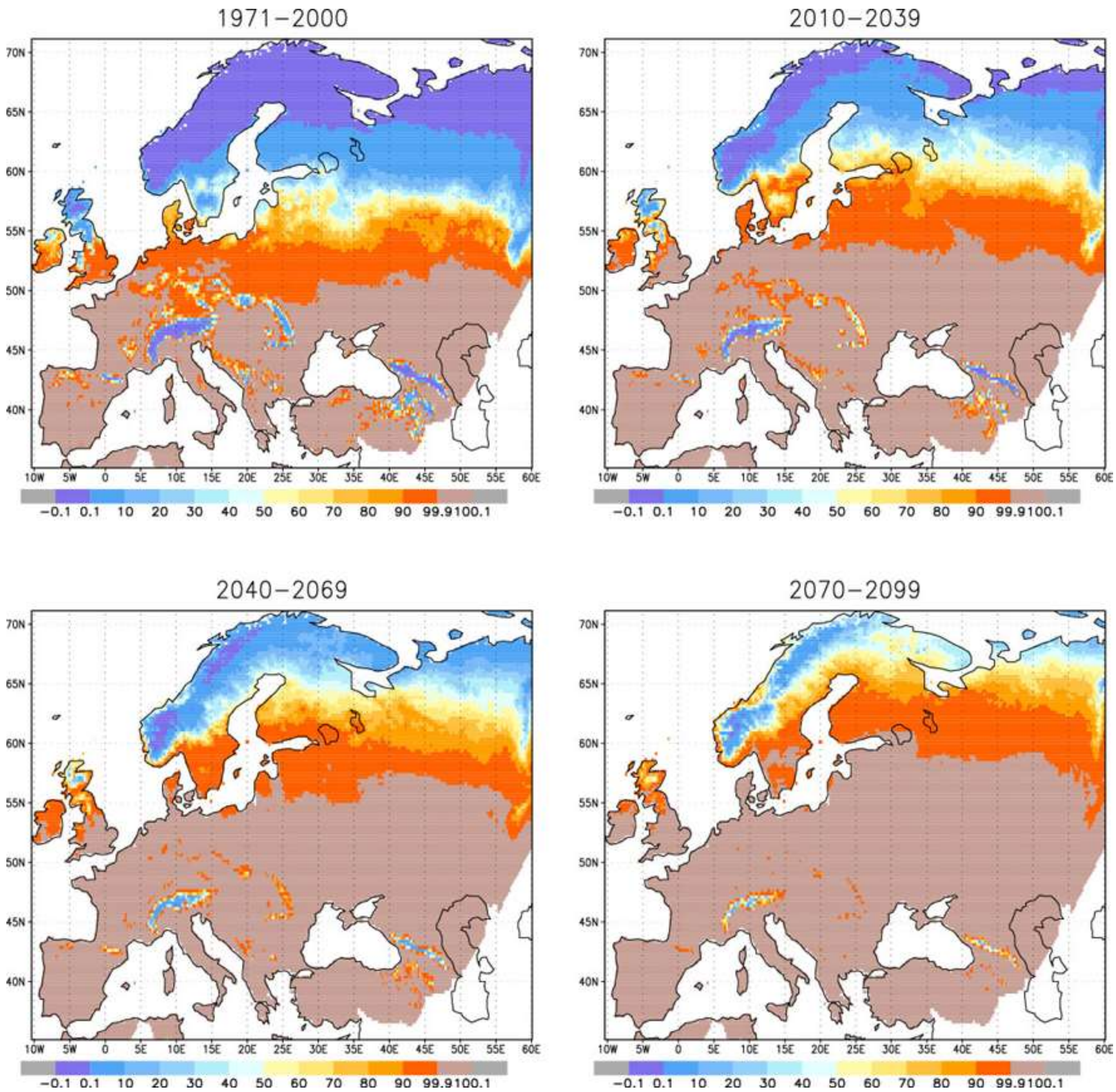

Figure 2 Probability of 1500 dd (threshold value for Spruce bark beetle to produce two generations in a summer) in Europe (Asikainen et al. 2018).

3. Forest operations and climate change

3.1 Terrain machine interactions

Changing climate can have both positive and negative impacts on the soil bearing capacity and trafficability. In Finland we have experienced two extremes of terrain conditions due to deviant weather conditions within a year. The fall 2017 was extremely difficult for the wood sourcing because summer 2017 was extremely rainy and the winter came late. Sawmills had to stop their operations due to sourcing problems. Pulpmills had to use sawlogs to keep their processes running. Heavy rutting on logging sites were reported. When the winter started, cold weather allowed the logging also on the soft soils and situation from wood sourcing point of view was normalized. Spring and summer 2018 have been very dry and it was possible to conduct logging operations on peaty soils that normally are so wet in the summer that machines can not enter the site. However, when the dry season and elevated temperature had been continuing longer, forest fires caused by machines were identified and it was even considered to halt the harvesting by a law.

Forest machine manufacturers have reacted strongly to the challenges and they develop solutions for the challenging harvesting conditions (Väätäinen et al 2010). Today, probably the most intensive research input is in the use of terrain and weather data to improve the efficiency of harvesting operations in changing climate conditions (Uusitalo & Ala-Ilomäki 2013). Several national and EU level projects such as FORBIO, EFFORTE and Tech4Effect seek solutions for this phenomenon. Terramechanics is the field of research where the use of large datasets on forest soils and roads and weather are linked with the operational planning of biomass flow management.

3.2 Heat stress of forest workers

Although forest operations are more and more mechanized, large part of logging operations is done by using motor manual methods. Also silvicultural works such as planting and clearing are done with manual or motomanual methods. Climatic heat affects labour productivity, primarily through dehydration. Moderate dehydration amounting to a body-mass loss of 4 percent may reduce physical work output by 50 percent (Staal Wästerlund 2018). The ambient temperature and relative humidity of the air have a great impact on the need for fluid requirement. Motomanual forest work tends to be very heavy physical work. The quantity of fluids required ranges between 2 litres per day for light work in temperatures around 10 °C WBGT and in extreme cases 15 litres per day for very strenuous work in 30 °C WBGT (Staal Wästerlun 2018). The length of work day has to be reduced and timing of work has to be changed so that it starts in early hours. In the mechanized logging operations, especially when modern forest machinery with air conditioning is used, the heat stress can be practically eliminated.

3.3 Unplanned, large scale salvage loggings

Large forest disturbances can have major impacts on the wood sourcing and forest operations. At the same time they cause disturbances on the wood markets having impacts on the economic outcome of forest owners. In Europe there have been two main factors associated with the climate change that have caused long lasting disturbances in timber markets and wood sourcing: Storm and spruce bark beetle. In addition, forest fires have caused disturbances in wood sourcing especially in the Iberian peninsula. Salvage loggings after a storm such as Gudrun in Sweden and Baltic countries, have long lasting impacts changing the sourcing areas. The work force and machine capacities move over borders of countries and this can last even years. In Central Europe (Austria, Czech Republic and Slovakia) a permanent spruce bark beetle infestation has caused a situation, where forest industry gets large part of its raw materials from salvage loggings. The disturbance is associated with droughts in the area as well as large proportion of aging spruce forests in the landscape.

3.4 Supply logistics of wood

Wood transportation is also effected by the changing weather. The forest road network is under a greater stress when precipitation is high or when there is no frost on the ground. The uncertainty of accessing the storages at the forest road side has already caused major changes in the storage of roundwood. The forest industry is increasing the size of their storages at terminal and next to major roads to secure the wood supply during spring when road network is not bearing heavy vehicles. In addition, in the forest energy biomass sourcing, use of terminals has become more common to avoid sourcing problems during winter when the access to storage is reduced due to heavy snowfall or cold periods. This year, the Finnish Forest and Park Service announced that they will invest in the forest road network to be able to operate in the changing weather conditions. Also truck manufacturers are developing systems e.g. CTI to improve the accessibility of forest roads.

4. Discussion

Cost-effective, on-time and quality-conscious deliveries of wood biomass from the forest to refineries are a vital part of both the industrial and energy wood delivery chains (Bits and biomass 2018). Changing climate challenges the wood sourcing by increasing weather extremes, causing large scale forest disturbances such as storm damages, devastating forest fires and insect outbreaks. The forest operations at the all stages at the supply chain need to identified the potential changes in the operating environment. Solutions need to be developed for more efficient use of sensors, big data-based trafficability prognoses and use of meteorological data more efficiently to be able to operate in extreme conditions. Forests are have become an essential part of EU's climate policy (Regulation…2018). The wood availability may be restricted due to the role of forests as a carbon sink, when countries are aiming to their climate targets.

Forest engineering and wood sourcing are already in the forefront in the researching and applying the means that digitalization offers (Talbot et al 2018). Designing forwarding networks and timing of operations with the help of combinatory use of forest and soil data and meteorological information is essential as the weather conditions vary. In the monitoring and controlling of forest disturbances the use of crowdsourcing is a rising tool to be able to response rapidly to e.g. forest fires and other threats induced by the changing climate. People running the machines and doing silvicultural works are the key subset of crowdsourcing to detect the threat and report about it to start counteractive measures rapidly.

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INNOVATIVE WILDFIRE PREVENTIVE MECHANIZED OPERATIONS

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Keywords: Shrub land, biomass harvesting, logistics, fire risk

Climate change during the 21st century is expected to cause more frequent fires in many boreal forests, with severe environmental and economic consequences. Fire-prone conditions are predicted to increase across the world and especially in territories with Mediterranean climates. This could potentially result in a doubling of the amount of burned area by the end of this century, when compared to burned amounts in recent decades.

In addition, scientists agree on climate change-driven vegetation shifts towards draught resistant types. This fact will increase fire frequency and size and will have a larger overall effect on future total burned area than direct climate effects. Vegetation shifts, which are highly sensitive to precipitation pattern changes, will be also a strong determinant of the future spatial pattern of burn rates and will have different effects on fire in currently forested and grass/shrub areas.

According to the EU official soil Land Use database (LUCAS, 2012), six Mediterranean countries have over 50% of EU28's shrub lands (21 Mha), from which slightly above half (10.6 Mha) are located in Spain. Currently, the shrub land extension is favoured by several causes, such the high frequency of forest fires, the dramatic reduction of traditional extensive livestock, the abandonment of low productive cropland (marginal land), and climate change favouring sclerophyllous shrub species that best cope with draught and high temperatures.

Although a planned and sustainable management of shrub lands areas would be highly desirable, as has been proved in the LIFE ENERBIOSCRUB project, at present, shrub lands and many low tree density forests are mostly unmanaged. Silvicultural activities are limited to minor linear underbrush clearings in roads or trails edges for fire prevention and pastures clean-up.

The LIFE ENERBIOSCRUB Project has demonstrated that mechanized tasks for sustainable shrub clearing and biomass collection are feasible in many thousand hectares of unmanaged land in Spain. However, some barriers have to be overcome in order to reach economic profitability. The most important it that the current medium quality biomass market prices for energetic uses are too low, usually lower than 40 €/wet ton at final destination. As the clearing and logistics costs estimated in the ENERBIOSCRUB project often exceed that number, several critical aspects must be addressed: harvesting productivity improvement, logistics optimisation, and market development.

The ENERBIOSCRUB project performed mechanized clearing and harvesting trials, over 140 hectares and more than 600 hours in different shrub formations in six Spanish provinces, handling biomass in two different formats: cylindrical shrub bales using a harvester baler machine (BIOBALER WB55) and crushed biomass using a harvester shredder machine (RETRABIO), requiring each product a different collection and logistic system.

The machines used in the ENERBIOSCRUB project could generally work on terrain with slopes up to 30%, provided adequate soil characteristics (low roughness and acceptable rolling resistance), and were handled with a certain degree of superficial stoniness and / or ground roughness.

The demonstration trials allowed improving the knowledge of the different productive chain phases, in order to evaluate the work, and define its advantages and disadvantages.

The sustainable shrub biomass collection requires an appropriate mechanized clearing and harvesting system, and an evaluation of the logistic chain, in order to control the biomass quality before final destination.

Throughout the ENERBIOSCRUB project, more than 1,600 tons of green biomass have been harvested, which is equivalent to 1,000 tons of dry matter (tDM), obtaining a productivity based on the effective work time between 0,6-2,1 tDM /h and 0,1-0,7 ha/h with BIOBALER, and between 3,3-4,5 tDM /h and 0,1-0,3 ha/h with RETRABIO.

Currently, mechanical improvement of the collecting machine is being studied in order to increase collection efficiency, to improve their mechanical reliability, and to adapt the equipment to the type and species of vegetation to be processed.

Notes: DM (dry matter)

WILDLAND FIRE SUPPRESSION OPERATIONS WITH HEAVY EQUIPMENT

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Abstract: *Heavy equipment is actively involved in fire suppression operations in many parts of the world. However, the capabilities of today's modern heavy equipment is unfamiliar to many fire managers. Wildland fire suppression operations globally have evolved into more complex and critical activities. This is especially true with the increased availability and use of modern heavy equipment and attachments designed for use in both logging, road construction, and increasing being adapted for fire suppression & fuels reduction operations. In North America there are more than twelve common types of heavy equipment being utilized to prevent and fight wildfires. This paper will acquaint the reader with the evolving world of the methods and machinery in the wildland fire manager's tool box. It will show an overview of how these tools and techniques can increase worker safety, reduce operational cost, and help reduce the effects on wildlands from destructive wildfires. The paper also describes how heavy equipment can play a role as a "force multiplier" for crews and other fire resources increasing their mutual capabilities, efficiency and safety. As a retired National Incident Commander (USA) said "Mechanized equipment is the most over-looked, under-utilized, and misunderstood firefighting resource."*

Keywords: fire, heavy equipment, logging, dozers, task forces, incident command, fireline, fire agencies

1. Introduction

Globally, the forest products industry has steadily replaced manual methods with mechanical means to accomplish tasks on industrial forest lands. Government land managers are seeking to adopt these improvements in operational cost efficiency, decrease adverse site impacts and increase worker safety in their fire suppression and fuels reduction programs.

Wildland fires have become more complex and costly during recent decades. The role of Heavy equipment (HE) is evolving in fire prevention, suppression and site rehabilitation operations in many parts of the world. In the hands of experienced operators directed by knowledgeable fire overhead, modern mechanized machinery is a powerful tool in the land mangers' toolbox.

Currently advances in the design of modern machinery built for operating in fire prone wildlands is often underutilized. Fire overhead is generally not aware of modern machine capabilities. An example is the use of cable assisted, or tethered, steep-slope logging methods developed in New Zealand and spreading to the US and Canadian Pacific coast timber country.

As a literature review of heavy equipment use (over the last 30 years),concludes additional fire command and control personnel training is needed to update the fire work supervisors familiarity with the proper use of heavy equipment as a solution to this underutilization problem.

We outline the various operations that can be executed by modern purpose built machinery. Increased use of modern forestry machinery provides the Incident and land managers expanded operational capabilities, as listed below:

- Safer night time fireline and area infrastructure (roads, trail, water sources) construction.
- Faster, safer direct, indirect and contingency fireline construction.
- More opportunities for direct line on fires or in vegetation too dangerous for hand crews.
- Safer methods of hazardous tree removal and brush clearing.
- Expanded 24-hour ground based water delivery; beyond the reach of engines, water tenders and during hours when the use of conventional aircraft is prohibited.

We present lessons learned from the author's experience using these tools in various fuel types and fire behavior conditions, primarily in Europe and North

America (USA and Canada). Lastly, this paper addresses future opportunities, and challenges facing the wildland fire community.

2. Historical background of the use and integration of heavy equipment (HE) in fire suppression, primarily North America and Spain

The use of heavy equipment (HE) in wildland fire suppression started in the USA and Canada in 1940. Use of logging equipment was at one time a primary response tool for controlling fire starts, and was a contract requirement for logging on most public lands. This was an operational necessity. As often the machinery and logging methods at that time often started fires.

Since the mid-1970s in North America industrial lands still relied on equipment contractors, primarily road builders and loggers, to extinguish fires with their equipment. On government lands the role of hand crews and aviation has increased, while use of heavy equipment declined. In the 1990's there were fewer fire managers with the knowledge and field skills to effectively utilize the full range of logging equipment on the fireline.

During the 1980's, forestry equipment designs rapidly improved to increase operational safety by keeping operators in better protected cabs, and incorporating improved hydraulics, electronic systems, and building more specialized machines and attachments. This both increased the equipment cost and machine productivity. This specialized machinery required better understanding of the "synergy" effect of coordination between complimentary machines. An example is the Cut-to-Length (short wood) logging method invented in Europe and first tested in North America in the mid-80. This method used two machines, a Harvester to fell/process the tree and the Forwarder which was a self-loading off-road machine that carried the short wood logs to the road for later pickup by over the road trucks hauling to mills.

This machine design improvement trend continues to replace less efficient and more dangerous manual methods in many phases of vegetation clearing, forest product harvesting, material handling and dirt work. Improved designs are also making it possible to operate ground-based equipment on more difficult, terrain, steeper slopes, boggy soft ground, and to mechanically fell/process/handle larger trees. In most cases, these increases in efficiency and safety also reduce site impacts. This is the promise of helping wildfire managers to make suppressing fire safer, while minimizing suppression costs and hopefully reducing losses to wildfire.

Heavy forestry equipment has come a long way when compared to the previous fire suppression machine era of only dozers. The use of heavy equipment on fires is also evolving, especially in North America. During the Horse River Fire in 2016 located in Alberta, Canada, 269 machines were deployed to fight that fire (Nass et al. 2016).

The use of heavy equipment in wildland fire suppression in Spain and Portugal started in the Spanish provinces of Leon and Zamora (Circa 1960). In those years, dozers were used for several tasks related to reforestation and creating access by opening both firebreaks anda ccess trails.

At times, prescribed burning to remove existing vegetation (scrubs) was performed prior to reforestation. Dozers were used to build control lines (firebreaks) to control the burning operations. Dozers were used regularly in those two provinces, to secure or prepare controlled burns. In the early 1970s it is also used in the direct attack in wildland fires. From there dozers become popular in other provinces with intense reforestation activity carried out by Spanish Forest Service.

Heavy equipment is now commonly used in wildland fire suppression in Spain to implement fuel breaks and for fire suppression direct attack (to the fire perimeter): Dozers perform many other common forestry tasks. Dozers are used in forest thinning, logging-both skidding/forwarding, earthmoving and fire suppression.

Experience after 55 years using dozers (1960-2015) in different provinces, make them an invaluable resource to control large fires. Currently there are about 68 heavy equipment teams(dozer, lowboy and all terrain support vehicle) working in suppression wildland fires in Spain contracted by the Fire Agencies in some regions (see details below), Castilla-La-Mancha, Castilla-y-León and Galicia are the three Spanish regions that stand out in number and use of heavy equipment sets. In Portugal there are 102 heavy equipment teams, most of private owners and municipalities, available to work in suppression wildland fires but not specifically hired to work in this function.

Currently, there is a lack of information and training on dozer capabilities in different Fire Agencies. The need is for more training for managers to gain more familiarity with Dozer capabilities and limitations.

The maximum deployment of heavy equipment in Spain was in 2006 at Riba de Saelices Wildfire, in Guadalajara province involving 20 dozers. In Portugal one of the maximum deployment was in 2018 Monchique Fire involving 25 dozers.

3. Overview of Heavy equipment types and attachments (capabilities, limitations)

Figure 1: Heavy Equipment Task Force (HETF), common machine types: dozer, feller buncher, grapple skidder, skidgine, excavator. Source: Basko, www.forestoperationsmt.com

There are many different machine types under the broad title of heavy equipment (HE). Normally in North America wildland fire organizations refer to all the following equipment as heavy equipment. Other names referring to the same machine classification often vary by location, occupation, or manufacturer.

Other names for HE in this paper include: logging equipment, mechanized equipment, ground-based and forestry equipment. The most common equipment categories are based primarily by carrier type (tracked- ridged or flexible, wheel or rubber tired, track banded). The other feature is by frame construction (swing, ridged or articulated). Equipment designations are still evolving.

The following will use common types of primarily forestry equipment found in North America and Europe. Unless noted all forestry equipment used in wildland fire use are equipped with a minimum of a partially or fully enclosed canopy, have adequate lighting for operating at night, require daily maintenance and are transported to fires by some type of highway transport truck and trailer combination

Machine performance, capabilities, and limitations vary by modifications, customization, machine condition, and how well the selected machine matches the terrain, vegetation and the assigned task. The skill and experience of the operator is also a variable.

3.1. Dozers/Tracked skidders/Pumpercats

Dozers (Bulldozers, Tractors, CATs) are the most widely recognized mechanized fire-fighting tool across North America and Europe. They are built for pushing soil or clearing vegetation with their blade. The blades can accept pin-on brush rakes for piling brush and slash. On the back is commonly mounted a tool bar for various combinations of ripper teeth, or a cable winch. In Australia it is common to use dozer fitted with tree pusher to increase the safety of the operator and the machine effectiveness when pushing trees. Tracked skidders are dozers rigged with either a skidding arch with a winch and log chokers, or a hydraulic grapple. They are specifically designed for skidding trees and logs, and retain all the capabilities of a dozer.

Pumpercats are dozers with a water tank, pump and live hose reel. All three are mounted on rigid steel tracks with various grousers (cleats) to ensure traction. Generally, Dozers working fires are planned to perform work on ground slope limits of up to 75% downhill, 60% traveling uphill, 40% working uphill.

3.2. Wheel Skidders and Skidgines

Wheel or Rubber Tire Skidders (RTS) are the most common machines to drag (skid) trees or logs. Wheel skidders use either a boom mounted grapple or cable winch with an arch. Grapple skidders can efficiently load pre-bundled trees or pre-piled brush. Wheel skidders are planned to perform on 30% uphill, 45% downhill, and 30% sidehill.

Wheel or Rubber Tire Skidgines are skidders with generally a 200+ gallon (760 l) water tank (detachable or permanently fixed), pump and live reel and/or water cannon mounted on them. Skidgines are designed to deliver water to locations beyond the capabilities of an off-road fire engine. They are well suited to accompany other equipment to handle any machine caused fires, or for patrolling firelines to minimize the chances of entrapment and to link up with hand crews to ferry water/supplies. Skidgines can serve as a fire engine and assist with toppling small trees, moving downed trees and breaking apart fuel concentrations for crews working the line. Skidgines equipped with detachable tanks are designed to quickly drop their tank in the field and if equipped with either a grapple or winch can double as a skidder.

Both machines are articulated to increase maneuverability. Both can increase traction by fitting tires with chains or 6 wheel models with track bands. Both are equipped with light duty blades for minor earthwork, trampling brush or toppling small trees. Winch equipped machines are useful for assisting stuck vehicles or overturned equipment.

3.3. Feller bunchers and Harvesters

Both feller bunchers and harvesters are the best alternative method for reducing timber felling fatalities by reducing the need for manual chainsaw felling and bucking of trees. This class of machinery also allows for the felling of trees 24 hours a day due to their light packages designed to allow night time logging in properly size machine matched vegetation and terrain. Feller bunchers are either a track mounted swing boom machine or a 4 wheeled mounted articulating frame machine. Both accept felling heads which can either be rotating disc or intermittent chainsaw bar style saws.

The track mounted swing boom feller buncher has the cutting head attached to the boom. For operating in wet soft soil areas (ex. swamps or muskegs) they are equipped with larger tracks (lower ground pressure), and a long reach boom (9,14 m +).

For operating in steep mountainous terrain they come equipped with leveling cabs, larger track grousers, and a short boom (commonly 7,31 m). For fire planning these machines are designed for increasing the machines ability to work on steep slopes (up to 55%, 80%+ tethered).

The wheel mounted feller buncher has a carrier attached felling head with a saw (either rotating blade or bar saw) with grab arms (Commonly called a "drive to tree" feller buncher). These are found on gentle ground (<30% uphill/downhill, <20% sidehill) and are common in the pine plantations of the southern US. Both types of saw heads are designed to fell and allow the operator to hold and place the tree to build bundles in positions that are accessible to grapple skidders. Feller bunchers are locally available in forested area where whole tree harvesting is practiced.

Harvesters can be either track swing boom machine or wheel mounted (commonly with 4-8 wheels) articulated swing boom. The cutting heads (commonly called dangle-heads) are designed to handle one tree at a time and both fell and process (delimb, buck and top) the tree. Harvesters tracked swing boom machines are designed to operate on slopes up to 55%. Wheeled articulated harvesters are design for gentler slopes (< 40%). Harvesters are locally available where cut to length logging.

3.4. Excavators, tracked log loaders and shovels.

Excavators, shovels (commonly called hoes in Canada), and tracked log loaders are tracked machines with 360 degree rotating (swing) capabilities that have a boom. This boom allows for different attachments to be placed on the end of the boom. These machines are versatile based upon the attachment(s) that come with the machine.

Excavators usually are equipped for moving dirt. They are designed to operate on gentle ground (construction sites or gravel pits). Excavators equipped with a bucket with an attached thumb, or a clam bucket can now pickup and place large rocks or vegetation like brush or downed logs. Good for rehab erosion prevention structures (water bars).

Tracked log loaders are excavator like carriers equipped with a special boom and log grapple designed for picking up logs and placing logs in decks. They are designed to work on roads, and landings.

Shovels are similar to log loaders designed to go off road and move large logs toward landings (truck or swing) and roads. They are built to operate in harvested areas where the majority of the vegetation has been felled but not removed. The specialized designed under carriages and long reach booms to reach difficult and broken terrain. Shovels are equipped with a log grapple and a heeling boom to lift, heel and swing large logs and whole trees. On fires they are good for clearing fireline locations of heavy downed wood to help other equipment dozers or excavators to dig down to the mineral soil with minimal damage to the residual trees. Shovels are used to breaking up fuel concentrations along access roads, firelines and during post fire site rehab.

3.5. Mulchers/Masticators

Mulchers, also known as masticators, come in various combinations of carrier types and mulching head shaft orientation (vertical or horizontal), and different types of teeth, hammers and flails. All mulchers are designed to knockdown, breakup or grind woody material at the stump. Boom mounted mulchers are wheeled or track mounted and have 360 degree swing boom machines similar to feller bunchers but with a mulcher head attached to the boom. Boom mounted mulchers are commonly used on steeper slopes (some models up to 70%). They are most effective on material <25 cm in diameter. On fires they are used to brush out vegetation along existing roads to increase driver sight distance or clearing undergrowth to prepare for follow up felling of large trees by manual or machine large tree felling.

Carrier mounted mulchers (commonly called strip mulchers) are either tracked or wheeled machines with either ridged or articulated frames. The mulching head usually mounted on the front. Strip mulchers are generally more powerful and commonly are used for larger materials, up to 76 cm diameter and are most effective on operating going directly up or down slopes. On fires they are a good tool for clearing long large straight strips like widening fuelbreaks parallel to roads, powerline clearing, or brushing out over-grown roads and trails.

3.6. Forwarders/Super Skidgines

Forwarders are articulated frame log carrying machines capable of loading and unloading generally short wood logs (commonly <7,6 m in length). They utilize 4-8 wheel carrier configurations. Forwarders are sized by payload capacity from 8-20 tons. They are the log transport machine in commercial "cut to length" logging. Due to the method of carrying their load in bunks clear of the ground and with low ground pressure rubber tires they are useful where roads need to be crossed unlike most heavy equipment that damage road surfacing. To increase traction on steep slopes the tires can be fitted with chains or track bands. Forwarders are designed to operate on ground slopes of less than 55% uphill, 45% downhill (load dependent), and due to the machines high center of gravity sidehill slope is limited to <12%.

Super Skidgines are forwarders that have mounted 3785-9463liter baffled water tanks, pumps, live reels and/or water cannons. They are the largest ground based off-road water haulers commonly available on fires. On fires they can act as off-road water tenders for refilling smaller wheel skidgines or making night time refilling of port a tank water sources for hose lays normally served by helicopter drops during day shifts.

3.7. Road graders/farm tractors

Road graders are widely available in rural areas with extensive native surface roads. Road Graders do not need to be trailered by transports (lowboys). Road Graders have maximum speeds of 25 mph (40 km/h) and can quickly drive to nearby fires. They are useful for both quickly blading to mineral soil in mostly rock free soil types and gentle sloping terrain (< 15%). They can quickly remove light flashy fuels (grass)from overgrown roads and widen to mineral soil adjacent clearing strips along native surface rural roads.

Large agriculture tractors are locally available in farming areas. They can be used to quickly turn over strips of vegetation with conventional farm implements to construct fuelbreaks around rural structures (homes, barns, sheds, fuel tanks) and along fence lines, powerlines and other improvements where the soil condition and terrain is operable for the size, type, power and implements that are locally available.

4. Matching of machine type to common fire tasks

FIRE TASK / MACHINE TYPE	Feller Bunchers & Harvesters	Rubber Tired Skidder & Grapple Cable	Dozer & Tracked Skidders	SoftTracks/KMC	Excavators & Tracked Shovel Log Loaders	Forwarders & Super Skidgines	Skidgines (Tracked, Rubber-tired)	Mulchers/Masticators	Road Grader/ Motor Patrol
Tree Felling/Snagging	•	•	•	•	•		•	•	
Brush Cutting	•				•			•	
Tree or Log Skidding		•	•	•	•	•	•		
Pruning					•			•	
Log Bunching	•	•	•	•	•		•		
Log Stacking		•	•	•	•	•	•		
Fireline/Fuelbreak Construction	•	•	•	•	•	•	•	•	•
Water Hauling			•			•	•		
Water Use						•	•		
Emergency Vehicle Recovery		•	•	•	•	•	•		•
Site Rehab	•	•	•	•	•	•		•	•
Road Work			•		•	•			•
Night Operations	•	•	•	•	•	•	•	•	•

Figure2: Types of machines used for various fire tasks. Source: Jaffe and O´Brien 2009

5. Fire heavy equipment organization

The use of heavy equipment in most wildfire incidents starts with the first onsite incident commander's assessment of the situation. This leads to the development of an initial tactical plan. If the situation is suitable for heavy equipment tactics an initial equipment resource order it sent to dispatch.

In Spain and Portugal this would usually be a call for one or more Heavy Equipment team(s). HE teams are usually composed of a dozer, lowboy and all-terrain support vehicle. All-terrain vehicle must carry communications equipment and flashing light. Each dozer is fitted with communications equipment and GPS. Their attached lowboy, approximate 16 meters in length, is equipped with communications equipment and flashing light. The support All-terrain vehicle carries a diesel tank of about 300 liter, pumping equipment to refuel the dozer and basic parts for the tractor. The dozer with mounted blade is permanently loaded on the lowboy, on alert 24 hours a day. This is required to improve the respond time to approximately 30 minutes.

For heavy equipment transport drivers a special driving license is required to transport a dozer with mounted blade, as it is considered a wide load.

In Spain there are 68 heavy equipment teams employed by the Regional Fire Agencies. The Army through the Military Emergency Unit (UME) has 53 machines between dozers, loaders, backhoes, mini-loaders, dump trucks and heavy cranes (they can be used as fire resources and for other emergencies). In Portugal there are 102 heavy equipment teams, most of private owners and municipalities, available to work in suppression wildland fires but not specifically hired to work in this function.

If the strategy is to control the spread of the fire by establishing a direct control and containment line against the fire perimeter, the primary task is to construct fireline using HE teams. The tactic maybe one of a combination of direct, parallel or indirect attack (see Figures 5, 6, 7, 8, 9). Depending on vegetation, terrain, and availability other resources maybe dispatched to help. Other HE resources may include one or more dozers, excavators, mulchers or graders.

Each dozer can go directly to the site and begin constructing fireline. Note that in Spain, dozers are almost the only HE used because they are the most versatile machines in clearing shrubs and small tree vegetation. They can work on steep slopes and are able to complete fuel breaks or fire lines construction working as an independent single resource.

In North America dozers are also the most commonly used heavy equipment resource. Heavy equipment dispatch orders also include transports, and machine support trucks for fueling maintaining and repairing the machine. If it appears night work is possible the dispatch order includes spare support drivers, equipment operators and additional agency overhead. In the US southeast pine country dozers are commonly equipped with fire plows and are used on initial attack. In the chaparral brush covered steep mountainous terrain of southern California they primarily use multiple large Dozers working together in pairs called strike teams.

In the incident command system (ICS) a heavy equipment strike is made up of 2 machines (3 in Canada) with the same capabilities and size. Larger dozers are labelled as Type 1, and the smallest dozers are Type 3. There is similar strike team typing for other categories of heavy equipment, like skidgines. Grouping into teams is primarily for safety and to reduce impacts of breakdowns on time critical tasks. ICS heavy equipment teams made up of different machines types or a mix of other resource types are labelled task forces.

In the mountainous heavily forested regions of western US and Canada task forces of complimenting machines, similar to local logging sides are used. A common task force on a major fire may include; 1-2 earth moving machines (dozers or excavators), 1-2 tree felling machines (feller bunchers or harvesters), 1-2 skidders to move the felled trees and 2 or more skidgines or pumpercats to extinguish fires and patrol the newly constructed fireline. If underbrush or small trees need to be cleared a task force would include mulchers. For safety and efficiency hand crews and machines generally work apart from each other.

Figure 3: Heavy Equipment task force in US. Source: Stephen O'Brien

Command and control of these machines require fire team personnel. In Spain heavy equipment sets (HES) include a heavy equipment boss. In the US and Canada each machine also have a heavy equipment boss (HEQB). In both organizations the principal value is the skill and experience of the team members; bosses, operators and drivers.

In Spain the dozer boss, machine operator and lowboy drover are trained and certified as a team, this guarantees safe transport, and efficient, effective suppression operations. Training is necessary for the three components of the HES personnel. Machine operators and lowboy drivers work at a basic scale, and the dozer boss would operate within the scale basic for managers. HES qualifications are at the levels 3 and 4 within the 5 level training and qualification system in the European Union.

In North America wildland firefighters are mobilized under a national Incident Command System (ICS). Under ICS heavy equipment resources are directed by agency personnel. This is usually a heavy equipment boss (HEQB) for single machines, a strike team leader (STEQ) trained for multiple machines of the same type or a task force leader (TFLD) for task forces of mixed machines or including other resources such as crews or engines.

6. Suppression Operations in wildland fires

Depending on fire characteristics (flame length and fire spread), site conditions (fuels, slope and rockiness), access, and the environmental factors (weather, visibility) heavy equipment can used in various ways to attack a fire.

6. 1. Direct attack

If fire behavior permits (low intensity flame fronts, minimal spotting, and no canopy crowning)heavy equipment can engage in a direct attack. Often dozers are the best tool for direct attack. In the case of light or flashy fuels we distinguish direct attack actions depending if fire is spreading uphill or downhill. If fire spreads uphill, the dozer´s (or grader, excavator)fundamental role is pouring mineral soil over the light flashy ground fuels and therefore eliminating contact between the oxidizer (oxygen) and fuel. If fire is spreading downhill, or if the fuels include woody materials the machines built an unbroken fireline(an area cleared down to inflammable mineral soil) a small distance back from the fire flank.

If we have several dozers on duty in a section of the fire perimeter, progress in direct attack can be continuous, alternate or opposite (Figure 4) depending on the arrangement and direction of advancement of the different machines.

Figure 4. Progress continuous (a), alternative(b) and opposite (c) in direct attack. Source: Juan Caamaño

The second case of two or more dozers alternate advance work uncoupled moving in the same direction, leaving unanchored areas between them. This may be effective because it maximized the fire perimeter length suppressed by unit time, but may involve safety concerns by not providing proper anchoring[1] for the equipment placed at least for a limited time during in the early moments. This tactic is risky and not commonly practiced in many fuel types or terrain conditions.

Such operations can be combined with aerial resources means to stabilize and effectively monitor the buffer zone (minimizing safety concerns) until complete control of the perimeter is achieved. Aerial resources are planes or helicopters dropping retardant or water and act as “an eye in the sky” providing ground forces with critical fire information and provide scouting reports on the best location for the fireline location. The fire boss or incident commander (IC) is able to monitor both fire suppression and fire activity with the help of theses aerial resources.

[1] Anchoring: the action of find an anchor point, usually an advantageous location, from which to start constructing a fireline.

6.2. Parallel or indirect attack

The parallel attack with heavy equipment consists in opening lines by logging the forest to open up the canopy space over the fireline, removing ground and surface fuels and top soil layers to expose the mineral soil. In some cases, it may be supported by existing fuel breaks or existing roads (in this case it would be an indirect attack). In short, we are looking for areas where they can produce good opportunities of suppression at a close but safe relatively short distance from the flames. Noteworthy are the combined operations involving heavy equipment and technical fire (backfire or burning out).

Indirect attack is used if the anticipated fire spread is faster than the time for the heavy equipment to complete the fireline and position holding resources, crews, engines or hose lays can be positioned. Often the capabilities of heavy equipment task forces to both build the fireline and to open up the canopy in heavily forested situations exposes a wider opening over the ground. Wider canopy openings increased the efficiency of aerial water or retardant drops effects and technical fire use on fire spread without the need to locate ground personnel or machines on the fireline in cases of rapid fire spread toward the indirect fireline.

6.3. Control of fire perimeters

Another function of heavy equipment is the stationing of machinery in natural or constructed safe staging areas adjacent to the machine built indirect firelines. Personnel can be pulled from the lines for safety. After the fire perimeter "bumped" or halted by the combination of suppression activity (technical burning, retardant and firelines) the personnel can be brought back to the line and use the staged machinery to quickly patrol, secure and quickly extinguish any spot fires or places where fire burned across the fireline.

6.4. Creating access to other resources

In some remote areas heavy equipment is critical in improving access and escape routes for other resources (fire engines and pick-up vehicles). In this way, water and firefighters canget accessto very difficult areas and from there carry out hose lines or incident and post-fire operations that are necessary (i.e. post-fire site rehabilitation).

Figures 5, 6, 7, 8: Top left, direct attack in wooded areas. Top right, direct attack shrubs areas. Bottom left, Indirect attack in wooded areas. Bottom right, parallel attack with technical fire maneuvers. Source: Junta de Castilla-La Mancha

7. Safety in Suppression Operations

7.1. Topographical-Driven fires (slope is the main spreading vector)

We use direct or parallel to the tail and flanks to limit its opening and preventing new fire runs (as head fire runs). Tail and flanks are usually within suppression capacity.

We use indirect attack on the fire head to limit its ability to spread by spot fires.

Figure 9: Direct attack or parallel to the tail and flanks Topographical fire. Source: Junta de Castilla y León

7.2. Wind-Driven Fires (wind is the main spreading vector)

We use direct attack from tail to head. Tail and flanks are usually within suppression capacity.

7.3. Convection fires/Plume driven fires (air fluxes produce by increasing temperatures due to excessive heating of the surface air, is the main spreading vector)

We use direct attack to the tail and flanks to limit its opening and avoid new fire runs (as head fire runs), preventing the length of the front of the fire from increasing. These fires are very dangerous to firefighters, since they generate large number of spot fires by precipitation of embers by gravity from the convection column. They occur in the direction of the convection column.

Parallel Attack to tail, flanks and head to generate discontinuities at amplitude greater than the emission distance of firebrands. The fire's own dynamics can give a magnificent opportunity of attack by suppressing the flank that feeds back the convection, turning it into a fire dominated by low speed wind, much more predictable, less dangerous and easier to extinguish.

This attack can be carried out through the massive use of aerial resources, supported by construction fire lines by heavy equipment and ground resources that consolidate these positions, or through the use of technical fire (burn out), taking advantage of the fire feedback in the lower part, by where the entry of clean air occurs, provided that precaution is taken with the possible fall of embers to the back by gravity from the column. This type of attack should always be carried out with the maximum of safety the anchors at all times, and from the tail to the head.

Worker's safety considerations from the point of view of HE:

- To facilitate anchoring of the flanks in safety or survival zones, mainly in burned areas with no return potential.
- To avoid repositioning of flanks.
- To address the massive emission of embers. High throwing distance of spots.

- It is necessary to support it outside the area of influence of the convection column, in points where the falling of embers cannot surprise the personnel with fire to the back, especially in the zone of the head, since the fire will absorb again these spots towards the main focus if they are given at a short distance, at 100 or 200 meters.
- To establish a lookout.
- To establish aerial support.

We use indirect attack on tail, flanks and head to break the propagation dynamics by spots.

Worker's safety considerations from the point of view of HE:

- It is necessary to support it outside the area of influence of the convection column, at points where the falling of the buckwheat cannot surprise heavy equipment with fire on the back, especially in the area of the head, since the fire will absorb these spots again towards the main focus if they are given at close range, at 100 or 200 meters.
- You have to support them in areas without fuel or with low fuel load.
- To establish a lookout.

8. Efficiency/Performance of lines implementation

Performance yields are shown here from established literature. Appendix D of the *S-232 Dozer Boss Manual* (USA). According to the table for a tractor Type 1 tractor performance would be 300-900 m / hour, depending on fuel type; Type 2 tractor executes line at a production rate of 200-700 m / hour. In the same manual, execution line yields are also displayed for a single dozer pass in m/hour, determined through a test carried out in the field and depending on the type of tractor (Type 1, 2 or 3), steepness of the slope in three categories, fuel models and if the tractor works uphill or downhill.

Studies in Australia by McArthy et al. (2003), determine the performance of various operations implemented in 103 wildfires between 1997 and 2001.

In Spain, data available on bulldozer production rate under diverse fuel model determined by Ayala and Holguin (2000). This author depends on if the line is constructed on contour lines or downhill, obtained values very similar results to those determined in United States and Australia.

From these works several premises can be stated:

1) Fireline construction rates decrease with increasing fuel load.

2) The steepness of the slope has an effect on production lines, particularly when working uphill.

3) The type of tractor determines that some are better suited than others for certain jobs, the heavier are faster in implementing fire lines than smaller ones. In heavily loaded fuel models heavy tractors (Type 1) are the most suitable.

4) Experienced certified machine operators, especially in difficult terrain and vegetation, they are substantially faster in the construction of lines that inexperienced operators.

5) The amount of rocks along line significantly reduces performance.

9. Costs

The service dozer and lowboy prices, for 10 hours in the presence of the team and 24 hours of on call availability with two full shifts machine operatorand lowboy driver range from (Prices of Dozer Service in Castilla-La Mancha (Spain) for 2012):

- Dozer type 1> 200 hp: The hourly cost per presence of the dozer and lowboy is about 87.2 €/hour.
- Dozer type 2 <200 hp: The hourly cost per presence of the dozer and lowboy is about 72.1 €/hour.

The price of the extra hour in suppression tasks for dozertype 1> 200 HP: 75 €/hour + VAT = 90.75 €/hour. (1 Euro=$1.11 USD or $1.44C CAD).

Most Technical Conditions of the Heavy Equipment in differentRegions in Spain the also has a portion of work by hectares or linear meters, to review firebreaks or improvement of roads.

Dozer production rate in Spain, determined by Ayala and Holguin (2000), can be determined operational costs, applying the price extra hour of 90.75 € (track-type tractor Type 1). Therefore these operational costs would range between 30 €/km-303 €/km.

The service dozer and lowboy prices, in the presence of the team (Prices of Dozer Service in Afocelca (Asociation of Private owners, Portugal) for 2018):

- Dozer type 2<200 hp: The hourly cost per presence of the dozer and lowboy is about 90 €/hour.

- Dozer type 3<150 hp: The hourly cost per presence of the dozer and lowboy is about 60 €/hour.

Attached below are Wage &Equipment rates for the Washington State Fire Service

DOZER POWER CLASS

TYPE – POWER CLASS		FWHP RANGE	Daily Standby Rate	Daily Single Shift w/Operator	Daily Double Shift w/Operator	Daily Single Shift w/o Operator	Daily Double Shift w/o Operator
1A	Heavy	Over 300	$400	$3,448	$5,896	$2,605	$4,455
1B	Heavy	250 – 299	$400	$2,820	$4,822	$2,225	$3,805
1C	Heavy	200 – 249	$400	$2,136	$3,653	$1,945	$3,326
2A	Medium	150 – 199	$300	$2,002	$3,423	$1,525	$2,608
2B	Medium	100 – 149	$300	$1,741	$2,977	$1,305	$2,232
3	Light	Under 100	$200	$1,550	$2,651	$1,045	$1,787

(US) for 2018:

Table 1: Wage & Equipment of Dozers in Washington State. Source: http://file.dnr.wa.gov/publications/rp_fire_wage_equipment_rates.pdf pg 5

SKIDDER POWER CLASS

POWER CLASS	FWHP RANGE	Daily Single Shift w/Operator	Daily Double Shift w/Operator	Daily Single Shift w/o Operator	Daily Double Shift w/o Operator
1	200 - 275	$1,872	$3,201	$1,340	$2,291
2	140 - 199	$1,392	$2,380	$860	$1,471
3	100 - 139	$1,222	$2,090	$690	$1,180
4	81 - 99	$1,042	$1,782	$510	$872
5	0 – 80	$982	$1,679	$450	$770

Table 2: Wage & Equipment of Skidder in Washington State. NOTE: Skidgine rates add: $101 (200-399 gal tank), $168 (400-799 gal), $350 (800+ gal).Source: http://file.dnr.wa.gov/publications/rp_fire_wage_equipment_rates.pdf pg 8

EXCAVATOR POWER CLASS

TYPE – POWER CLASS	FWHP RANGE	Daily Single Shift w/Operator	Daily Double Shift w/Operator	Daily Single Shift w/o Operator	Daily Double Shift w/o Operator
1	Over 230	$2,252	$3,851	$1,720	$2,941
2	161 – 230	$1,712	$2,928	$1,180	$2,018
3	136 – 160	$1,475	$2,522	$980	$1,676
4	111 – 135	$1,412	$2,415	$880	$1,505
5	86 – 110	$1,262	$2,158	$730	$1,248
6	76 – 85	$1,172	$2,004	$640	$1,094
7	61 – 75	$1,092	$1,867	$560	$958
8	50 – 60	$1,052	$1,799	$520	$889

Table 3: Wage & Equipment of Excavator in Washington State. Source: http://file.dnr.wa.gov/publications/rp_fire_wage_equipment_rates.pdf pg 9

FELLER BUNCHER POWER CLASS

TYPE – POWER CLASS	FWHP RANGE	Daily Single Shift	Daily Double Shift
1	Over 226	$2,474	$4,230
2	160-225	$1,975	$3,337

Table 4: Wage & Equipment of Feller Buncher in Washington State. Source: http://file.dnr.wa.gov/publications/rp_fire_wage_equipment_rates.pdf pg 13

10. Actions to ensure the intrinsic safety of the heavy equipment used in suppression wildland fires

In Europe heavy equipment must have CE declaration of conformity and CE labeling. If the first market and/or putting into service in Spain is later than 29/12/2009, the CE declaration of conformity and CE labeling shall conform to the RD 1644/1997. These machines shall be fitted with ROPS, FOPS and OPS (http://standards.sae.org/j1119_201307/) type properly certified according to the harmonized standard was applicable to it.

They should be subject to a preventive maintenance program according to manufacturer's instructions, ensuring that the initial compliance lasts throughout the life of the machine. A Senior Technician in Occupational Health and Safety, taking into account the criteria of the Spanish legislation, shall assess the risk of the work equipment (machine, etc.) and qualify the ability of the means of prevention used in that team to control those risks.

In the USA the regulations by the Federal Occupational Safety and Health Administration (OSHA) is: Standards – 29 CFR Logging Operations 1910.266.

The general safety requirements in the USA include good maintenance:

- Each machine cab must have second proper means of exiting.
- The engine exhaust pipes must be effectively muffled and be located to direct the exhaust away.

- Guards must be in place at all times the machine is in operation to protect employees from exposed moving parts of the machine and flying debris from the operation of the machine.
- Seats, securely fastened to the vehicle, and seat belts must be used by persons operating and riding in or on machines and vehicles.
- Vehicles used to transport employees off public roads or to perform logging operations must meet applicable requirements for machines.

The requirements for protective structures for operators. There are three primary hazards for in-woods equipment operators addressed by features of the cab structure: machine rollover, falling objects, and poking or cab penetrations by limbs or trees. The Society of Automotive Engineers (SAE) has developed performance criteria for the design of forest machine cabs (ROPS, FOPS and OPS).

11. Accidents of heavy equipment in Wildland fires

Of all the accidents with HE in wildland fires that documentation of their investigation is available, mainly in the United States, Spain and Portugal, a summary has been made with the main causes and their consequences.

It should be noted that only in the United States there is a high number of documented accidents. There are two typical Incidents, dozer rollover and entrapments, with several consequences in most of the cases.

Incident	**Date**	**Event Type**	**Principal Cause**	**Consequences**
Trabazos, Zamora (Spain)	August 16, 2002	Dozer Rollover	Lost traction and slid backwards downhill. Don't use the seat belt	Operator fatality
San Lorenzo de Calatrava, Ciudad Real (Spain)	July 22, 2009	Dozer burned	The radiant and convective or projections of embers in ignition to machine back, cause the beginning of the combustion of dead fuel in this machine part; the fire was then propagated to oil hoses	Dozer completely damage
Tortuero, Guadalajara, (Spain)	July 11, 2012	Dozer Rollover	Dozer rollover during the platform descent maneuver	Minor damage to dozer

Oleiros, (Portugal)	October 7, 2017	Dozer Rollover	Lost traction and slid backwards downhill	Operator fatality
Pine Fire, California (US)	September 12, 2007	Dozer Entrapment	Burnover	The Operator sustained 2nd and 3rd degree burns. The burns were considered moderate to major in severity. The dozer sustained moderate fire damage, mostly to the left side and in front of the cab
Colorado Fire, California (US)	October 8, 2007	Dozer Rollover	Lost traction slid & rolled over & flipped over on a very steep downhill slope	Operator Fatality
Poco Fire Incident, Arizona (US)	June 19, 2012	Burn over	Rapidly escalating fire activity in steep terrain	Finding only minor superficial damages, the dozer was started, removed from the site inspected for damage
Beaver Fire, California (US)	August 11, 2014	Dozer and truck entrapment	The fire cut off from their escape route	The DIVS pickup truck received heat damage and the bed and back seat caught fire. The Division Supervisor and Heavy Equipment Boss were able to put the fire out with two fire extinguishers. The Dozer received minor damage from a small fire which started behind the seat in the open cab
Lumpkin Fire, California (US)	September 14, 2015	Burn over	The group was cut off and could not make it to the road ahead of the advancing fire.	The two bulldozers were burned and were rendered inoperable. No injuries occurred.
Soberanes Incident, California (US)	July 16, 2016	Dozer Rollover	The dozer proceeded slowly over the embankment During this maneuver the dozer rolled onto its left side and roof.	During the rollover event the dozer operator was ejected from the cab. The operator suffered multiple injuries which resulted in the fatality. Damage of the dozer included a seized engine, light damage to the cab and sweeps
Nevada County, California (US)	August 30, 2017	Burn over/Fire shelter deployment	Hydraulic failure	Operator was treated and released the evening of the Incident. Dozer sustained major fire damage as a result of the broken hydraulic line
Crane Island Fire, Florida (US)	May 14, 2017	Burn over	Tractor plow unit become stuck and was overtaken by fire	Minor damage to equipment

Sheep Gap Fire, Montana (US)	September 12, 2017	Burn over	Inadequate time reach a safe zone	No injuries. 2 feller bunchers, a skidder, and pickup were burned and a dozer was damaged.
Ferguson Incident, California (US)	July 14, 2018	Dozer Rollover	Lost traction slid & rolled over on a very steep downhill slope	Fatal injuries to the Heavy Fire Equipment Operator. Dozer 1 was damaged beyond repair.
Carr Incident, California (US)	August 1, 2018	Dozer Rollover	Lost traction and slid backwards downhill	Moderate damage to the dozer and injuries to the operator

Table 5: Principal causes and consequencies of the incidents with HE in wildland fires. Sources: Wildland Fire Lessons Learned Center, Junta de Castilla-La Mancha, Ventosa, Radio Condestábel

Figures 10, 11: Left dozer burned in San Lorenzo de Calatrava (Spain). Right dozer rollover in Tortuero (Spain). Source: Junta de Castilla-La Mancha

12. Lessons learned by the authors

Lessons learned from the use of dozers and heavy equipment in suppression of wildland fires:

- Heavy Equipment Teams (HET) are highly adapted to the forest environment and to wildland fires. They have an excellent great grip and stability on steep slopes, slippery surfaces and rough land. They have greater maneuverability than other resources.
- HET are able to handle direct attacks on high intensity fireline wildland fires.
- HET are able to handle parallel or indirect attacks when the terrain, vegetation or fire characteristics (flame length and spread) not permit

direct attack. Especially in Convection fires where the possibility to work near the flames can be difficult.

- HET are used to implement emergency road access.
- HET are used to save time and hours of manual work in fire line control; therefore, unloading work to be allocated to other tasks.
- HET perform fire line control faster and in a less expensive manner.
- HET eliminate part of safety issues by reducing the number of people in your work area.
- The main incidents that happen with HE in wildland fires are rollover and entrapments, most of them caused by loss of traction and by changes in wind direction in indirect attacks. In some cases increases the risk of fatalities and serious damages.
- In Spain and Portugal, it is necessary to establish a training program for dozer boss, machine operators, and lowboy drivers to standardize and rank their capabilities (as regulated the Regional Fire Agencies) so they can fit into a system like the Incident Command System (ICS).
- In order to successfully introduce the HET, and be truly effective, it is also necessary to train middle managers and command officers in the equipment characteristics, types, potential utilities and integration within suppression operations.

  - The integration of the figure of Strike Team Heavy Equipment in the Incident Command System of the Regional Governments is necessary.
  - Investigation of accidents (and near-hits) involving heavy equipment is needed in order to establish the causes and resulting conclusions.

- In is critical for efficient transport of heavy equipment fire team must have accurate area maps identifying the location of lowboy turn arounds (drop points) connected by suitable road access for use by highway equipment transport truck and trailers (lowboys). Suitable access requires minimum (> 20 m radius curves, < 2% vertical curves and < 15% grade) plus lead and tail pilot vehicles.
- For efficient heavy equipment line deployment fire maps must identify ground slope groups corresponding to the design safe slope limitations for the various types of heavy equipment being ordered onto the fire.
  - (Example: For the intermountain region of western US and Canada the following slope breaks are useful. 0-25% (suitable for most HE use uphill, downhill and side slope), 26-40% (suitable for most wheeled and track machines to use uphill and downhill), 41-55% (suitable for most tracked machines), 56-75% (suitable downhill use dozers, and specifically designed steep-slope capable machines), > 76% (no ground based equipment unless secured to a cable assist tethered system).
- Always verify the ground slope by scouting the location with 2-3 experienced line scouts each equipped each with a radio, clinometer,

GPS, 1-2 compasses, topography map, range finder, and digital camera (for documenting hazards, improvements to protect, crossings, and site factors affecting machine traction).
- For critical machine assignments anticipate equipment breakdowns and personnel injuries. The old dozer boss saying is true, "to get through order two".
- Never commit machinery to downhill travel without scouting an escape route out the bottom of the slope.
- Scout all planned night operations during the day. If possible double shift the line scout to assist the equipment supervisors during the night operation.
- In rough country or heavy timber a 3 dozer group is much more efficient then a 2 dozer group. For efficiency and safety organize to minimize machines backing up.
- In hot weather utilize opportunities to blowout filters and keep windows clean.
- Prior to starting the assignment work out alternative communications with equipment operators if radios fail.
- Be aware of any health problems or medical needs of equipment operators and truck drivers before moving onto the fire grounds.
- Contact locals for the existence and depth of underground hazards, bridge weight limits, and other potential hazards in the area you are traveling thru and working in.

13. Future challenges (innovation and development)

Innovation Projects and Development can make these HE able to work with greater performance, efficiency and safety in the close future. Therefore, it is important to learn about the current lines of work that can have further development in the future are used. Here are some realities that are already or can be short and medium term is detailed.

Use of cable assisted (tethered) logging systems to construct firelines. On the Whitewater Fire, near Detroit, Oregon, USA in July 23, 2017 Logging contractor used a tethering system attached to a tracked feller buncher, along with dozers to build a contingency fireline. This system allows HE to operate on up to 100% ground slopes. It was the first use of what is commonly called steep-slope winch assist system tethered to a track feller buncher to be used in the US to build fireline. It took 3 days to build the fireline versus what would have taken weeks for manual timber fallers and hand crews. (Source: Mohlere, L, Timber West January/February 2018 "First on the Slope: an Evolution, Siegmund Excavation & Construction, Stayton, OR,")

Development of safety equipment such as fire shelters, fire curtains, oxygen bottles.

Development tools such as water tanks approved for dozers and forwarders. Implements as AquaDozer, are developed to achieve the CE label makes present their approval from the point of view of workers safety. The availability of water can increase operability of the dozer by lowering fire intensity on the flanks and heads of fires during direct attack. This will reduce the risks of accidents, damage to machinery and injuries to fire fighters

Remote Control assumes some of the newer challenges today for application to firefighting. Currently it is being used in mining widely, essential to collect piles of coal and other minerals. Its first use was in New Guinea in 1989 and marketed since 2003 in various models of Caterpillar and Komatsu. The USDA Forest Service has funded a pilot project on remote control dozers for use in wildland fires. In Spain an example of remote control over a machine chains is small Dronster VF designed by Vallfirest, S.L. (http://www.vallfirest.com/dronster). Fire teams in Oregon have used a remote control wheeled skidgine (Bobcat A300 skid steer loader) with a detachable 1500 l water tank, and water cannon for fire camp and helispots dust abatement. (Source: Horizon Development, Inc. Clackamas, OR)

Finally the possibility of conducting machine driver training in **simulated virtual environments** can provide the experience and the necessary training in suppression wildland fires, made it difficult to carry out in real environments and makes difficult the formation of new generations machine operators specialized in wildland fires. This would solve the doubts of many Regional Fires Agencies about hiring such equipment with qualified and experienced staff. Bulldozer simulators are very advanced in mining, as developed by Caterpillar Simulation, Simulation Thoroughtec and in Spain by the Santa Barbara Foundation. In the case of simulators which also includes the simulation of forest fires include SEILAF, S.A. (http://www.seilaf.com/) as a virtual training environment that also integrates other participating units in suppression wildland fires, a stage that reproduces what really happens in wildland fires.

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ENCE - TQM: APPLICATIONS TO FOREST MECHANIZED HARVESTING PLANNING AND CONTROL: THE ENCE SPANISH CASE-STUDY IN EUCALYPTUS OPERATIONS

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ENCE (SPAIN)

ENCE is a BHKP pulp manufacturer with two plants and a production capacity of 1,1 millions of Tn per year. In addition, ENCE is the Spaniard biggest renewable energy producer with biomass. It has a capacity of 170MW.

The supply of Eucalyptus logs is about 60% by medium and big suppliers and 40% by forest harvesting contractors who work for us directly and harvest the bought Eucalyptus field by ENCE´s buyers. In ENCE´s supply chain management, we work with 70-80 forest harvesting teams (80% mechanized). We also manage about 200 trucks every day.

ENCE has begun to deploy continuous improvement methodology (Total Quality Management) 3 years ago at supply chain management (from the wood purchase to its reception at factories). The main goal is to increase the sense of ownership for ENCE´s employee, to reduce the costs through the elimination of wastes (for example: to eliminate the unplanned stoppages of forestry harvesting teams) and to maintain it.

TQM is focused on three basic pillars. One of them is the "culture transformation" (to drive people towards the proactivity, to prioritize and to increase people safety. To strengthen the strong and soft skills). Another basic pillar is "to focus on customer" (to eliminate the complaints of logginglandlords, to eliminate quality defects like logs out of specifications). The third pillar is "to increase the efficiency and sustainable in all process of supply chain" (to standardize and to control the process, to reduce the cost, to develop a management model).

The TQM deployment in ENCE meant a mindset change, to work daily according to Deming cycle, known as a PDCA cycle. The first phase of the deployment was about defining the main objectives for supply chain management and the data collection system in order to set the improvement actions and to prioritize them. The data collection system development was part of the mobile application development to make easier people daily work. With this mobile application, Ence´s employees do the following tasks:

- The Ence´s buyers introduce the information of wood purchases (for example, data of land registry, the slope of field). According to introduced parameters, the mobile app recommends the harvesting model, calculates the price (€/Tn) to pay to landlord of wood and the price (€/Tn) to pay to harvesting contractor.
- The supervisor of harvesting contractors has to review the purchases and he has to approve them.
- The forest harvesting contractors send the production data (produced tons, time of stoppages and coordinates of the place where logs are to load by trucks) daily and for each field they harvest.

The logistics department also has another application mobile for trucks. The truck drivers received the assignation (where they have to go to load and the coordinates where logs are). This application mobile also registers the GPS route and it can use to communicate and to resolve events.

The second phase of TQM deployment is to apply continuous improvement and to maintain it. The application consist of:

- [P] Plan: Lean Sigma Projects, Kaizen events (to analyse small problems with 5 Why´s methodology), quality and environmental inspections.
- [D] Do: To carry on the action plans form Lean Sigma Projects and kaizen events. To standardize the process.
- [C] Check: To review the indicators (safety, quality, cost, delivery, moral) at daily and weekly operational meetings). If the indicator is red, we review the trend and the pareto charts to identify the main cause to analyse it.
- [A] Act: According to indicators, the first step (plan) is reconsidered.

Two of the indicators that we follow daily and weekly are efficiency and productivity for forestharvesting teams. We calculate them with information that they send us daily, with mobile application. The efficiency is the time percentage they are working (to produce tons of Eucalyptus logs). The productivity is the amount of cubic meters they manufacturer in a hour.

To accomplish with one of the basic pillars of Total Quality Management, we have started doing quality and environmental inspections of loggings. We have a quality manual to meet with requirements of landlords and with specifications of the factories. We also have an environmental good practice manual to obey with legal requirements and with FSC and PFC standards.

To achieve the commitment of ENCE´s employee, we have started to use the improvement suggestion. Each employee and each people who works for harvesting contractors can propose improvement actions to eliminate wastes and to increase the eff.

MECHANIZATION OF FOREST OPERATIONS: NEW DEVELOPMENTS, TRENDS AND CHALLENGES

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This presentation offers a tentative review of the main new developments within the field of forest mechanization, which may serve as a platform for discussing the role of forest operations research and determining new subjects for future studies.

After acknowledging the strong subjective bias of any such reviews, the Author makes a first attempt at defining what can be considered as a new development, under any specific context. In particular, new developments can be found in conceptual research, applied research and actual practice. Each of these domains has different time horizons and different drivers, and therefore one must always indicate whether the new trends being discussed refers to conceptual research, applied research or actual practice (Figure 1).

Type	**Time**	**Drivers**
Concept	Someday	Projections
		Creativity
R&D	Tomorrow	Policies
		As below
Practice	Now	Economics
		Regulations

Figure 1 - New developments

The discussion is then organized according to a forest operations model, which has the main purpose of extracting a somewhat coherent narrative from an apparently chaotic mix of subjects. After all, reality is a haphazard collection of isolated events: it is always the narrator who tries to compile them into an orderly scheme, based on his/her own subjective intuition of an underlying rationale. Obviously, the narrator's interpretation is a function of his/her own variable involvement with different subjects, which defines one's own capacity to catch specific hints while missing others...

...and that brings us to the first caveat: this just one among many possible ways to organize such presentation, many of which are equally valid in their capacity to make sense of our common experience.

In this specific case, forest operations are represented as an input/output model, whereby "time" and "energy" are the main inputs, "timber" and "biomass" the main outputs and "forest", "terrain", "machine", "operator" and "business" the main process elements (Figure 2). Henceforth, the presentation is articulated according to these elements, in order to obtain a logical sequence that can support common understanding and an orderly narrative.

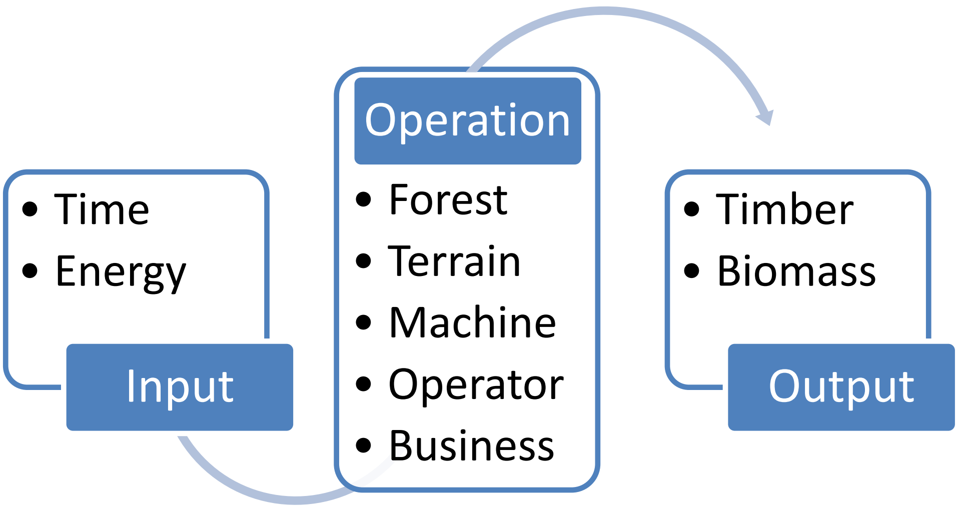

Figure 2 - Input-output model for forest operations

Traditionally, forest operation research has devoted much effort to reducing time inputs, but the improving trend started in the 1960s is now flatlining. Can we further increase productivity? Can we do more time studies? At the moment, the main trend in real practice is towards increasingly larger machines, which may clash with environmental requirements and infrastructural limitations. Further improvements are likely obtained through incremental automation. Some past great ideas, such as harwarders, high-speed forwarders etc. proved locally successful but have remained a niche phenomenon, with limited general impact on current practice. Remote controlled and unmanned machines are developing, but they are still too advanced and expensive for making any impacts on actual practice.

Lots of work is being devoted to reduce energy inputs. Introduction of new devices and manipulations of machine settings are becoming common in actual practice, and may accrue fuel savings in the order of 10-15%. Hybrid-electric solutions are at the pre-commercial stage, and very close to full commercial success. They represent a strong new trend in applied R&D, and may soon make a real impact on current practice.

Concerning timber output, the new trend in applied research and field practice is a paradigm shift from the maximization of value recovery to the management of one's forest as a product warehouse. For biomass, the new trends are towards vertical integration, whereby forest owners and operators are changing from fuel to energy suppliers, thus capturing most of the value generated through conversion and delivery to the end user. On the other hand, biomass processing technology shares in the same general trend, where bigger is better.

Concerning forest type issues, new developments have the same general goal to increase efficiency when dealing with difficult forest types, and especially small trees. These represent a large resource, poorly utilized due to the limitations tree characteristics impose on machine efficiency. While not a new trend for itself, multi-tree harvesting is finding new solutions that resort to software adaptations more than to hardware adaptations, as in the past.

Another old idea that turned into a new trend is winch assist. While the concept was tested over 30 years ago (i.e. Allied feller-buncher) and fully developed commercial products were available already 15 years ago (i.e. MTH harvester), winch assist has enjoyed great operational success in recent times and is now a growing phenomenon in many countries.

Additional new trends for steep terrain operations are unguyed yarders, full suspension yarding and the introduction of European style yarding outside Europe. It is still too early to say if these new developments in yarding technique will become main trends in actual practice, but they are certainly strong with applied research.

Conversely, the limitations imposed by soft terrain are still faced with new and promising adaptations of relatively old concepts, including new high-floatation machinery (i.e. multiple axles, tracked locomotion etc.) and wet area maps. The latter developments are greatly assisted by the recent advances in UAV technology and remote sensing.

Concerning machines, the strongest trend is found in actual practice and consists in the growing mechanization of operations worldwide. While the classic JD1270 is still the best seller it was 10 years ago, the difference today is that no one is questioning whether a harvester is a suitable solution for this or that Country, but all agree that mechanization is the only way ahead, regardless of terrain type, silvicultural prescription and labour cost: that is indeed a radical break when it comes to actual field practice! This new development is dictated to a good degree by such challenges as operator safety and labour shortage - more than labour cost.

While the challenges and the trends are indeed clear, very little research is supporting the strong normative and training efforts that are shaping the sector. Everyone is busy teaching other people how to do things, without taking the time to study what works and what does not. As a result, speculation often takes the place of scientific research, which seems far from ideal. The Author believes that increasing the efficiency of forest operations may require additional quality research in such fields as: operator safety, training needs, training effectiveness, contractor welfare, business management, business models. Studies on these subjects are more rare and urgent than any additional productivity studies, for as useful as the latter can still be. Furthemore, operator and business studies offer stronger opportunities for interdisciplinary research, compared with other more traditional forest operation studies.

STATE OF THE ART OF EUROPEAN TOWER YARDER MANUFACTURERS AND MODELS

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Timber harvesting in steep terrain is very often executed with cable yarders. In Austria, for example, where 57% of the forest area has a slope of more than 30%, 22% of the timber is harvested with cable yarders. Despite the relevance of this harvesting technology, a survey of the current state of European tower yarder technology is missing.

The aim is to present an overview of tower yarders presently available on the European market as well as analyse their state-of-the-art. In addition, technical modifications of Austrian tower yarders are demonstrated by a comparison with surveys conducted 20 and 30 years ago.

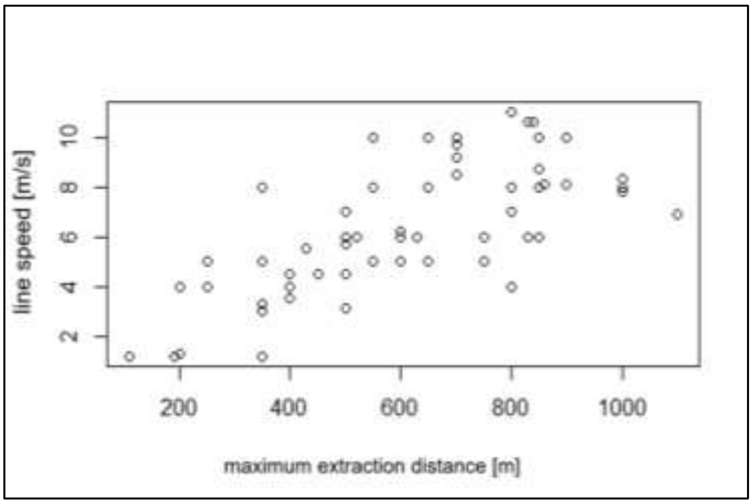
An analysis of manufacturer and the evaluation of brochures form the basis for the overview. Subsequently, the collected technical data was entered in forms and submitted to the respective manufacturers to check the data and to give the possibility to make adjustments. Cable yarders have been classified according to the main components (mounting system, tower, winch unit, operator workstation etc.) and operational range (cable logging systems, harvesting systems, terrain conditions).

The survey of the European tower yarders shows that 15 manufacturers in seven countries offer 63 types of tower yarders. This includes 17 types of tower yarders to be connected to the 3-point hitch of a tractor as well as two tower yarders to be implemented on the excavator arm. However, 42 tower yarder models are suitable to be mounted on a frame of a truck, a crawler track or a trailer and therefore constitute the vast majority among the available types of tower yarders. Yarders which are appropriate for standing skyline systems are mainly offered in Europe. In contrast, manufacturers recommend only 3 types of machines to be used in the running skyline system.

Technical characteristics of European tower yarders

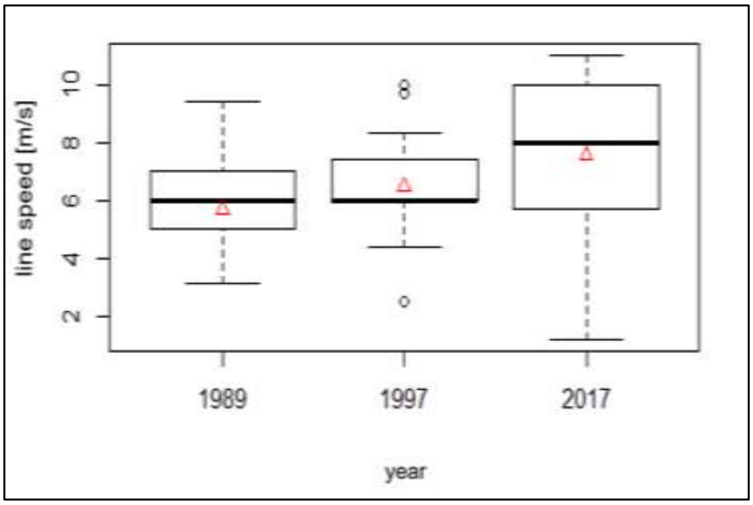
	Min	Max	Averag	Media	Unit
Tower height	2.4	17	11	11	[m]
Number of anchor	2	6	4	4	[n]
Length of anchor	30	80	57	55	[m]
Pulling speed max.	1.2	11	7	6	[m/s]
Max. extraction	110	1100	608	575	[m]
Pretensioning force	30	160	88	85	[kN]
Pulling power main	15	80	35	35	[kN]

The analysis of the technical characteristics reveals that the line speed and the tower height as well the pulling capacity increases with the technical extraction distance of the tower yarders. However, the statistical analysis shows a better correlation of maximum extraction distance and line speed as well maximum extraction distance and tower height compared to the correlation of the maximum extraction distance and pulling capacity.



Distribution of max. pulling speed depending on max. extraction distance

Finally, the comparison with surveys conducted by Erlacher (1989) and Trzesniowski (1997b) shows an increasing number of manufacturers and machine types, more variants of carrier vehicles and improvements in the average technical extraction distance and the mean velocity of the mainline drum.



Temporal development of the maximum pulling speed of tower yarders available in Austria in the years 1989, 1997 and 2017

Future developments of tower yarders are expected by adaptation of various components to increase efficiency, using hybrid and electric propulsion technology, auxiliary engine for 3-point hitch of tractors, and devices for reducing mounting times.

ORAL PRESENTATIONS

FUEL LOAD REDUCTION WITH MECHANIZED HARVESTING EQUIPMENT: PRODUCTIVITY RESULTS FROM TRIALS IN AUSTRALIA

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Abstract: Commercial mechanical fuel load reduction (MFLR) activities can be defined as mechanised operations with an end goal of changing forest fuel structure while extracting fibre in hopes of producing utilizable wood products that can be sold for a profit. These systems have been reported to have merit for reducing forest fuels. mechanical harvesting differs from other methods of fuel reduction, especially prescribed fire, in that removal is immediately effective, does not result in air pollution or escaping fires, and may be economically self-sustaining. In addition, reducing fuel loads through thinning could slow or even prevent catastrophic fire occurrences. In Australia, given the lack of information concerning fuel reduction thinning with commer-cial harvesting systems, there is a great opportunity for research in the area. Specifically, operations need to be investigated for system performance along with treatment effectiveness implications. Little is known about how different systems compare with respect to fuel reduction objectives, economics, and environmental effects. Any additional information in this area would be a great supplement to the current deficiency that exists to aid decision making. This study presents the results of a study on two MFLR with commercial harvesting systems in the States of New south Wales, Victoria, and Western Australia. The primary objectives of the study were to: 1. Examine the productivity of mechanical fuel reduction operations conducted in native forests, 2. Statistically analyse work elemental times and productivity of harvesting equipment related to tree size, and, 3. Develop predictive productivity equations for mechanised harvesting equipment (harvester/processor and feller-buncher in MFLR operations.

Keywords: mechanical fuel load reduction, bushfire management, thinning, native forest, harvesting productivity, Australia

FUEL LOAD REDUCTION WITH MECHANIZED HARVESTING EQUIPMENT: PRODUCTIVITY RESULTS FROM TRIALS IN AUSTRALIA

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PRODUCTIVITY AND ECONOMIC IMPACTS OF HARVESTING WITH SPATIAL AND SIZE CONSTRAINTS

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Abstract:

Many challenges exist for the harvest of industrial plantations, and a key aspect of it deals with the clearfelling practice. In the last decades, there has been an increasing social pres-sure to reduce clearfelling as one the strategies to balancing the social, economic, and envi-ronmental use of the land. In some countries, this balance has been achieved by new volun-tary regulations promoted by certification systems, which involve spatial and size con-straints to harvesting.

Despite the significant progress made in recent decades on forest planning methodologies and solution techniques, the productivity and economic impacts of harvesting with spatial and size constraints have received little attention. Harvesting with spatial and size con-straints have economic consequences for the plantation-based forest industry, which results in strategic or tactical plans with lower harvested volumes, and reductions in the financial value of the forestry state as a consequence of harvest units being harvested at suboptimal ages.

The dispersion of the harvest in a greater number of units resulting from spatial and size constraints has various operational effects, including higher investment and maintenance costs of the road network, and higher establishment and harvesting costs. Regarding the latter, operations highly mechanised are the most negatively impacted on an average cost per m3 basis, due to the high capital costs involved and the productivity loss of the harvesting equipment due to more frequent relocations per year.

In this study, we analysed and quantified the impact of spatial and size constraints to harvesting on the financial value of industrial plantations (NPV), on road construction and maintenance costs, and on harvesting costs including relocation costs of the harvesting equipment. To conduct the analysis, we have developed a metaheuristic-based optimisation harvest model, using a few hypothetical scenarios and simulated landscapes.

INDUSTRIAL STRESS-TEST OF A MAGNETIC RESONANCE MOISTURE METER FOR WOODY BIOMASS IN MEDITERRANEAN CONDITIONS

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Abstract: In bioenergy systems, moisture content (MC) is the most important quality parameter for wood chips. An elevate water mass fraction in biomass has detrimental effects in the whole forest-energy supply chain, leading to higher costs as well as lower efficiency and durability of the combustion systems. Considering these problems, plant managers must secure that the biomass delivered fulfils the given quality values. Nevertheless, controlling MC in operative conditions is difficult because the Standard method for biomass MC evaluation requires 48 hours of oven drying, while the decision to refuse a load must be taken on the spot. Similarly, invoicing the contractors according to the MC moisture content of the delivered biomass, should be done before the emptied truck leaves the plant. For this reasons, the bioenergy industry needs to deploy an alternative method for MC estimation, coupling fast measurement and reliability. The market provides several moisture meters based on diverse technologies but most of them require biomass-specific calibration models, to be changed according to bulk density and species composition. This is an important limit, particularly in Mediterranean areas, where wood chips feedstock can be very inhomogeneous. The aim of the present study was to test if Magnetic Resonance technology provides the necessary reliability to be considered an alternative to oven drying method. For this purpose, a stress-test was performed at the premises of an energy facility in Southern Italy. MC of 350 samples was measured both with the Standard oven method and with a commercial Magnetic resonance analyzer thanks to the non-destructive action of the biomass. Several wood chips characteristics were considered as possible sources of variability in MC estimate (e.g. species, granulometry, etc.). Results confirm the validity of the analyzer, which is insensitive to external factors. Accuracy and precision of the machine are both satisfactory, with over 95% of values within ±2.5 % of deviation (Standard - Estimated MC value) and a SEP of 1.179%. R&R gauge analysis showed that the routinely calibration of the machine represents about 20% of total variance, a drawback that should be solved by the manufacturer in order to further improve accuracy. Performance is very high, with over 15 MC estimations per hour in real working conditions, enough to cope with intense arrivals at the storage yard. We can conclude that the analyzer may be regarded as a suitable substitute to the Standard method.

PROMISE OF DIGITALIZATION FOR FOREST OPERATIONS AND MONITORING OF DISTURBANCES

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Abstract:

The digital revolution is transforming the fundamental nature of the economic environment. Digitalisation refers to the use of information technology so that ICT tech is increasingly merged into the everyday lives and work of individuals and companies. Big data refers to the foundation of digitalisation, the enormous amount of data that can be gathered through advanced sensors and networked devices. Crowdsourcing refers to a method of operations enabled by the internet and mobile devices, in which a task, data gathering or collecting funding can be shared across a large group of people. The Digitalisation-Driven Bioeconomy roadmap study examines how the transition to the smart utilisation of biomass flows and intangible ecosystem services can be achieved in a manner that simultaneously promotes the sustainable use of natural resources and creates potential for new primary production and processing business in agriculture and forestry.The Digitalisation-Driven Bioeconomy roadmap was drawn up in cooperation by VTT Technical Research Centre of Finland Ltd (VTT) and Natural Resources Institute Finland (Luke). This paper presents the key findings of the roadmap revealing three identified development pathways that are already changing the practices in forest operations and monitoring of the forest resources: These are 1) smart biomass flow management; 2) a data-driven bioeconomy; and 3) a networked and collaborative natural resource economy. Cases illustrating these developments are presented and their implications on the surveillance of forest disturbances, planning of forest operations and management of the quality of wood and biomass along the supply chain. Also different feedback loops from the refining industry to the wood sourcing are presented.

Keywords: forest operations, big data, roadmap, forest technology

THE TECH4EFFECT EFFICIENCY PORTAL: ARCHITECTURE, CHALLENGES AND PRELIMINARY OUTCOMES OF AN AMBITIOUS BENCHMARKING SYSTEM

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Abstract: Econometrics based benchmarking tools such as Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA) are widely applied in all sectors today, where they are used in comparing the performance of similar business units, ranging from single machines to government departments. The TECH4EFFECT Efficiency Portal is a globally accessible system designed for forest contractors to monitor both their own performance over time, and the performance of their individual machines or even contracting business against others that work under similar conditions. In this paper, the background, the system architecture and some of the early system outcomes will be presented. In addition, the experiences and especially the challenges faced in centralising a system built on a widely distributed and highly variable network of machines will be shared. Forest operations, from site preparation to final harvesting, take place in one of the most marginal industrial economic settings. While technical or operational improvements do lead to incremental increases in productivity, studies show that modern forest machines are no longer the main constraining factor in productivity improvements. Productivity, or technical efficiency, is a measure of the relationship between inputs to a process and its outputs, while economic efficiency is also affected by adjustment to prices (allocative efficiency) and economies of scale (scale or profit efficiency). The profit-efficient forest operation system is technically, allocatively and scale-efficient, and it maximizes productivity in the short run. Variation in performance between similar machines within the forestry contracting sector is large and suggests that other aspects, such as work organization, investment levels, and machine utilization are at least as important as individual machine production rates for contractor enterprise profitability. An identification of the relative importance and the contribution of these factors to overall profitability allows for the generation of an efficiency frontier, one that defines the location of the best performing actors, but more importantly, an indication of how others can approach this frontier. Even a relatively small shift in the direction of the best performing contractors would likely increase sector-wide efficiency to a far greater degree than further technical advances. R&D efforts may be better invested in knowledge management systems, making the causes of this variation explicit and using the information in a constructive way. The Efficiency Portal presented in this paper is an ambitious yet solidly implemented mechanism, with 8 European and 2 foreign countries already contributing to the data flows. This report reflects the status approximately 2 years into an ongoing process characterized by a large and growing interest from forest contractors and forest research alike. The TECH4EFFECT project was funded under H2020, BBI grant agreement No. 720757.

Keywords: forest operations, DEA, SFA, harvesting, performance

1. Introduction

Econometrics based benchmarking tools such as Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA) are widely applied in all sectors today, where they are used in comparing the performance of similar business units, ranging from single machines to national agencies or government departments. The TECH4EFFECT Efficiency Portal is a globally accessible system designed for forest contractors to monitor both their own performance over time, and the performance of their individual machines or even contracting business against others that work under similar conditions.

Forest operations, from site preparation to final harvesting, take place in one of the most marginal industrial economic settings. While technical or operational improvements do lead to incremental increases in productivity, studies show that modern forest machines are no longer the main constraining factor in productivity improvements. Productivity, or technical efficiency, is a measure of the relationship between inputs to a process and its outputs, while economic efficiency is also affected by adjustment to prices (allocative efficiency) and economies of scale (scale or profit efficiency). The profit-efficient forest operation system is technically, allocatively and scale-efficient, and it maximizes productivity in the short run.

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In this paper, the background, the system architecture and some of the early system outcomes will be presented. In addition, the experiences and especially the challenges faced in centralizing a system built on a widely distributed and highly variable network of machines, while meeting the constraints imposed by the GDPR, will be shared.

The Efficiency Portal presented in this paper is an ambitious yet solidly implemented mechanism, with 8 European and 2 foreign countries already contributing to the data flows. This report reflects the status approximately 2 years into an ongoing process characterized by a large and growing interest from forest contractors and forest research alike. The TECH4EFFECT project was funded by the Bio-Based Industries Joint Technology Initiative under the European Union's Horizon 2020 Research and Innovation programme under grant agreement No. 720757.

BIOMASS COLLECTION FROM WILDFIRE PREVENTION TREATMENT ON ROCKROSE SHRUBLANDS WITH A HARVESTER BALER (BIOBALER WB55) IN SORIA (SPAIN)

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Keywords:Harvester-baler, rockrose, shrub, biomass, wildfire prevention treatment.

A shrub clearing and biomass collection trial was carried out on 21.43 ha of rockrose (Cistus laurifolius, L.) next to an extensive pine forest, in order to evaluate the technical and economic viability of collecting biomass from a wild fire prevention treatment. The harvester-baler BIOBALER WB55 model, from Anderson Group, was used in the test.

This equipment,designed to cut woody crops and compress the biomass into round bales (1.2 diameter), had been evaluated for baling woody biomass in forest applicationsin USA and Canada, but it had not been enough tested on Mediterranean shrub formations.

A monospecific mass of rockrose, one of the most abundant shrub species in central northern Spain, was chosen to carry out the test. The scrublandwas 11 year aged, 1 meter height and 56% in fraction canopy cover. Soil conditions were very similar across the scrubland, with gentle slope and little or no stoniness. The studied scrublandrepresentsmany abandoned pastures and farmlands that exist in Spanish rural areas nowadays.

The study aims at determining the efficiency of this equipment in Mediterranean shrub collection. Secondly, assessing the influence of the cutting rotor tools (blades or hammers) on biomass collection yields, and finally, estimating the harvester-baleroperating costs.

The work was carried out at the beginning of 2016 by the company TRAGSA, in the framework of the LIFE ENERBIOSCRUB project, based on sustainable forest management of shrub formations for energy purposes.

Shrub harvest capacity measurements were based on continuous monitoring of the full harvesting cycle of the individual bales, including baling, tying, and deposition time, carried out by technical staff. The tests lasted 30 productive hours over 7 days. A total of 181 bales were collected, with an average weight of 444 kgDM·ha^{-1}and a moisture content of 37.2%.

The average production of collected biomass was 2.4 tDM·ha^{-1}, with a harvesting capacity of1.6 tDM·h^{-1} (5.9 bales·h^{-1}), equivalent to 2.6tWM·h^{-1}, and average yield of 0.7 ha·h^{-1}. A total of 31 tons of dry matter were collected. The average biomass collection efficiency (collected biomass in relation to standing biomass) was 32.5%.

Regarding the brush cuttingtool, better results were obtained withhammersthan with blades:53% more production (2.6 tDM·ha^{-1}versus 1.7 tDM·ha^{-1}), 73% more collection capacity (1.9 tDM·h^{-1}compared to 1.1 tDM·h^{-1}), 34% more bales (6.5 bales·h^{-1} versus 4.3 bales·h^{-1}), 17% more yield (0.7 ha·h^{-1}compared to 0.6 ha·h^{-1}) and a collection efficiency 3.2 times higher than with hammers (39.3% versus 12.3%).

However, it was observed, that regardless of the brush cutting tool, there was a decreasing tendency of the collection efficiency in relation to the standing biomass load.

The average clearing and harvesting costs were estimated at 80.61 €·h^{-1} and 115.16 €· ha^{-1}. The BIOBALER maintenance costs using hammers in the shrub cutting rotor were ten times lower than with blades.

As a conclusion, it can be said that the BIOBALER WB55 was successfully operated to harvest a typical Mediterranean shrub formation. It collected up to 40% of the standing biomass,using blades in theshrubcutting rotor. The amount of not collected biomass (73% of the standing biomass), suggests possible improvements in the equipment to avoid such high biomass losses.During the clearing test, it was observed that continuous amount of biomass was lost during the transfer from the brushcutter to the packing chamber, so possible improvements could be related with the feeding aid of the packing chamber.

Biomass collectioncan contribute to the reduction of wild fire prevention costs, by obtaining sustainable solid biofuels from shrublands of high flammability risk, using innovative harvesting methods that have not been enough tested in Southern Europe.

The CIEMAT (Center for Energy, Environmental and Technological Research), owner of the harvester-baler used in the test, is currently working to improve biomass collection efficiency. On the other hand, a weighing and moisture measurement system is being implemented in the equipment, as well asa GPS and a webcam to monitor the routeswhen the equipment is packing, in order to facilitate data collection in upcoming biomass collection trials.

Notes: DM (dry matter), WB (wet matter)

A NEW MODEL FOR LOCATING TERMINALS OPTIMALLY IN REFERENCE TO THE RESOURCE BASE, TERMINAL TYPE AND INFRASTRUCTURE

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Abstract: Terminals for storage and refining of forest biomass are needed in order to ensure the availability of biomass during periods of high industrial demand or periods of low access to the forest due to e.g. unfavourable soil conditions (soil and/or roads too wet to have ongoing forest operations). Terminals can be a first point of measuring the volume of the forest biomass delivered from forest owners and some facility for biorefining processes can be established there to improve the raw material flow. The location of the terminals plays a central role into whether the terminals are cost-efficient and fully utilized. Usually, forest biomass producers own transhipment terminals that are strategically important for their operations and are unwilling to share those with other producers (i.e. closed terminals). In this paper a novel methodology to select optimal locations of terminals for forest biomass will be presented. The methodology is based on available volumes of forest biomass in the adjacent area, the location of forest biomass consuming facilities (heating plants, biorefineries, pulp industries), forest land ownership, terminal ownership, transportation cost depending on truck type and comminution option as well as procurement and terminal costs. The paper addresses also the question of making closed terminal available to other forest biomass producers as well as the issue of forest biomass swapping between producers and tries to estimate the most profitable logistic system from forest to terminal. Preliminary results showed that forest biomass transportation costs can be reduced by 16% if forest biomass producers are keen in cooperating in operating forest biomass terminals. For a forest biomass producer that does not own terminals transportation costs to the terminals proved to be less when both open and closed terminals were used for storing pulpwood. When distance from the terminals to the pulpmill was assumed to be 70 km the total supply chain costs were reduced by 32%. The results are specific to the region of northern Sweden but the methodology can be applied at a wider scale.

Keywords: Terminal location, GIS

SYSTEMATIC REVIEW OF EFFICIENCIES IN COMMINUTING OF FOREST FUELS

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Abstract: The demand for biomasses for refinery purposes is globally increasing. Refining industries require that the biomass is down-sized to specific qualities before entering the process. To ensure delivery of solid fuel fractions at low cost and high quality, knowledge about factors influencing the comminution efficiency is fundamental when engineering operational systems. There are many studies made on specific systems and conditions, and thus there is a need of generalization of results to be used for systems analyses on e.g. international scales. Further, operational data available from equipment manufacturers are based on idealized conditions, while scientific studies consider ordinary working conditions. The study objectives were therefore to combine data from literature and manufacturers on comminution performances (e.g. energy demand, productivity, fuel quality) for various comminution systems, in order to identify deficiencies and limitations as areas for further Research and Development. Our study shows that productivity and energy efficiency of comminution systems are influenced by a multitude of factors such as e.g. produced fuels particle sizes, comminution method and the feeding rate. Based on these findings, our study point out specific issues which need to be addressed in future R&D of comminution equipment and systems.

Keywords: chipping, grinding, productivity, wood fuels

SIMULATION AND COST COMPARISON OF THREE INNOVATIVE BIOMASS HARVESTING SYSTEMS FOR YOUNG DENSE THINNINGS

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Astract: There are vast biomass resources available in early thinning of boreal forests, but the harvesting and supply operations are costly. The objective was to simulate and analyse three innovative supply systems, reflecting different development steps of systems for early thinnings, and compare the supply cost from forest to industry. The FlowConv system constituted of a conventional harvester featured with an innovative continuously cutting, accumulation and bunching head and biomass were transported as loose tree-parts. The FlowFix system constituted of a harvester featured with the same cutting head as in the FlowConv system, but also featured with a bundling unit and followed by a standard forwarder and a conventional roundwood truck. The FlowCin system constituted of a harvester featured with the same cutting head as in FlowConv and FlowFix, but featured with a second crane that delivers the cut trees from front of the machine to the back were a bundling unit receives the material. Forwarding and trucking was made as in FlowFix. FlowCin gave 6-10% lower supply cost than FlowFix, and become in average 24-29% more cost-effective compared to the FlowConv system. Thus, the FlowCin system is more prepared to be featured with cutting technology that gives significantly higher cutting efficiency, e.g. up to 100%, compared to present technology. The strength of the Cintoc system is its design with a buffering cradle and that two cutting crane cycles are delivered to the intermediate delivering crane, which together eliminates possible waiting times during operation.

Keywords: bioenergy, boom-corridor thinning, fuel wood, pre-commercial thinning

MULTI-CRITERIA DECISION ANALYSIS (MCDA) IN FOREST OPERATIONS – AT TUTORIAL REVIEW

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Abstract: MCDA methods, or do not see a benefit of using them. Therefore, the prime objective of this review was to make MCDA methods more intelligible to novice users within the field of forest operations. For that purpose, basic ideas of selected MCDA methods are presented as well as their strengths and limitations. Since there is no “golden” MCDA method that suits all kind of forest operations problems, a general recommendation to practitioners is to concentrate on the selection of criteria and definition of alternatives, which will be essential for the outcome from all methods. If all relevant criteria and alternatives are included, with reliable data, then the output of most MCDA methods will substantially decrease the risk of making decisions that lead to undesired outcomes. The second objective was to review and discuss applications of MCDA methods in forest operations. Of the reviewed papers, 65% simultaneously included economic, environmental and social criteria. The two most common MCDA methods were analytic hierarchy process (AHP) and multi-attribute utility theory (MAUT), used in 52% and 22%, respectively, of the papers. Of the reviewed papers, 70% represented a group decision-making context. Strategic planning issues were addressed in 40% of the papers, whereas tactical and operational issues were addressed in 65% and 26%, respectively. Some of the papers contained several planning perspectives and were thus counted twice. The review showed that practitioners in collaboration with researchers have found MCDA applications suitable for forest operations problems on all three planning levels, but with least use on the operational level. Possible reasons for this can be; 1) limited availability of temporally relevant and correct data, 2) lack of time – although MCDA can be used on operational level, they cannot be used in real time applications, 3) many operational planning problems are solved with one key criterion (often economic) while the rest of the criteria serve more as frames. However, to conform to the ongoing transformation of forestry, with increased importance of environmental and social aspects, it is considered essential to further develop and incorporate MCDA methods in decision-making on also the operational planning horizon of forest operations.

Keywords: multi-criteria decision analysis, decision-making, forest operations

OPTIMIZING THE LAYOUT OF AN EXISTING FOREST ROAD NETWORK IN STEEP TERRAIN

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1. Extended Abstract

Most existing forest road networks in Switzerland were built between the 1950s and the 1980s, so they were planned for different conditions that we find today (different harvesting and hauling technology as well different financial restriction). At latest when reaching the end of the life cycle, those road networks need to be redesigned. For example some road segments will not be required anymore, some need an upgrade and some road pieces need to be new constructed.

There are few methods that consider redesigning of existing road networks. Henningson et al. 2007 presented a model for redesigning forest road networks. They considered road upgrades to reduce the losses due to road closures caused by heavy rains or thawing. As this model is hard to solve, Flisberg et al. 2014 presented an easier-to-solve implementation for this problem. But however this model is still large and hard to solve as it integrates harvest and logistic planning into the model. Integrating harvesting and logistic planning is not necessary in our case, as there are different silvicultural restrictions in the alps.

Based on an existing road network, our model aims to identify a harvesting and road network layout that minimizes concurrently the cost for the road network (construction, upgrade and maintenance), the wood harvesting and the hauling operations over an entire life cycle. This is accomplished by selecting road segments that are necessary, assigning them a certain road standard, determining which parcels are to be harvested by what harvesting technology and to detect the hauling route. We require to harvest all timber parcels.

We present an Mixed Integer Linear Programming Model, which was applied to optimize the road network of the entire Poschiavo Valley in the Swiss Alps. The valley was split into 7 catchments for which the optimization was done. Computation time for these areas was between few minutes up to 30 minutes, which allows also to do some sensitivity analysis. The harvesting methods were mainly cable based, the hauling was mainly done by truck, but also, as a particularity by railway.

When doing such simulations, a particular attention must be paid to an accurate cost estimation of road building or upgrading, or the uncertainty must be considered trough sensitivity analysis.

The results were evaluated and discussed with the forest service and road planning specialists. Results seemed to be very realistic and comprehensible. The represents of the forest service decided to consider the outcome of the project, before doing further investments in road networks.

Keywords: steep terrain, cable yarding, road network design, mixed integer linear programming

USE OF LARGE INVENTORY DATA SETS AND REMOTE SENSING DATA TO ANALYZE STAND STRUCTURE PARAMETER RELEVANT FOR WOOD HARVESTING AND FOREST OPERATIONS

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Extended Abstract

"Big Data" is already a big topic in quite a lot of disciplines and about to reach the field of forest operations. When speaking about "Big Data", the size of the data volume is usually not the problem, but the unstructured nature of the data. The great challenge lies [1] in extracting data features that say something about a system state, [2] merge very different data sources and [3] search for regime shifts in real time. In "Forest Operations", harvester data are a potential data source, the data format StanForD2010 offers a lot of possibilities, further data sources are remote sensing data and terrestrial plots of inventories. On the other hand, and efficient management and logistic is depending on accurate inventory data for at least at stand level. One can now think about integrating all those data sources (machine data, remote sensing data, sample plots from inventories) to improve the accuracy of inventory data. Classical statistical estimators require random sampling, which means that the probability of a plot or data source to be included in the sample should not depend on its output property. However machine data do not fulfill this requirement, as they are recorded mainly in aged conifer stands. In particular under central European conditions, where the share of motor manual harvesting is still high (because of deciduous and large trees), we have to deal with a lot of not randomly missing data. From a statistical point of view, the "big data" can be seen as a nonprobability sample.

To be able to deal with nonprobability samples, we developped a double-robust (DR) estimation procedure. The Double-robust (DR) procedures integrates two models: the π-models and the y-models. The π-models are probability models, they predict the probability that a sample observation *i* could belong to the population of interest (the small-area in the current parlance), so called "propensity scores". The y-models links the field attributes to auxiliaries, for examples with a regression model in the following form: $E(y\_i \mid X\_i)=\xi(X\_i)+\varepsilon\_i$, with $E(\varepsilon\_i)=0$; In the simplest case, the coefficients of $\xi(X\_i)$ can be estimated by ordinary least squares. The main idea behind the DR approach is to tailor the y-models to each particular small-area via the propensity scores predicted by the π-models.

To test this approach, artificial datasets were created from empirical data from 2016, consisting of: A field sample of 137 field plots from a local Forest Management Inventory in Fribourg canton, Switzerland. Further, ALS data (GPD ~ 5 points m2) were available, from which height percentiles and density features were extracted from the point cloud data, to use as auxiliaries in regression models.

The propensity scores were predicted by two types of estimators: [I] a parametric model formulated as generalized linear model for binary responses (GLM) and [II] Support Vector Machines (SVM).

Response models (y-models) were predicted either by Linear regression models estimated by OSL and WLS, or Linear regression models estimated by the Least Absolute Shrinkage and Selection Operator (LASSO). The results are promising. Compared with state of the art estimators, our double robust estimators show the lowest bias and variance. Further, although not considered in this case study, they are able to take machine data into account, where the other estimators fail. The strength of the DR estimator consists in doing predictions for small areas / stands, where only few or no terrestrial samples are available.

Keywords: BIG Data, Propensity Score Matching, Machine Data, Machine Learning, Artificial Intelligence, Forest Management Inventory

THE PROFITABILITY OF DIFFERENT METHODS OF WEED CONTROL WHEN ESTABLISHING SHORT ROTATION COPPICE IN ORGANIC FARMING

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Abstract: Organic farms in Germany ought to be energy self-sufficient. One mean to achieve this can be the production of energy wood in short rotation coppice. When establishing a short rotation coppice an effective weed control guarantees a sufficient survival rate of plants and a high yield already in the first rotation. The use of herbicides is a well-proven and recommended method of weed control. But organic farms are not allowed to use herbicides. Therefore we tested other methods of weed control which are in accordance with the principles of organic farming. In the same experimental setup we tested two different clones of poplar and the tree-species Black and Gray alder which were not genetically engineered by breeding. We choose a random plot design with five replications of the two factors "weed control" and "tree species/ variety" at plots of 75 m² each in size. We simultaneously conducted this experiment at two different farms in the southern part of Bavaria. Initially the ground was mechanically cultivated by ploughing and harrowing. We sow four different crops (Black medic, White clover, False flax and Rye) before planting the trees. The display of a self-degradable mulch film was the fifth method of weed control. At the control plots no further weed control was applied beside the initial mechanical tillage. In the second year we counted tree survival and replaced died off trees. Each year we measured tree height, the diameter at breast height and at the stump collar. After seven vegetation periods we harvested the trees and measured the yield. We calculated the profitability of the short rotation coppices assuming four rotation periods. For the second, third and fourth rotation we assumed that all treatments of weed control have the same biomass yield as the treatment with the highest yield in the first harvest plus 10 %. All revenues and costs were discounted with an interest rate of 2 %. The annuity of the short rotation coppice was used as the standard for comparison with annual agricultural crops. Weed control by displaying a mulch film achieved a significant higher biomass yield in the first rotation period than other methods of weed control at both sites. The yield was 36 % higher at one farm and 38 % at the other location compared with the mean yield of the other treatments. This was due to a higher growth during the first two years. The yield surplus of the mulch film treatment couldn't compensate for the higher cost. The greatest annuity achieves the treatment of the undersown crop White clover at one site and the control at the other site. If the mulch film treatment achieves an additional biomass yield of 9 % at one farm and 14 % at the other in the further rotations compared with the other treatments it will be the most profitable method of weed control. But this is rather unlikely. The biomass yields of the undersown crop

treatments in the first rotation didn't differ significantly from the control. Also Stoll and Dohrenbusch (2009) determined no higher yields of poplar clones with undersown crops compared with natural weed infestation. But a prediction of the species composition of the weeds and the associated risk of reduced tree growth is difficult. Thus we recommend the undersown treatment when establishing short rotation coppices in organic farming.

Keywords: short rotation coppice, organic farming, weed control, biomass yield, annuity

1. Introduction

Organic farms in Germany ought to be energy self-sufficient. One mean to achieve this can be the production of energy wood in short rotation coppice. When establishing a short rotation coppice an effective weed control guarantees a sufficient survival rate of plants and a high yield already in the first rotation. The use of herbicides is a well-proven and recommended method of weed control. But organic farms are not allowed to use herbicides. Therefore we tested other methods of weed control which are in accordance with the principles of organic farming.

2. Method

In the same experimental setup we tested two different clones of poplar and the tree-species Black and Grey alder which were not genetically engineered by breeding. We choose a random plot design with five replications of the two factors "weed control" and "tree species/ variety" at plots of 75 m² each in size. We simultaneously conducted this experiment at two different farms in the southern part of Bavaria. Initially the ground was mechanically cultivated by ploughing and harrowing. We sow four different crops (Black medic, White clover, False flax and Rye) before planting the trees. The display of a self-degradable mulch film was the fifth method of weed control. At the control plots no further weed control was applied beside the initial mechanical tillage. In the second year we counted tree survival and replaced died off trees. Each year we measured tree height, the diameter at breast height and at the stump collar. After seven vegetation periods we harvested the trees and measured the yield. We calculated the profitability of the short rotation coppices assuming four rotation periods. For the second, third and fourth rotation we assumed that all treatments of weed control have the same yield as the treatment with the highest yield in the first harvest plus 10 %. The cost of recultivation after the last harvest was obtained from other investigations (Stoll et al. 2016). All revenues and costs were discounted with an interest rate of 2 %. The annuity of the short rotation coppices was used as the standard for comparison with annual agricultural crops.

3. Results and Discussion

Weed control by displaying a mulch film achieved a significant higher biomass yield than other methods of weed control at both sites. The yield was 36 % higher at one farm and 38 % at the other compared with the mean yield of the other treatments. This was due to a higher growth during the first two years. The increment of both the tree height and the diameters were significantly higher only in the first two years on plots with a mulch film. Gray alder achieved a yield of 53 % respectively 65 % and black alder a yield of 35 % respectively 43 % compared with the poplar clone which had the highest yield. The yield surplus of the mulch film treatment couldn't compensate for the higher cost. The greatest annuity achieved the treatment of the undersown crop White clover at one site and the control at the other site. If the mulch film treatment achieves an additional biomass yield of 9 % at one farm and 14 % at the other in the further rotations compared with the other treatments it will be the most profitable method of weed control. But this is rather unlikely. The biomass yields of the undersown crop treatments in the first rotation didn't differ significantly from the control. Also Stoll and Dohrenbusch (2009) determined no higher yields of poplar clones with undersown crops compared with natural weed infestation. But a prediction of the species composition of the weeds and the associated risk of reduced tree growth is difficult. Thus we recommend the undersown treatment when establishing short rotation coppices in organic farming.

The annuity of Grey alder is only 16 % at one site and 38 % at the other site compared with the best poplar clone. This is due to both, the lower biomass yield and the higher costs of plants and planting. Planting of poplar cuttings is much cheaper than planting of bare-rooted alder plants. The annuity of Black alder was even negative. This species had the lowest survival rate during the first year. A longer rotation period of the alders might improve the profitability.

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PHYSICAL STRAIN, EXPOSURE TO NOISE AND POSTURAL ASSESSMENT OF MOTOR-MANUAL FELLING OF WILLOW SHORT ROTATION COPPICE USING BRUSH CUTTERS

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Abstract:

Biomass for energy production and other bioproducts may be procured from various sources including short-rotation willow cultures (WSRCs). Management of WSRCs involves several operations, including harvesting. The latter accounts for the greatest cost share and if conducted motor-manually it can expose the workers to noise and uncomfortable work postures. In addition, brush cutting operations are known to be physically demanding for those workers carrying them on. In this study we evaluated the physical strain, exposure to noise, and postural risk index for workers operating in motor-manual felling of willow stems. A small-sized noise level meter was placed according to existing standards on the helmet of the feller and was used to collect the sound pressure level (SPL) at one second sampling rate. Heart rate (HR) was also sampled at a one second rate using a Polar V800 device that incorporated a GPS receiver. Two workers carried out the harvesting operations of WSRC and both of them were observed by videotaping to be able to evaluate the postural risk index (PRI). One of them manipulated the brush cutter while the other helped to fell the stems using a wooden stick. Based on the GPS collected data (more than 23000 positions), specific work tasks such as moving and felling, moving-without-felling, stopping etc. were separated using the movement speed derived from BaseCamp software and paired to the HR recordings. Then, the SPL data was paired to the GPS dataset based on time labels. Postural analysis was developed based on the videotaped files, using the OWAS system, by extracting frames at one second rate (more than 2300 for each worker). Physical strain of brush cutting operations was rated at 41.11-41.76% of the HRR using three calculation approaches, indicating a heavy work experienced by the worker. However, we observed that significant increments in HR were the effect of changing the tasks from cutting to walking-without-cutting to start a new row. Data coming from the first part of the working day differed from that coming from the last part, indicating an accumulation of physical strain. SPL exceeded most of the time 90 dB (A), and it was in the range of cca. 85-110 dB (A) when actually operating the brush cutter to fell the stems, indicating the need to reconfigure the work organization. PRI was evaluated at 181.31% for the worker handling the brush cutter and at 185.00% for the manual assistant indicating that there is a need to take corrective measures in the near future. While the values of the two were close, the differences between the two operational tasks rest in the back posture which was evaluated as being more difficult for the manual assistant. The latter was evaluated frequently as having the back bent and twisted. Based on the obtained results, we propose measures for improvement in motor-manual felling of WSRCs

Keywords: ergonomics, physical strain, exposure to noise, postural assessment, productivity, willow, short rotation coppice, sensors

PRODUCTIVITY OF CTL HARVESTERS IN HARDWOOD HARVESTING

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Abstract: The development of cut-to-length (CTL) harvesters and harvesting heads has been primarily focused on felling and processing of softwood trees, and thus these machines usually yield their optimum productivity with conifers of medium dimensions in relation to their capacity range. With increasing mechanization and growing shares of hardwoods in central European forests the use of CTL harvesters in hardwood dominated stands, including trees of larger dimensions, is gaining importance. However, while numerous productivity studies of CTL harvesters in softwood stands have been performed over the last decades, productivity studies in medium- and large-size hardwood stands are still scarce. The first investigations on CTL harvesting operations in hardwoods that have been performed indicated a pronounced influence of the complex tree form and wood properties of hardwoods on harvester productivity.

In four case studies, i.e. at four different sites denoted BB, HA, HG and RO, four different types of CTL harvesters have been tested under conditions typical for close-to-nature forestry in southern Germany:

a wheeled harvester with an operating weight of 26 metric tons, 8 meters crane reach and a maximum cutting diameter of 80 cm in BB,

a wheeled harvester with an operating weight of 23 metric tons, 10 meters crane reach and a maximum cutting diameter of 75 cm in HA,

a tracked harvester with an operating weight of 54 metric tons, 15 meters crane reach and a maximum cutting diameter of 110 cm in HG,

and a tracked harvester with an operating weight of 51 metric tons, 14.5 meters crane reach and a maximum cutting diameter of 80 cm in RO.

Harvested trees were almost entirely beech (*Fagus sylvatica* L.) with a small number of oaks (*Quercus* spp.); mean diameter at breast height (dbh) for the four case studies ranged from 36 to 47 cm with single trees exceeding a dbh of 60 cm. The number of trees considered in the analysis for the four case studies were 67 for HA, 72 for RO, 79 for BB and 104 for HG, respectively. In the case studies HA and RO fully mechanized felling and processing of all 67 and 72 trees was carried out. In the

other two case studies a portion of the harvested trees (23 trees for BB and 56 trees for HG) were pre-felled motor-manually before being processed by the machines while the remaining trees (56 trees for BB and 48 trees for HG) were handled entirely by the harvesters.

Despite the harvested trees being more difficult to process than common softwoods, high productivities of the tested machines have been observed. In the case of fully mechanized processing of trees, productivities were

29 m^3/PMH_0 in HA,

34 m^3/PMH_0 in RO, and

43 m^3/PMH_0 in both BB and HG.

With the groups of trees that were pre-felled motor-manually in BB and HG, processing productivities of 50 m^3/PMH_0 and 39 m^3/PMH_0 have been recorded. Harvesting productivity observed for the wheeled harvester in case study BB was thus on par with the heavy tracked machines tested. Working technique – especially during processing – as well as motor-manual preparation of large trees for felling by the harvester as it was performed in BB had considerable influence on machine efficiency.

These findings should primarily be conceived as a general orientation on the operational capabilities of the tested machines, and they suggest further research to ascertain the influence of complex tree architecture and the seemingly pronounced operator effect.

Keywords: mechanized operations; hardwood processing; work technique; time and motion study

SURVEY OF HARVESTING PRACTICES FOR WOOD CHIPS IN FRANCE: SYNTHESIS AND RECOMMENDATIONS ON HARVESTING PRACTICES TO INCREASE ENVIRONMENTAL PERFORMANCE

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Abstract: French forest policies call for additional wood mobilization to contribute to the energy transition and the further development of the bio economy. In this context, wood harvested for energy purposes has already increased from 3.8 million cubic meters in 2009 to 8.1 in 2016, with prospects for strong developments. In parallel, adapted harvesting systems introduced during the last decade, particularly whole-tree harvesting or stump extraction, mobilize relatively new machines such as feller-bunchers or shear heads. Several studies and research projects supported that transition to offer knowledge-based characterizations of the potential impacts of these new practices on forest ecosystems (biodiversity, landscape, soil fertility) and to provide forest managers, logging companies and governance stakeholders with recommendations to minimize these impacts. In this purpose, the national project Gerboise surveyed forest wood-chip production practices with 2 main work packages. The first one aimed to establish a national review of the main harvesting methods in France: 71% of the volume come from hardwoods. Chips are mainly processed from whole trees (51%) and large beech and oak crowns (33%). Lessons were learnt also on the types of harvesting operations and stands: 43% of the volume is extracted from traditional coppice (with or without standards) and 12% from young regular stands where skid trails are opened for the first time. The second part set a precise monitoring of harvesting methods on logging sites in order to quantify mineral exports and analyze the potential impact on biodiversity. This monitoring included several steps defined in an experimental protocol: stand inventory including standing and laying dead wood, green trees sampling to determine in laboratory the mineral contents and quantities for each part of the biomass (trunk, bark, big and small branches, foliage). Measurements are repeated before and after felling and forwarding in order to quantify and qualify mineral exports related to the considered harvesting methods. Soil analyzes and biomass sampling on the landing site at roadside are also included in the protocol. The latter was applied on thirteen logging sites so far, datasets were analyzed and synthetized in short case-study reports for future dialog between researchers and practitioners. Finally, pre-existing national recommendations for wood energy harvesting practices (ADEME 2006) were up-dated. The main principles of these revised guidelines are: avoid foliage export, adapt the quantity of harvested fine wood and extracted stumps to soil fertility conditions, keep biodiversity supports (dead trees…). The 2018 recommendations are now specified for stands and harvesting operations according both to soil type (3 sensitivity classes) and biodiversity (3 levels). This biodiversity concern and the adaptation of fine wood and slash residues harvest are a new paradigm for practitioners in comparison with previous recommendations

Keywords: forest biomass, wood chips, logging operations, environmental performance, mineral export, biodiversity

EFFECT OF SOIL COMPACTION ON TREE GROWTH: A META-ANALYSIS.

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Abstract: In recent decades, many papers about the effects of forest operation on soil compaction and thus tree growth and regeneration have been published. Most of them examined one or few compaction degrees, tree species, taxonomic groups or soil types, providing interesting result but without interconnections among studies. In order to fill this gap, our study aims to draw general conclusions concerning the impact of mechanized harvesting and soil compaction on tree growth and regeneration by means of a meta-analysis. We specifically addressed (i) the effects of soil compaction on shoot morphological and physical traits as well as root parameters (ii) the effects of compaction degree, soil type and tree species (iii) the experimental factors which affect the variation in growth responses to compaction. The data of several studies were collected taking into consideration peer-reviewed literature indexed in several databases and published between 1948 and 2017. A cross-disciplinary approach was applied including researches under natural environmental conditions and manipulative experiments. The studies were initially filtered by title and subsequently the abstracts were examined with regard to the possible relevance to the research questions. Additional criteria used for inclusion into the final stage of the meta-analysis were: the presence of the mean value of the response variable (root, shoot or total dry biomass: length, width or root diameter; photosynthetic and leaf traits) before and after soil compaction; a number of replicates available together with their standard deviations or standard errors; individual observations, values obtained from different cultivars/clones within a plant species, different soil compaction treatments and measurements made on different dates in the same experiment, to be statistically independent. Only the papers reporting a metric to quantify soil compaction were included. At the end of data collection, 58 articles with all the relevant details were identified and included in the meta-analysis. Our results suggest that compaction affects seedling growth by an overall decrease of shoot and root growth with increasing levels of soil compaction; the effect resulted higher in loamy soil than in sandy soil, and significant on main root length and total and roots dry biomass. On the contrary, significant differences did not occurred comparing morphological characters of conifers and hardwoods species. Compaction significantly reduced net photosynthesis, did not affect leaf nitrogen content (as a proxy of nutrient uptake from roots) but decreased leaf water potential (as a proxy of water uptake from roots). Therefore, the reduction

of water availability was a primary cause for the decline of photosynthesis. Interestingly, those negative impacts of soil compaction on leaf physiology occurred in loamy soils rather than in sandy soils

Keywords: compaction, meta-analysis, seedlings growth, seedling root-system, physiological attributes

FORESTRY RESIDUES AS POTENTIAL BASE MATERIAL OF HEAT PRODUCTION

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Abstract: *Heat energy can be produced by using a number of basic materials. Among them, in this research the potential amount of forestry residues were examined. Today, their use is not considerable yet due to collection difficulties and technical obstacles. The knowledge of potentially useable forest wood and other by-products of wood is very important in order to meet the new EU directive requirements.*

Our research was carried out by using GIS methods. To get more accurate and detailed information, statistical data and harvest data of forests as well as the results of literatures were also taken into account. The Bioenergy Reasearch Group of the University of Sopron have planned to examine the real amount of forestry residues in different areas.

This paper aims to estimate the potential mass of the economically collectible forestry residues. The survey has been made for the whole territory of Hungary. During the assessment of base material the user market was also examined. The main users of forestry residues are soil melioration, power plants, heating plants, boilers, pellet and briquette plants.

Keywords*:* biomass potential, forestry residues, heat production

1. Introduction

A significant part of Hungary's territory, 21% is covered by forest. The size of the forestry area is constantly rising, which among woodland areas, includes other forest roads, clearings and seedlings. The 1.86 million hectares of forest in 2016 increased by 7.9%, 148 thousand hectares compared to 2000 (KSH 2017). The forest areas are located in a concentrated region in the country. Extensive forests, mainly due to geological and climatic conditions, developed in the hilly and mountain areas of Northern Hungary and Southern Transdanubia. According to the counties, the largest forest area is in Borsod-Abaúj-Zemplén (217 thousand hectares), which is 11% of the country's forest area. Somogy, Bács-Kiskun, Zala and Pest counties also have a significant forest area, as shown in Figure 1.

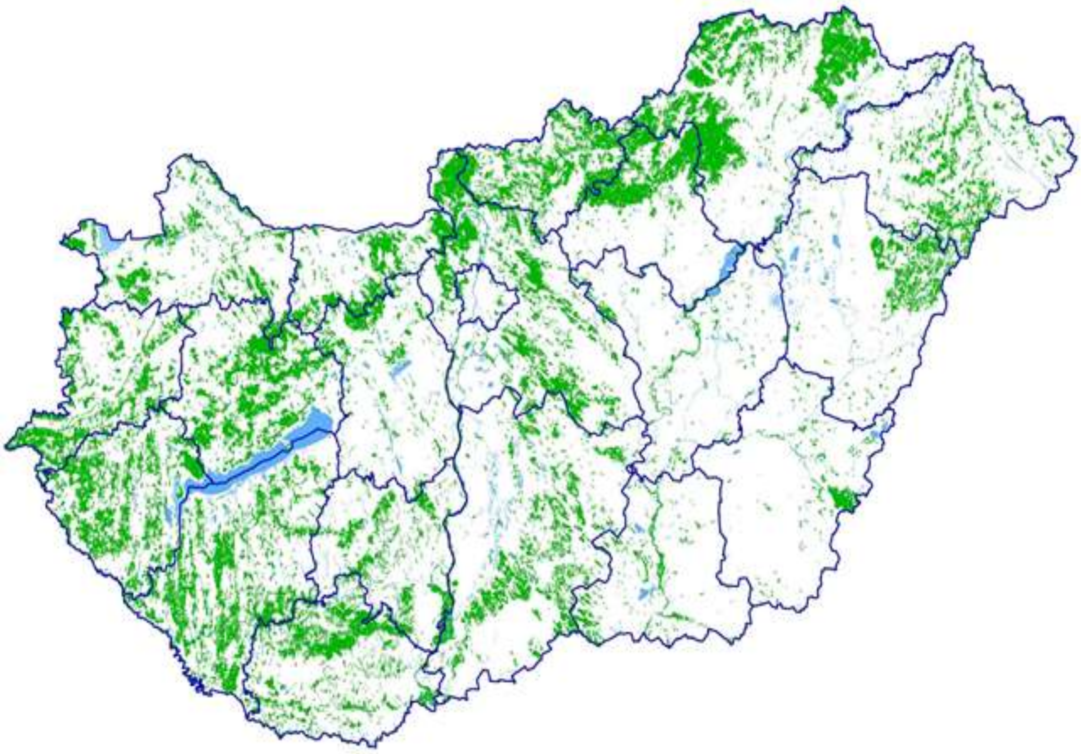

Figure 1. Distribution of the Hungarian forest area based on the Corine Land Cover map

According to the data of the Central Statistical Office of 2011, total (gross) logging amounted to 8.1 million m^3, of which 6.9 million m^3 was delivered for use. According to forestry research, this means that 1.2 million m^3 of residues (branches, tiny trees, etc.) remained in the forest without use, which was 14.8% of gross logging (Molnár *et al.* 2011).

In the case of forest biomass, it consists mainly of by-products of forest management. In other words, products that are felled during commercial and non-commercial operations but are not utilized for conventional forest industries such timber and pulp. Available biomass fractions for energy uses include small diameter stems, branches, tops, needles and even stumps and roots (Karjalainen *et al.* 2004) and have been the focus of several studies aiming at estimating forest based potentials for wood biomass for energy, revealing large amounts of unused biomass resources (Asikainen *et al.* 2008, Anttila *et al.* 2009, Díaz-Y *et al*. 2012) The European Union directives on the utilization of biomass by-products may receive an increasing role in the future (EEA 2013).

Wood energy possibilities of Hungarian forests depend on the expected amount of firewood and forest exploitation of the possibility of logging waste. Most of the wood that is not suitable for industrial use is already utilized in power plants or firewood. A significant part of the resulting quantity is used in the form of chips, in heat plants and in boilers. Wood which has not been used yet can be a part of the felling logging residues.

2. Logging residues

During the logging produced by-product is called logging residues, includes wood chips, sawdust, wood wedge, thin twig, as well as industrial tree bark. The 5 cm thicker material called thick, the thinner thin logging residues (Göde 1985). Thin wood mainly can be economically collected after clearcutting. Bearing in mind the ecological aspects, 2/3 of logging residues is actually collectable. The use of stump-root is not yet resolved, although the technical condition of processing is right. The harvested stump-root is treated as waste, or pushed paste and leaved in the field, or stored without energy recovery. The harvest of stump-root can be performed flat or only slightly wavy surface area and only a few genetic soil types, for example sandy soil. The tree species of these areas are mostly robinia, poplar and pine (Szakálosné M. *et al.* 2013).

The felling logging waste collected in the form of stacking, or crushing as wood chips. In the case of wood chips, the shredding is carried out in the logging area or near that place, usually with a mobile lower-capacity shredder. Wood is transported in the form of chips to the final user site where it can be directly used (Barkóczy 2009).

Based on forestry research, while the produced firewood can be fully utilized for energy production, only a small part of the significant amount of logging residues can be delivered from the forest to the site of energy production (Szakálosné M. *et al.* 2012)

3. Materials and methods

The amount of annual generated by-products was determined by using geoinformatic, statistical and literature data. In estimating the mass of forest residues we considered that the amount of by-products decreased due to the development of the logging technology. Since by-products can not be collected in full because of ecological and technology considerations, we have estimated the weight of the generated and recoverable by-products. The amount of residues was examined by Corin Land Cover map, as well as data collected from central statistical and forestry data collection.

The significance of our research is that the estimation of the raw material potential is carried out in a number of database systems, which was supplemented by a GIS method for greater reliability of the data. The method is to determine the biomass production area and land use categories by Corine Land Cover map. After the determination of the forest cover and wood species of the region, the annual yield, and estimation of the total amount of usable biomass is made by using the literature and statistical data. The amount of logging and growing stock changes annually, so we have taken into account the yields of the last five years in the calculations.

During calculations we calculated on the basis of the county forest data obtained from the Corine Land Cover maps and by means of forestry and Central Statistical Office. Literature data were also used for the amount of by-products. From 2012, the GIO-Land project takes place under the Copernicus program. Its main tasks are updating the Corine land cover database for 2012 (CLC 2012), as well as looking for land cover changes in 2006-2014. As new items, High Resolution Surface Layers are also made for Europe. The CLC2012 databases were prepared in the framework of the GIO-Hungary project, completed in autumn 2014, financed by EEA (Fömi 2015). According to the Corine maps, the area of the deciduous and coniferus trees can be separated by county, as shown in the following figure.

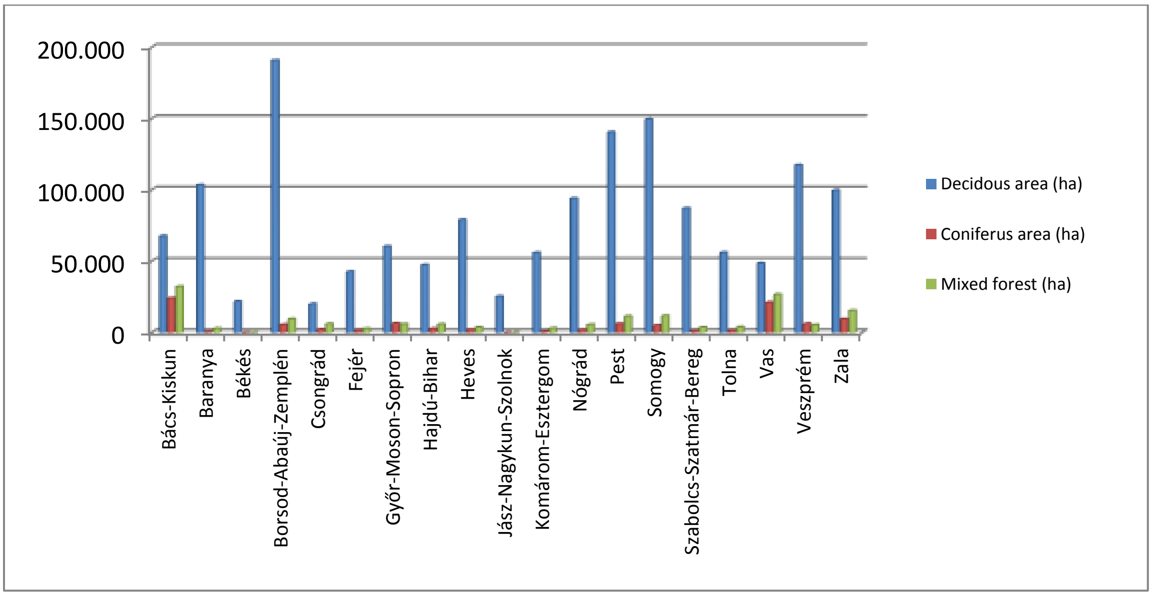

Figure 2. County distribution of deciduous, coniferus and mixed forests in Hungary

As shown in the 3. figure, the largest area is represented by deciduous species. Spruce pines (*Picea abies*) have become a smaller and smaller area due to the decline of recent years.

As regards the composition and annual logging of the tree species in Hungary, acacia (*Robinia pseudoacacia*) is the higher, but the size of the oak and beech covered areas is also significant. As shown in the figure, the largest area is represented by deciduous species.

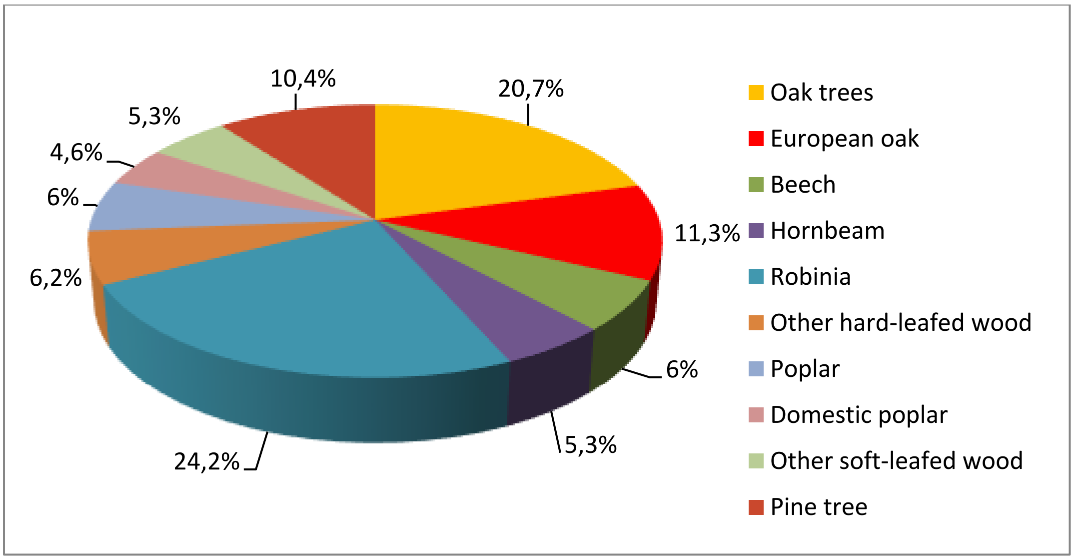

Figure 3. Distribution of wood production by tree species (KSH 2017)

The growing stock has been increasing in the last ten year, 373 million m^3 was in 2016. The annual logging was between 6,9-8,01 million m^3 in the last five years (KSH 2017). Different sources of literature are available in the amount of annual generated by-products. One of the reasons is that the harvesting technology also greatly influences the amount of byproducts produced. For example, the felling logging waste due to the more modern extraction processes decreased in the last 15 years from 20% to 12-13% (Molnár 2012). The average of forest residue factor, according to most analyzes is 12% of the harvested timber (Cosi, *et al.* 2011). Measurements on test plots in Slovenia showed that they can produce up to 0,13 m^3 of forest residues (for wood chips production) per each m^3 of roundwood harvested (Krajnc *et al.* 2012).

5. Results

There are different opinion in the collection and utilization of forestry waste. The European and Hungarian forest programs, however, want to achieve not only economic but also ecological sustainability of forests (FVM 2004). So it becomes questionable whether the ecological sustainability principle corresponds to the utilization of the forest logging residues. The removal of branches and leaves causes much greater losses of the nutrient flow of the site than the wood (Mátyás 2004). However, there is no specific task for the utilization of logging by-product (FVM 2004, 61/2009, FVM Decree, Act of XXXVII of 2009). It is probable that, as long as the regulation does not provide otherwise, it will be used for energy purposes in the near future (Pappné V. 2010). Bearing in mind the ecological reasons, in potential estimation, 2/3 of the annual forest residues could be collected realistically.

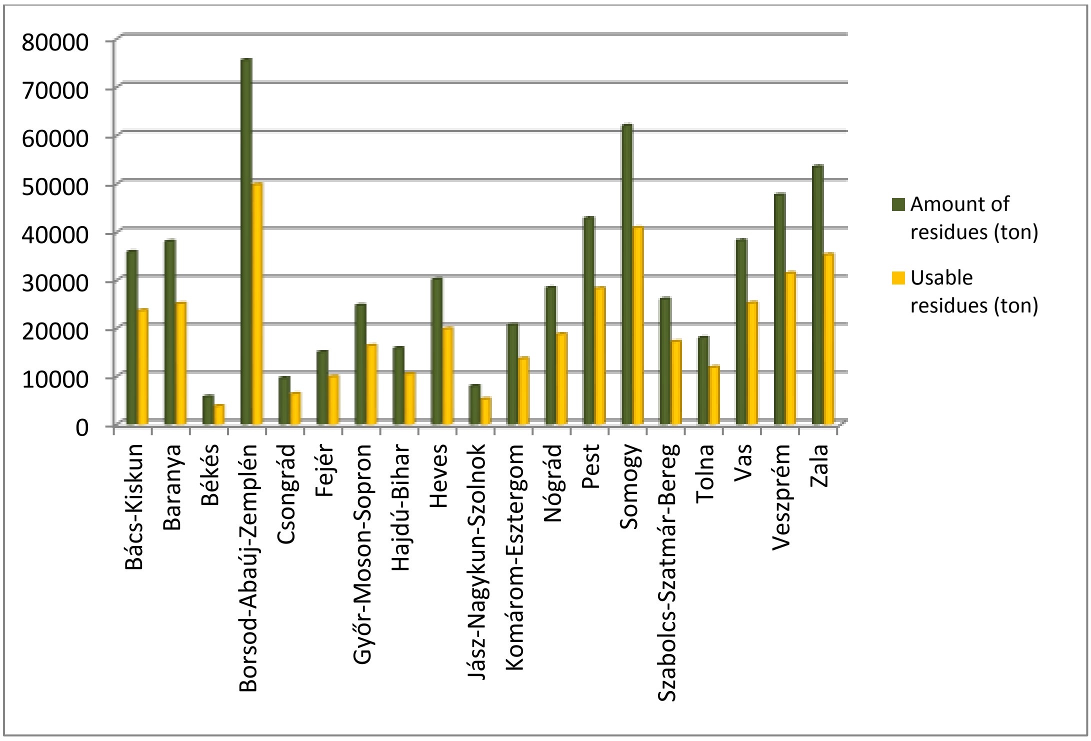

Figure 4. The amount of annual generated and theoretically usable by-products

Based on the results, it can be said that a significant amount of by-product is generated each year during the harvesting. During logging, 595,000 tonnes of by-products are generated in wet mass, with about 390,000 tonnes being utilized taking into account technological and ecological considerations. According to the counties, the higher by-product potential is in Borsod-Abaúj-Zemplén. Baranya,Veszprém, Somogy, Bács-Kiskun, Zala and Pest counties also have a significant by-product amount.

During the assessment of base material, the user market was also examined. The main users of forestry residues are soil melioration, power plants, heating plants, boilers, pellet and briquette factories. In general it can be stated that the by-products are collected only in few places. Nowadays, forestry by-products are the most commonly used in power plants.

6. Conclusions

Overall, a significant amount of forestry by-products is generated annually. Taking into account the ecological and technological aspects, the amount of by-products that can be used for energy purposes is between 390-400 thousand tons each year. Nowadays the collection and utilization of by-products is only slightly solved. The European Union directives on the utilization of biomass by-products may receive an increasing role in the future. The energy utilization of forest by-products will be expected in Hungary. The spread of utilization is justified by newer processing technologies, therefore demand for by-products will increase.

Acknowledgement

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LIFE CYCLE ASSESSMENT OF DECENTRALIZED MOBILE PRODUCTION SYSTEMS FOR PELLETIZING LOGGING RESIDUES UNDER NORDIC CONDITIONS

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Abstract:

The development of mobile systems for the decentralized pelletizing of forest-based residual biomass is currently underway. However, there is a lack of knowledge regarding the environmental impacts of such systems that needs to be developed for correct judgements on the most sustainable developing paths. The objective of this study was to quantify and compare the environmental impacts of a decentralized mobile production system for pelletizing logging residues in Northern Sweden operating at either the forest landing or forest terminal from a Life Cycle Assessment (LCA) perspective.

The results showed that the landing- and terminal-based scenarios showed similar environmental profiles. The pelleting, transportation and drying stages of both scenarios were identified as environmental hotspots. These production stages accounted for 62%, 14% and 14% of the total greenhouse gas emissions, respectively. Key factors influencing the system were the use of electricity at terminals, the increase in pelletizer capacity, and long transportation distances. The use of a Swedish electricity mix in the terminal-based scenario reduced all of the environmental impacts by between 68% and 83%, with the exception of fresh water eutrophication potential, which increased by 26%.

In conclusion, our findings indicate that an electrified mobile pellet production system with high operational efficiency and situated at a terminal close to the harvesting sites could, from an LCA point of view, be an interesting option for pelletizing Nordic logging residues, especially in regions with long transportation distances to industry.

Keywords: (komaseparated): environmental evaluation, bioenergy, LCA, GHG emissions, pellets

ANALYSIS OF UNREGISTERED TIMBER VOLUME IN ALLOWANCE IN CUT-TO-LENGTH LOGGING

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Abstract: *When producing logs or whole-stem logs by cut-to-length logging, it is common practice to add length margin to the length of the produced logs in favour of the customer. This measure is motivated by the necessary cross-cutting which results in shortening of length, making it in turn impossible to achieve the standardized log lengths. The said length margin either follows an agreement between the supplier and customer or is set by a standard of 2 % of the nominal length (in accordance with the recommended regulations valid in the Czech Republic). As a rule, length margin is not added to the length of logs intended for disintegrated wood production or for chemical processing (e.g. pulpwood). In cases when harvester technology is deployed, the length margin is increased to include the clearance required by the setting of cutting windows in the wood procurement software. This measure decreases the sensitivity of the measuring device (measuring wheel) to increase the machine's performance in favour of the length measurement precision. The standard range of the cutting window is 0 – 2 cm. Based on the above-mentioned facts it can be stated that the length of the produced logs is increased by 2 % of the nominal length combined with the maximum length of the pre-set cutting window. This timber volume is not registered in forest management records and as such represents a factual loss for forest owners. The analysis was conducted in advance felling with produced timber volume ranging from 0.11 – 0.20 m^3 i.b. and in final felling with produced average timber volume of assortments 0.304 m^3 i.b. The data collected during the conducted study allow us to quantify the losses suffered by forest owners in planned felling at 1.68 – 1.72 % of the produced timber. In spruce harvesting, no length margin is added to pulpwood and pole production, thus it reflects purely the allowance for the cutting window; the estimated losses account to 0.22 – 0.45 % of the production volume. In other assortments the* *estimated losses range from 2.06 – 3.88 %, depending on the given assortment. In planned final felling, with an average volume of harvested trees at 1.23 m³ i.b., the total volume of allowance amounted to 2.31 % of the production volume. The lowest allowance ratio, ranging to 1.33 % of production volume, was recorded in mechanical pulpwood and other pulpwood; the highest ratio was recorded in saw timber at 3.41 % of production volume. The extent of this loss may vary, primarily in relation to the tree species, the ratio of produced assortments and the harvested stem volume. Calculations of allowance volume may represent one of the points accounting for the more than 20 % difference between the timber volume recorded by national forest inventory survey and the merchantable timber volume.*

Keywords: harvester technology, CTL method, allowance, assortment, timber registration.

1. Introduction

During timber production, the forest owners lose timber volume due to either fictitious or factual timber losses. These losses can occur because the timber producers and customers measure log parameters differently, round down lengths, diameters, involuntarily interchange logs, or because the producers leave unprocessed timber in the forest stand (Simanov 2003). The factual losses include losses due to length margin and other allowances, like the cutting window used by harvesters (if the diameter is greater than 7cm).

The length margin is the allowance to the nominal length of the log given to the customer free of charge to account for technological losses such as timber shrinkage, crosscutting losses, etc. (Poleno et al. 1994). In the Czech Republic, the length margin is advised to be about 2% of the nominal log length but can be negotiated differently by the contracting parties (DPMTD 2007, LČR 2009). This approach is similar to most countries, where the length margin is also negotiated by the contracting parties (NRCC 2003), commonly about 3% of the nominal length (Anonymus 2006). The length margin is added to all assortments intended for sawn wood production but not to those intended for chemical processing or production of disintegrated material.

Another type of allowance to the nominal length, the so-called cutting window, is used in harvester technology, commonly in the 0–2 cm range. However, it can be occasionally increased to as much as four centimeters. The cutting window affects the tolerance of the measurement sensors (the measurement wheel) in the harvester head. As a result, the time needed to adjust the stem to the correct bucking position shortens and productivity of the machine increases. The cutting window is set for each produced assortment type, including pulp wood.

Pre-setting the length margin and the cutting window within the wood procurement systems of the harvesters is carried out by a technician or a skilled forestry official. On the other hand, in manual log production the loggers only add the length margin to the log's nominal length.

The factual losses from both types of allowance can show in the differences between the volume of raw timber estimated by the National forest inventory of the Czech Republic survey and the producers' records of raw timber production. The difference between these two estimates reaches more than 20% of timber (MZe 2017) in the Czech Republic. By estimating the share of both allowances, we can partially explain the difference.

The aim of this analysis is to estimate the volume of the timber lost by allowing for the length margin and the cutting window, in relation to the produced assortments and selected cruising factors. We shall focus on timber produced by harvesters, as they conveniently measure and record the log parameters and harvest a relatively large share of the total volume in the Czech Republic — about 36% of the annual harvest.

2. Material and Methods

For this pilot study, we chose three spruce stands. This species is optimal for deploying harvester technology and the most abundant species in the Czech Republic (51%) (MZe 2017). The selected stands had varying age to account for the different mid stem diameter (tab. 1). This allowed us to analyse the effects of the cruising parameters (length, diameter) on the volume of the length allowances. Furthermore, we selected stands where thinning and final felling took place (ČESKO 1995), which enabled us to analyse the relationship between the volume allocated to the allowances and the harvest type.

Tab. 1. Cruising parameters of the studied forest stands according to the Forest Management Plan

tree species	share	mean tree volume	height	diameter at breast height	yield class	standing volume	Felling type
	[%]	[m^3]	[m]	[cm]	[-]	[m^3/ha]	[-]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
stand 2A4b							
spruce	100	0.15	16	16	28/3	243	T
stand 73A6							
spruce	100	0.29	20	20	28/3	339	T
stand 128C15b							
spuce/beech	83/17	2,1/1.6	35/30	44/38	35/30	685	F

T – thinning; F – final felling

In the selected stands, nine assortment types were produced. Their volume was estimated by the following price types (tab. 2, column 2):

m3toDE – including this price type in the wood procurement software of the machines was requested by German foresters. Volume estimations are based on the mid-diameter of the particular log and its nominal length. The mid-diameter is rounded down to the nearest cm and subsequently serves for estimations of the log's volume. Within this price type, logs are graded by the minimal small end diameter. This standardized procedure of volume estimation is used, apart from the Czech Republic (DPMTD 2007), mostly in Germany and other countries (NĚMECKO 2015).

m3f - The volume of the whole stem or log is estimated from the real (not rounded off) section diameter. The diameter is measured in mm each 10 cm of the stem's or log's length. The assortment is graded by its large end diameter. This price type served for volume estimations of higher grade pulpwood (further: pulpwood mechanical), regular pulpwood, and pulpwood for manufacture of particle boards

Tab. 2. Recorded production and "price types" for calculating volume

assortment	price type	min. small end diameter	nominal log length	specified quality	quality class	length margin	cutting window
		[cm]	[m]	[-]			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Butt	m3toDE	35	4.00	1,2	II.	X	X
Roundwood	m3toDE	20	4.00 / 5.00	1,2,3,4	III.	X	X
Aggregate	m3toDE	12	4.00 / 2.45	1,2,3,4,5	III.	X	X
KPZ	m3toDE	17 (18)	3.00 / 4.00	6	III.	X	X
Poles	m3toDE	6	2.55	1,2,4	IV.	-	X
Pulpwood mechanical	m3fm	8	2.00	1,2,4	IV.	-	X
Selection pulpwood	m3toDE	12	2.45	1,2,3,8	V.	X	X
Pulpwood	m3fm	5	2.00	1,2,3,4,7	V.	-	X
DTD	m3fm	8	2.00	1,2,3,4,7	V.	-	X
„slash“	m3fm	4	0.01	1,2,3,4,5, 6 7,8	-	-	X

KPZ – Roundwood for sawn wood production; ROTO - mechanical wood pulp; DTD – assortment for particle boards.

(DTD) is estimated through this price type.

The timber volumes were recorded inside bark (i.b.), which was estimated from the measured over bark (o.b.) diameter through a species specific polynomial function (Černý, Pařez 2019). Table 2, column 7 and 8 shows the customers who demanded the length margin, as well as those to whom only the cutting window was allowed for. The last item recorded in production was „slash ", which normally stays in the forest stand. Its volume was estimated separately, as no desired assortments could be produced from it. The nominal length of slash did not reach more than two meters; however it could contain some timber over seven centimetres thick.

The timber was produced by John Deere harvesters — thinnings were carried out by a John Deere 770 and the final felling by a John Deere 1070. The parameters for timber production were put into the wood procurement software of the machines through the software SilvaA as *.APT files. The data on production were saved in the database of the TimberMatic 300 and TimberMatic H-12 software. We collected data from *.STM and *.PRD files. The *.STM files were pre-set to save individual trees as individual files.

For each assortment, we recorded the total number of logs produced, the total volume of allowances according to Czech standards, using Huber's formula (1). Over bark log mid-diameters were put into the formula. The formula (1) also contains the bark deductions according to the Czech polynomial function (Černý, Pařez 2009), so that the inside bark volume was estimated.

$$V_{bk} = \frac{\pi}{4} * \left[d_{sk} - (0{,}57723 + 0{,}006897.\, d_{sk}^{1{,}3123})\right]^2 * l * 10^{-4} \qquad (1)$$

where: V_{bk} - log volume inside bark (m^3), d_{sk} - log mid-diameter measured over bark (cm), l - log length (m).

From the estimated volumes, we determined the share of timber for allowances based on the assortment types, the total volume of produced timber in the selected forest stands, and the harvest type, thus estimating the total volume of actual timber losses due to allowances. Through ANOVA, we then analysed the mean allowance volume in the particular stands, as well as the relationship between the allowance volume and the harvest type (thinning vs. final felling).

3. Results

The study material consisted of 1,418 trees (6,988 logs) from three forest stands (tab. 3).

In stand 2A4b, 69.644 m^3 of timber were harvested, with another 1.17 m^3 not recorded as allowances. The share of the allowances was 1.68 % of the total volume of the produced logs. In assortments that contained the length margin, as well as the cutting window, the share of allowances on total harvested volume ranged from 2.06 to 3.88 %. In those assortments where the length margin was not allowed for, the total allowance ranged from 0.28 to 0.45 %. The low share of the volume of the allowances (1.65 %) was given by the high share of poles and pulpwood production (54.6 %) (tab. 4).

In the second stand (73A6), 100.319 m^3 of timber were produced. The allowances added another 1.72 % to the total volume of timber extracted from the stand. The length margin was added to Aggregate, KPZ, Roundwood, and Pulpwood selection assortments and together with the cutting window, they ranged from 2.76 to 3.47 % of the total production volume. In ROTO, and pulpwood assortments, which did not contain the length margin, the allowance through the cutting window accounted for 0.22 to 0.26 % of the total produced volume. The low volume of timber for allowances was again affected by the large share of lower grade assortments (54.7 %), to which the length margin was not added (tab. 4).

In the stand, where the final felling was carried out (128C15b), the volume of produced timber was 355.723 m^3. The allowances added another 2,31 % to the total volume of produced timber. The length margin, as well as the cutting window was added to all assortments, apart from DTD and coniferous pulpwood, for which the machine was set to only allow for the cutting window. In those assortments where both allowances were added, the share of allowances on the produced volume ranged from 2.17 to 3.41%, and in those assortments where only the cutting window was allowed for, the share of allowances ranged from 1.01 to 1.33% of the total log volume. The volume of timber allocated to allowances increased by 0.59% with the growing production of Roundwood for sawn wood production.

Tab. 3. The logs produced in the selected forest stands.

assortment	No. of felled trees	No. of logs produced	Mean log volume	Median log volume	Std. dev. Of the log volume
	[ks]		[m³]		
	stand 2A4b				
Aggregate	628	154	0.079	0.074	0.020
KPZ		12	0.154	0.158	0.025
Roundwood		2	0.167	0.167	0.015
Poles		1,208	0.018	0.017	0.005
Pulpwood		607	0.028	0.016	0.025
Pulpwood selection		529	0.033	0.031	0.008
	stand 73A6				
Aggregate	496	622	0.048	0.044	0.017
KPZ		20	0.166	0.158	0.028
Roundwood		20	0.176	0.174	0.028
ROTO		29	0.015	0.014	0.004
Pulpwood		2,445	0.022	0.016	0.023
Pulpwood selection		158	0.055	0.051	0.025
	stand 128C15b				
Aggregate	294	91	0.112	0.110	0.023
DTD		114	0.295	0.284	0.166
KPZ		154	0.381	0.364	0.203
Roundwood		465	0.495	0.438	0.247
Butt		10	0.869	0.870	0.286
Pulpwood – C.		333	0.040	0.032	0.046
Pulpwood – D.		15	0.061	0.051	0.037

KPZ – Roundwood for sawn wood production; ROTO - mechanical wood pulp; DTD – assortment for particle boards.

Fig. 1 demonstrates a slightly growing trend of the total unrecorded timber volume for allowances in individual forest stands related to the increasing volume of the harvested trees. This was affected by the requirements for allowances applicable to Roundwood. In the stand, where the mean stem volume was 1.23 m^3, the volume of Roundwood for sawn wood production was 86.5%, whereas in the youngest stand, with mean stem volume of 0.12 m^3, the share of this assortment type was 45.4% of the total harvested volume.

Tab. 4. The share of timber volume allocated to allowances.

assortment	Assortment volume according to Huber i.b.		Allowance volume according to Huber, i.b.	Total volume of produced assortments incl. allowances	Share of allowance volume
	[m³]	[%]	[m³]		[%]
	stand 2A4b				
Aggregate	12.219	17.5	0.288	12.507	2.30
KPZ	1.850	2.7	0.044	1.894	2.32
Roundwood	0.333	0.5	0.007	0.340	2.06
Poles	21.285	30.6	0.059	21.344	0.28
Pulpwood	16.699	24.0	0.075	16.774	0.45
Pulpwood selection	17.258	24.7	0.697	17.955	3.88
	stand 73A6				
Aggregate	29.913	29.8	1.074	30.987	3.47
KPZ	3.316	3.3	0.094	3.410	2.76
Roundwood	3.516	3.5	0.104	3.620	2.87
ROTO	0.449	0.4	0.001	0.450	0.22
Pulpwood	54.389	54.3	0.144	54.533	0.26
Pulpwood selection	8.736	8.7	0.307	9.043	3.39
	Stand 128C15b				
Aggregate	10.235	2.9	0.232	10.467	2.22
DTD	33.614	9.4	0.343	33.957	1.01
KPZ	58.611	16.5	2.070	60.681	3.41
Roundwood	230.214	64.7	5.117	235.331	2.17
Butt	8.686	2.4	0.264	8.950	2.95
Pulpwood – C.	13.454	3.8	0.181	13.635	1.33
Pulpwood – D.	0.909	0.3	0.023	0.932	2.47

KPZ – Roundwood for sawn wood production; ROTO - mechanical wood pulp; DTD – assortment for particle boards.

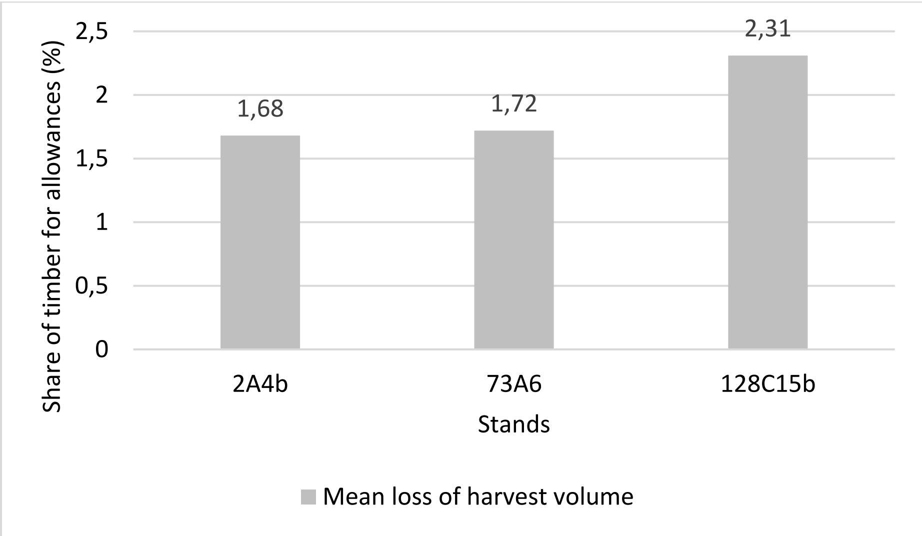

Fig. 1. Loss of timber volume from allowances.

Through ANOVA, we observed the relationship between the volume of allowances in particular stands and the mean volume of produced logs, as well as the harvesting type carried out in the particular stands. From the outcomes, presented in Fig. 2, we can see a significant difference in allowance volumes between stands 2A4b and 128C15b, as well as 73A6 and 128C15b. This outcome was logical, since the sizes of logs produced in thinnings (stand n. 1 and 2) and final felling (stand n. 3) were different, resulting in the production of different assortments and therefore a different share of allowances – tab 5. In thinnings (stands n. 1 and 2), even though the mean volume of produced logs was different, the difference between allowance volume was not statistically significant. To conclude, we can say that the harvest type was reflected in the allowance volume, as we saw significant differences between allowance volumes in stands where different harvest types were carried out. Conversely, in stands where similar harvests were carried out (thinnings) the volumes allocated to allowances were not statistically significant.

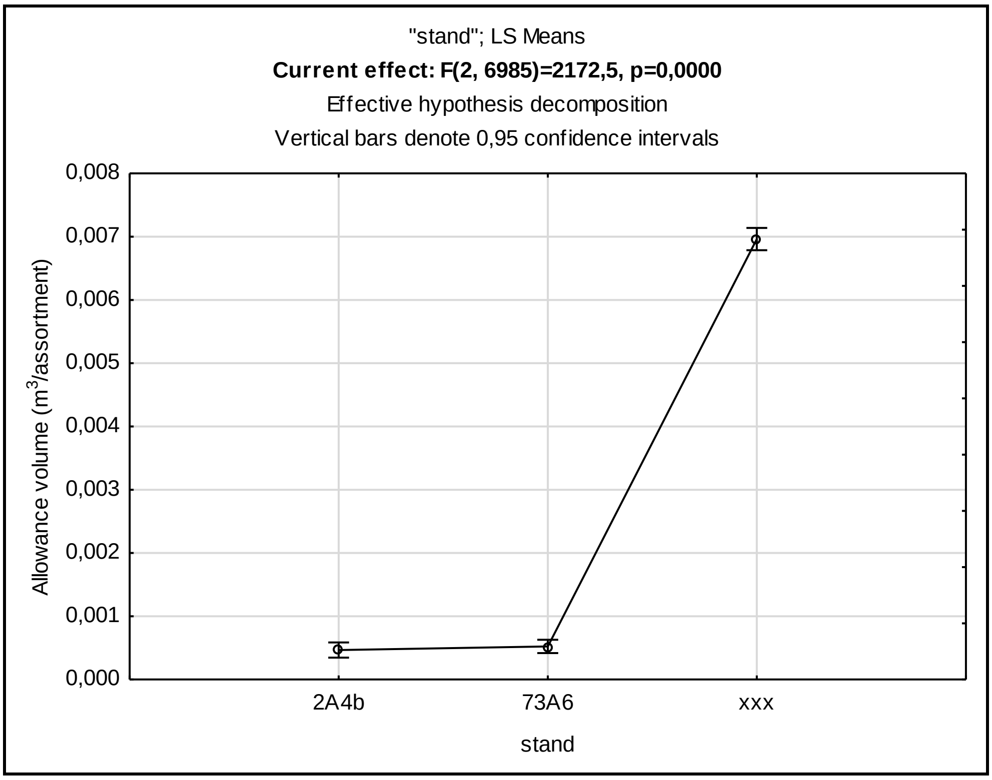

Fig. 2. Variability of the allowance volume in the selected stands and harvest types (1, 2 – thinning, 3 – final felling).

Tab 5. *LSD* test – multicomparative test.

Stand	2A4b	73A6	128C15b
2A4b	-	0.48	0
73A6	0.48	-	0
128C15b	0	0	-

The volume of the assortments ranged from 0.004 to 0.351 m^3 in thinnings, with the allowance volume reaching up to 0.009 m^3. The relationship between the allowance volume and the total volume of the particular log can be seen on Fig. 3.

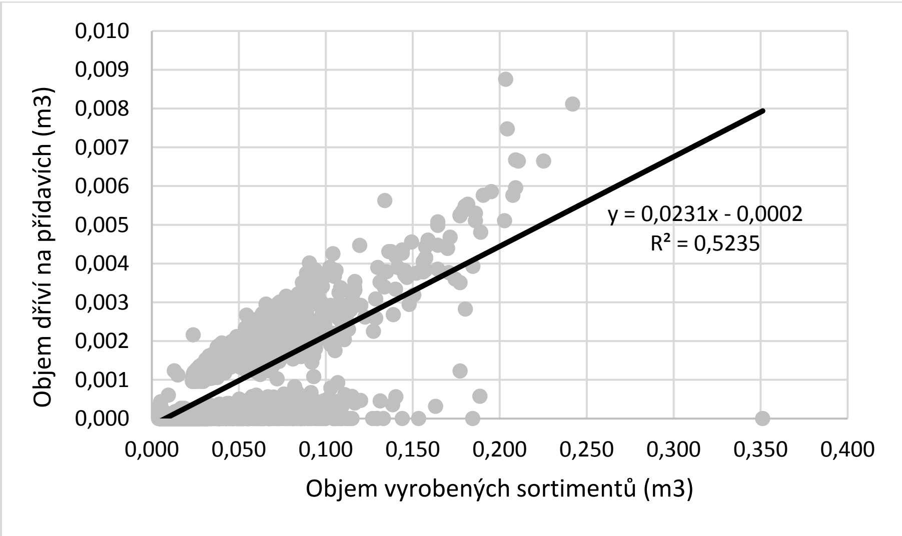

Fig. 3. The relationship between allowances volume and the total log volume in thinnings.

In the final felling, the volume of produced logs ranged from 0.005 to 1.292 m^3, and the corresponding allowance volume reached up to 0.038 m^3. The relationship between the allowances and the total log volume was strong, with the coefficient of correlation reaching 0.8673 (Fig. 4).

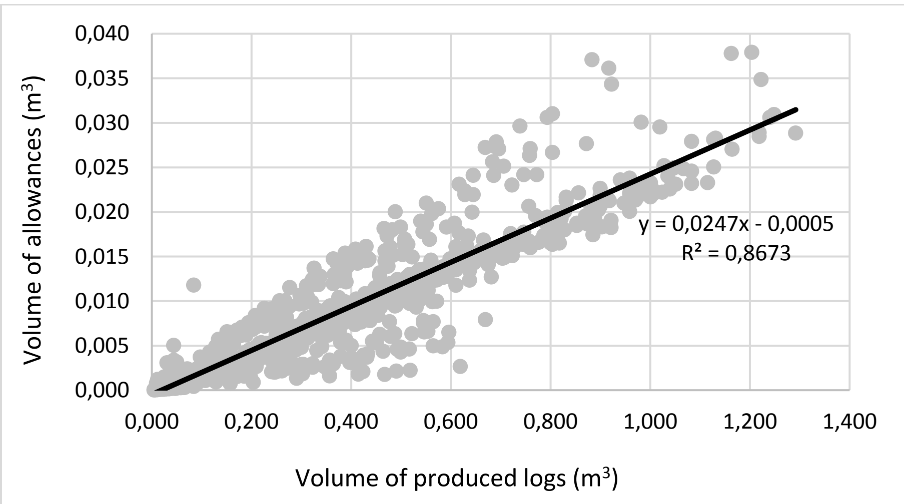

Fig. 4. Relationship between the allowances volume and the total volume of the produced logs in the final felling.

4. Discussion and Conclusions

When producing timber by harvesters, two allowances are accounted for — the length margin (commonly around 2% of the nominal log length in the Czech Republic) and the cutting window (0 – 2 cm, seldomly four cm). The volume of these allowances is not recorded in the forestry records and constitutes a factual loss for the forest owner. The aim of the presented contribution was to roughly estimate the volume of these allowances in spruce thinnings and final fellings. Within this study, we analysed 5,806 logs in thinnings and 1,182 logs in a final felling, from the records in the wood procurement systems of the John Deere harvesters that carried out the harvests in the observed forest stands. The statistical analyses showed a significant difference between the allowance volumes in the different harvest types. In thinnings the allowances made up between 1.68 and 1.72 % of the total log volume, depending on the production structure, whereas in the final felling, the volume of the allowances was 2.31%, i.e. 0.59 or 0.63 % more than in thinnings. Smaller allowances were added to assortments that only contained the cutting window, such as poles, pulpwood, ROTO, and DTD, where the allowance share ranged from 0.26 to 1.33 %. These assortments are suitable for chemical or pulp processing, so no cross-cutting losses are presumed. I other assortments, meant for sawn wood production, length margin was accounted for as well as the cutting window, which increased the share of the allowances to 2.06 – 3.88 %.

This type of factual loss should be accounted for in the forestry records, as well as the national forest mensuration survey.

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FIRST ACCURACY TEST OF A NOVEL MOBILE DEVICE BASED APPLICATION FOR VALUE-OPTIMIZED BUCKING IN MOTOR-MANUAL HARVESTING OPERATIONS

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Abstract: *In motor-manual felling and processing operations, the chainsaw operator has to consider tree parameters and contractual requirements in order to optimize value recovery. Hitherto, this task is not supported by IT. A novel mobile device based application ("Bucking App") provides the user with a value-optimized bucking scheme solution based on contractual requirements and tree parameters. In this study, its reliability in estimating tree shape and providing a value-optimized bucking scheme was investigated. The estimated taper curve deviated with an absolute mean deviation of 1.1 ± 0.6 cm with and 1.0 ± 0.6 cm without bark from the observation. It could further be shown that the app provides a value-optimized solution compared to all possible solutions. The total volume of the test set trees was overestimated by 0.29 % and their value by 1.15 %. Summarily, the "Bucking App" can be considered sufficiently accurate for the intended task.*

Keywords: bucking, motor-manual harvesting, optimization, mobile application

1. Introduction

When timber is harvested, trees are felled and bucked into assortments of different length, diameter and quality assortments with a respective price per m^3. Multiplying the price by the assortments volume gives the value of the assortment. In motor-manual felling and bucking operations, it's the chainsaw operator who is taking the value defining bucking decision. To optimize value recovery, he has to find the most valuable combination of assortments available according his logging contract that can be cut from a given tree.

The basics for bucking scheme optimization date back to the ground breaking considerations on “The theory of dynamic programming” by Bellmann (1954). Pnevmaticos and Mann (1972) then applied this principle on the bucking problem. In further studies, the approach was either refined for single tree application (Eng and Wythe 1982, Eng et al. 1986, Mendoza and Bare, 1986, Waddell 1988,), extended to other areas of use like lumber manufacturing (Faaland and Briggs 1984), yarder load optimization (LeDoux 1986) or applied to whole stands (Eng and Daellenbach 1984).

However, a mobile device based application was not realized till the late 1980ties, when a research group at Oregon State University around John Sessions developed the BUCK software which could be operated on a handheld computer. The software was firstly mentioned in an article by Cooney (1987) and then described in articles by Sessions (1988) and Sessions et al. (1988). Studies assessing the effect on value and volume recovery, as well as on operation costs followed (Garland et al. 1989, Sessions 1988, Sessions et al. 1989, Olsen et al. 1991, Olsen et al. 1997, Bowers 1998), as well as use extensions (Olsen et al. 1990). A further software, only operated on desktop PCs, was introduced in the mid-1990ties was HW BUCK (Pickens et al. 1993), which was specifically designed for training buckers for hardwood bucking operations. In 2005, the software was updated to a modern OS (Noble et al. 2005) and studies concerning training effect were carried out (Pickens et al. 2005). In 2005, Bont developed an Excel-spreadsheet based bucking optimization tool, which also took into account harvesting costs and fuel wood assortments.

The studies carried out with bucking optimization software showed that it can help to increase both volume and value recovery: Gross value recovery increased by 3.2 % to 18.7 % (Garland et al. 1989, Sessions et al. 1989, Olsen et al. 1997, Bowers 1998, Wang et al. 2004, Wang et al. 2009, Akay 2010, Akay et al. 2010), while net value recovery (after subtracting additional effort linked to operating the software) increased by 1.8 % to 6.9 % (Sessions et al. 1989, Olsen et al. 1997, Bowers 1998). Volume recovery increase varied between 0.1 % and 16.6 % (Garland et al. 1989, Bowers 1998, Wang et al. 2004, Wang et al. 2009). Pickens (2005) highlighted the potential for increasing value recovery through training with a bucking software. One year after an intensive training, value recovery had increased by almost 20 % in average in hardwood harvesting operations.

Despite obvious advantages, mobile application of bucking software did not gain widespread acceptance in motor-manual harvesting operations. Instead, bucking optimization techniques were applied to fully mechanized harvesting and focused more on stand-level bucking scheme optimization (e.g. Marshall et al. 2006, Kivinen 2007). However, the mobile hardware situation has dramatically changed since then and every smartphone user is today carrying more processing power in his pocket than was available with very expensive tower PCs in the 1980ties. Further, user's attitude concerning mobile device applications has somewhat changed. Especially younger users are highly receptive for this technology.

Within the scope of the project TECH4EFFECT, the Institute of Forest Engineering, University of Natural Resources and Life Sciences, Vienna (BOKU) and the Austrian-based forestry software company Latschbacher, have developed a novel application for bucking optimization in motor-manual harvesting operations for Android OS mobile devices, called "Bucking App". With this app, a value-optimized bucking scheme can be determined for a given tree from tree parameters and depending on contractual requirements entered by the user, thereby assisting the chainsaw operator during the bucking decision. Further, the app aims to close a data gap in these motor-manual operations through providing a proper performance documentation in the form of an assortment list and aggregated volumes per assortment, species, quality, length or diameter class. These after-operation statistics can be utilized for documentation and planning purposes. However, the success of such an application is highly dependent on its reliability.

Therefore, the aim of this study was to investigate 1) how accurately the app estimates the tree shape (felling cut and crown base diameter, taper curve, topping length) and 2) if the app's algorithm provides a value-optimized solution (maximum value; compared to all possible solutions). Dependent on the results, the effect of deviations from the observation on volume and value recovery should be quantified.

2. Material and Methods

2.1 Study location

In total, 20 Norway spruces (Picea abies L.) were selected for the field study during mid-April 2018 in three different stands of the forest district of Leiben (48.200549° latitude, 15.136091° longitude, about 300 m above sea level), part of the forest management unit Waldviertel-Voralpen of the Austrian Federal Forests (ÖBf). A large number of bark beetle trap trees had been felled in early April and no further manipulation or processing had taken place. Study trees were selected from a large variation in height and diameter (Table 1). As could be expected, stump height substantially increased with increasing diameter at breast height (DBH). For crown share, only a slight increase could be observed with increasing DBH.

Table 1: Parameters of the sample trees

	Parameter	Unit	Mean ± Standard deviation	Minimum	Maximum	Median
	Stump height	m	0.14 ± 0.07	0.05	0.31	0.12
Felled	Trunk length	m	13.45 ± 2.61	7.80	21.50	13.08
Felled	Crown length	m	10.50 ± 3.21	5.15	18.50	10.73
Felled	Tree length	m	23.95 ± 3.79	16.20	34.60	23.85
Felled	Crown share	%	43.35 ± 9.31	27.03	63.57	43.92
Felled	Topping length	m	21.12 ± 3.95	11.42	31.35	21.42
	Diameter at felling cut	cm	47.4 ± 19.0	19.6	89.0	48.6
	Diameter at breast height	cm	30.9 ± 11.6	14.2	60.2	29.3
	Diameter at crown base	cm	20.1 ± 8.7	7.1	46.1	21.1
	Volume in bark	m^3	1.03 ± 0.88	0.14	3.38	0.81

2.2 Measurements during the field study

For estimating the taper curve with the app, an approach described by Eckmüllner et al. (2007) is employed. The taper curve is defined by three geometrical shapes: neiloid (felling cut to DBH), truncated cone (DBH to the crown base) and paraboloid (crown base to top; for coniferous species). Thereby, felling cut diameter, DBH and crown base diameter form the basis for estimating the taper curve. The felling cut and crown base diameter are estimated from the input parameters DBH, stump height, tree height, crown base height and height above sea level. This approach was considered highly suitable, as all economic importance tree species in Austria are covered and it bases on detailed measurements of more than 17.000 trees from the Austrian Forest Inventory. Finally, the number of required measurements during app operation could be limit to a minimum.

During the field study, each tree's diameter at felling cut, breast height and crown base was measured with a caliper to an accuracy of 0.1 cm. Further, tree diameter was measured at 0.5 m and from there on at intervals of 1 m till the top of the tree. All diameters were measured cross-wise and averaged. Trunk length was measured from the felling cut to the crown base, while crown length was measured between crown base and crown top. Further, the topping length, where the defined topping diameter of 7 cm was located, was measured, starting from the felling cut.

2.3 Assortments, pricing and quality allocation

In this study, three different nominal lengths (3 m, 4 m and 6 m) were used. A respective price list for all diameter classes was compiled based on average timber prices in Austria in April 2018 (Table 2). As the app requires to define the quality allocation along the stem by length and quality, two qualities were assigned per tree: AC (A to C) below the crown base and Cx above it.

Table 2: Price list used for the study. Prices relate to combinations of nominal length, diameter class and quality.

Nominal length [m]	Quality	Diameter class	Price [€ m^{-3} without bark]
3, 4, 6	AC	2a, 2b, 3a, 3b, 4, 5, 6	91.50
	AC	1b	73.00
	AC	1a	47.00
	Cx	1a, 1b, 2a, 2b, 3a, 3b, 4, 5, 6	58.00

2.4 Tree parameter estimation accuracy

All calculations were carried out in the app prototype run in R (R Development Core Team, 2008). Measured tree parameters were entered and for each tree a taper curve with and without bark was generated in steps of 1 cm and the respective diameter class according to the Austrian Timber Trade guidelines (FHP, 2006) was assigned. These data were then filtered for diameters at the same distance from the felling cut as measured in the field. Further, bark deduction was carried out similar to the app's bark deduction procedure ("Baden-Württemberger" bark deduction functions by Altherr et al. 1974, 1975, 1976, 1978, 1979) for the measured diameters.

In the app, the estimation of the taper curve depends on the estimates of felling cut and crown base diameter. Therefore, the estimation of this parameters was compared to the field measurements. Further, the accuracy of estimating the topping length was assessed. Reasonable accuracy of this parameter is a further pre-requirement for accurate determination of the bucking scheme. Underestimation would eventually cause a too short log at the end, while overestimation would result in a log with a too small topping diameter.

According to the Austrian Timber Trade guidelines (FHP, 2006), a log's volume is calculated based on its middle diameter. As excess length allocation procedures differ, it was decided to locate the middle diameter of an assortment at half its nominal length measured from the small diameter. Thus allocating the full excess length at the large diameter end, this procedure ensures to stay on the safe side. In this study the shortest log was 3.12 m long, which included 3 m of nominal length, as well as 6 cm of mandatory and 5 cm of customized excess length, complemented by 1 cm for the cutting slit. Therefore, the first possible middle diameter could be located at 1.62 m, while the last one could be located 1.5 m from the topping diameter of 7 cm. For this reason, accuracy of diameter estimation was determined for the range of DBH position to topping diameter position. Both diameters with and without bark were compared. Further, the share of deviation in diameter class assignments was determined.

2.5 Bucking scheme estimation accuracy

Analysis started by computing the suspected value-optimized bucking scheme according to the app's procedure based on the entered tree parameter data and price list. To determine if the app really provides a value-optimized solution, the app's algorithm was bypassed and all possible bucking schemes were derived. The results were filtered for the maximum-value solutions. These were then compared to the app's solution in terms of revenue and volume. Further, the number of alternative maximum-value solutions was determined.

2.6 Effect of deviations on volume and value recovery

To quantify the effect of tree parameter deviations, the app's estimates of volume and value were compared to the measurement data. In a first step, the position of the log middle diameters was calculated for all value-optimized bucking schemes. Then the respective middle diameter without bark was determined from the field data via interpolation. Respective volumes were calculated and diameter classes were assigned. Based on these parameters, the observed value of the tree was calculated. Further, if the estimated topping length exceeded the real topping length and the last assortment exhibited a small diameter smaller than the required 7 cm, the volume and value of this log were set to zero. Finally, estimated and observed volume and value were compared.

3. Results

3.1 Tree parameter estimation accuracy

The felling diameter was regularly underestimated by the app and deviated markedly (-7.1 $\pm$ 6.5 cm) from the observation (Figure 1). To the contrary, the diameter at crown base (-0.90 $\pm$ 1.8 cm) and the topping length (-0.05 $\pm$ 0.70 m) were estimated sufficiently accurate. The topping length was underestimated more often (60.0 % of the cases) than overestimated (40.0 %). While felling diameter deviation increased significantly (p=0.006) with increasing DBH, no such relationship could be observed for crown base diameter and topping length deviations.

For assessing the accuracy of diameter estimation between DBH and topping diameter positions, the absolute values of the deviations were used. Otherwise negative and positive deviations probably could have canceled each other out. It showed that the mean absolute deviation (Figure 2) from the observation in bark (1.1 ± 0.6 cm) was slightly larger than without bark (1.0 ± 0.6 cm). Mean deviations in bark (0.8 ± 0.9 cm) and without bark (1.0 ± 0.8 cm) confirmed that the app tended to slightly overestimate diameters. This led to an average deviation of the estimated from the observed diameter class in at average 18.5 ± 14.4 % of the cases. Absolute deviations (p=0.003) with and without bark (p=0.002)) increased significantly with increasing DBH, as did, as a consequence, the share of misestimated diameter classes (p=0.006).

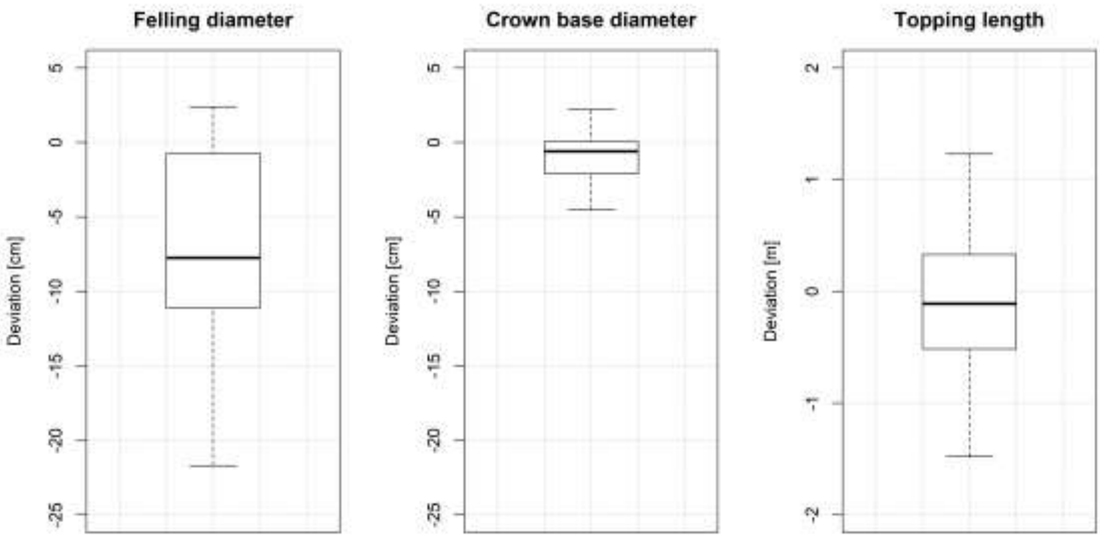

Figure 1: Deviation of the estimated tree parameters felling parameter, crown base diameter and topping length from the observation

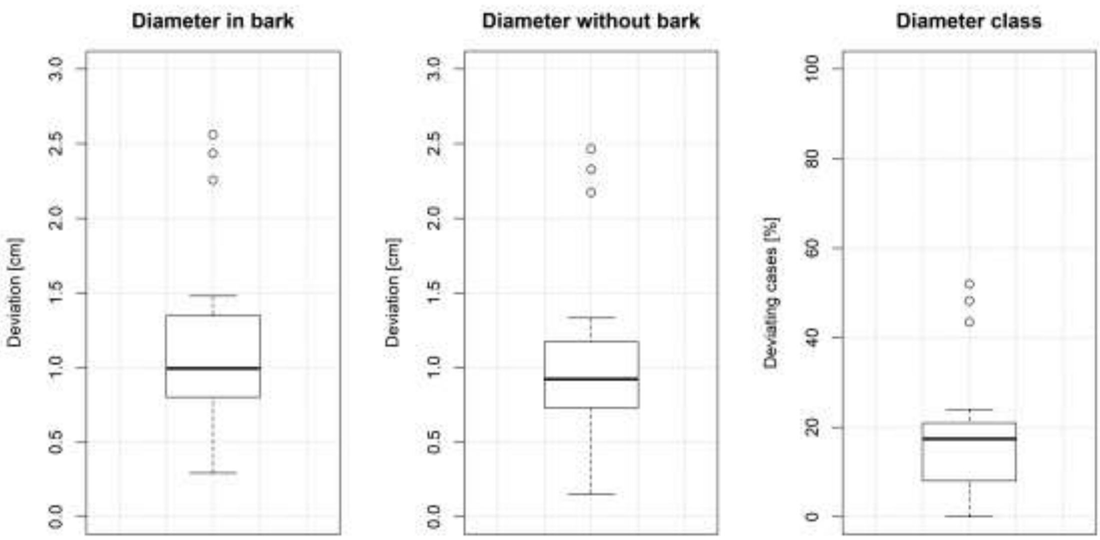

Figure 2: Absolute deviation of diameter in bark and without bark and share of diameter class deviations from the observation between DBH and topping diameter position

3.1 Bucking scheme estimation accuracy

All bucking schemes derived by the apps algorithm constituted a value-optimized (maximum-value) solution compared to all possible bucking schemes. For the 20 trees, 73 alternative bucking schemes with the same maximum-value and volume were found. However, the individual number of alternative solutions varied between 0 and 17, with an average of 3.7 ± 4.6 solutions and a median of 1. As was expected, the number of alternative solutions rose with increasing DBH ($p=0.028$), topping length ($p=0.007$) and volume in bark ($p=0.028$).

3.1 Effect of deviations on volume and value recovery

The app's algorithm provided 20 value-optimized bucking schemes, which constituted of 97 logs in total. Topping length overestimation caused the loss of six top end logs due to falling short of the required topping diameter. In total, these logs represented a real volume of 0.2 m^3 without bark and a value of € 11.49. At a mean observed log volume of 0.19 m^3 without bark, the mean deviation of the estimation from the observation was 0.00 ± 0.03 m^3 for the remaining 91 logs, while value deviated by € 0.10 ± 2.42 per log at a mean observed value of € 15.69. For six of the 91 logs, the app either over- (1) or underestimated (5) the diameter class, which led to a lower price per m^3 in one case. The observed total volume of the logs without bark was 17.05 m^3 and its total value was € 1,417.34. In total, the logs derived by the app would have had a cumulated volume without bark of 17.10 m^3 and a value of € 1,433.66, thereby representing overestimations in volume of 0.29 % and value of 1.15 %.

4. Discussion and conclusion

Accurate estimation of the taper curve is crucial for any bucking scheme optimization. The approach presented by Eckmüllner et al. (2007) proved very reliable, especially for estimating the crown base diameter. Contrary, the felling cut diameter was underestimated markedly. However, in practice this would not have much of an effect, as neither a middle diameter of a log is located between felling diameter and DBH position, nor is the felling diameter of any relevance, as the root collar is usually cut straight. Much to the contrary, the observed accuracy of the crown base diameter is crucial, as it defines the top end of the valuable trunk section. Likewise, deviation along the value-defining section DBH position to topping length proved to be within reasonable limits. Individual large deviations can, at least partially, be explained by large branches or secondary tops forking from the main stem. If this was encountered in the trees studied in the field, measurements followed the (thereby narrowed) main axis.

While, at a first glance, the share of diameter class deviations was considerably large, it showed that the share of logs affected by this was much smaller. On basis of the presented price list, this caused a change in price only in 1 out of 91 logs. However, this could considerably change with a different, more graduated pricing scheme. In comparison, topping length deviations affected the value outcome to a larger degree. Overestimation in 8 out of 20 trees caused 6 of them to lose their top end log due to falling short of the required topping diameter. In two of these cases, this could have been resolved by cutting a shorter top end log, while a more extensive change of the bucking scheme would have been necessary for the others. Luckily, the top end logs usually represent the smallest volume and value along the tree length. Therefore, their loss is only of minor importance. In none of the case where the app underestimated the topping length, the difference would have allowed to replace the top end log by a longer one.

The app proved to be capable of providing a value-optimized bucking scheme out of the pool of available value-optimized bucking schemes and the number of alternatives grew with increasing tree size. The app does not include any preferences for certain assortments, as would be required for bucking-to-order procedures. Therefore, the bucking scheme derived by the app might not be the preferred, but surely a value-optimized one.

Summarily, it could be shown that the Bucking App is reliable concerning its tree parameter and taper curve estimating accuracy. A small weakness is the tendency to underestimate the topping length and therefore sometimes cause the loss of (low-volume and low-value) top end logs. The employed algorithm provides a value-optimized solution out of a varying number of alternatives. Especially on operation level, in this study represented by the cumulated volume and value of the 20 trees, only small deviations between estimation and observation were encountered.

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DIRECT VERSUS VIA-TERMINAL SUPPLY OF FOREST RESIDUAL BIOMASSES: A SIMULATION-BASED ANALYSIS

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Abstract: Large amounts of forest residual biomasses such as slash from clear-fellings and small-diameter trees from early (first) thinnings and overgrown marginal land (e.g. farmland, power line corridors, roadsides, etc.) can be sustainably harvested in Sweden. However, these residual biomasses require efficient supply chains to make their utilization cost-competitive. One important part of the supply chain are terminals, which act as intermediate hubs between the forest and the industry, securing supply during e.g. peak demand periods. Bio-hubs also provide buffering capacity to industries with limited storage yards, e.g. industries close to populated areas. Compared to direct deliveries, deliveries via-terminal add inevitably extra costs in the supply chain due to the increased material handling. Discrete-event simulation (DES) has successfully been implemented for analysing biomass supply chains. DES allows evaluating different operation alternatives without performing real-world experiments, considering machines' interdependencies, uncertainty and time. The aim of our study was to compare the supply cost of chipped residual biomasses to an energy plant and a biorefinery, respectively, using DES and considering: direct or via-terminal delivery; machine system; end-user's demand curve; and degree of supply integration. The study will also investigate the effect on supply cost of hauling distances from the terminal to the end-user, and terminal storage size. In addition to costs for different simulation scenarios, the results will provide relevant information to decision-makers such as required machine fleet to meet a certain demand (number of machines and working shifts), machine utilization rates, terminal usage (storage time, dry matter losses throughout the year, etc.) and will identify eventual bottlenecks in the supply chains. The results of this study will be presented at the conference.

Keywords: supply chain, discrete-event simulation, logistics, bioenergy, biorefinery

DEVELOPING METHODS FOR TRUCK ROUTE SELECTION AND COST MODELLING IN NORWEGIAN TOPOGRAPHY

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Abstract: Payment tariffs for logging truck transport in the Nordic countries are typically based on the loaded transport distance. Local tariffs often provide a good representation of the overall cost, however, as the transport environment includes more varied topographies with increased fuel consumption and lower driving speeds, loaded distance alone provides a poorer representation of the actual cost. The same is true for routes with increasing curvature which involve more frequent braking and acceleration cycles. Moreover, winter driving conditions in such topographies raises additional issues with safety and operator stress. This study examines the situation in Norway where logging truck routes often originate in mountainous regions. This study tests the applicability of a route generation system developed for Swedish conditions to see if it can be calibrated for Norwegian conditions. The case study is based on 30 routes from each country, reported and analyzed by their respective transport managers. Based on stipulated tariffs, the results show the route-specific variation in both costs and profit margins associated with the varying transport environments. A framework for difficulty classification is proposed as a basis for tariff agreements that better represent the actual transport cost. The test shows that the approach developed in Sweden provided an efficient solution for calibrating route selection settings based on Norwegian key routes as input.

Keywords: logging truck transport, calibrated route finder, transnational development

1. Introduction

Forestry transport in the Nordic countries covers a range of transport environments. While the flatter topographies in Sweden and Finland have accelerated the development of higher capacity logging trucks (>70 tons), the more mountainous conditions in Norway still present challenges for conventional 60-ton logging trucks.

Every aspect of transport management and service payment is built on the assumption of efficient route choices between forest and industry. National road databases providing additional and detailed information for forestry transports are now readily accessible and these can support the establishment of more efficient routing based on new criteria. Fulfilling these assumptions in fully digital systems, however, presents a challenge. The range of transport conditions is particularly wide around the Scandinavian mountains whose topography includes highlands, valleys, fjords and lowlands. Payment tariffs in this region are typically based on loaded transport distance alone. Although negotiated tariffs may provide an acceptable representation for overall average costs, loaded distance alone poorly represent the actual cost for routes having various transport environments. Until a more analytic approach is adopted, dissent between service buyers and providers on route selection and tariff levels will persist. This paper identifies the necessary means to establish the best possible topographical routing and alternatives to design tariffs that better represent the true transportation cost. This also enables transporters to better balance revenues with costs.

2. Methods

The approach consisted of three phases. The first collected the best practice routes in selected regions of Norway and Sweden and defined the grade characteristics in the Calibrated Route Finder (CRF, see Flisberg et al. 2012, Rönnqvist et al. 2017) network for Norwegian summer and winter conditions. This was done in close collaboration with transport managers. The second generated CRF routes and compared best practices for summer and winter conditions, including the discovery of Norwegian CRF-settings based on the country's best practice routes (also called Key routes). The third developed a computationally efficient segment-level model (see Svenson & Fjeld 2016a, 2016b) for analyzing costs and profit margins of individual routes. This laid the base for an empirical categorization of operating conditions and proposal for further development of service payment frameworks.

3. Results and discussion

The test showed that it was possible to use the Swedish CRF system approach to generate correct routes and distances, even in areas with an increased proportion of steeper topography. The tested modifications were straightforward, though the best match was achieved by using a weight setting based purely on the Norwegian key summer routes. Some challenges remain for winter routes. The detailed route information approach made it feasible to compute the operating margin for individual routes. Additionally, it enabled more correct costing of varying transport environments. By defining a suitable scheme of difficulty classes based on information provided in the current road databases, it is possible to better reflect actual transport costs in more differentiated tariffs. These classes provide a basis for economic sustainability for transporters in regions with varied transport environments. They also enable a methodology for fixing prices per route instead of imposing flat tariffs that disregard the actual route's specific characteristics. It is also a first step for a direct cost computation and payment for each unique route and its characteristics.

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THE EFFECTS OF AN EXTRA FORWARDER AXLE ON WHEEL RUT DEVELOPMENT

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Abstract: The goal of the study was to compare 8 versus 10-wheel forwarders with respect to wheel rut development. The study was located on a wet lowland area in eastern Norway where 25 loads were transported side-by side with both 8- and 10-wheel configurations of a Ponsse Buffalo 14 t forwarder. The 8-wheel configuration was equipped with standard belts on both bogie-axles while the 10-wheeler was equipped with combi-belts. Given the low bearing capacity of the site, the strip roads were reinforced with a deeper layer of harvest residues. For the 8-wheeler, the residues were pressed below the level of the surrounding soil surface on 50 % of transects. The corresponding value for the 10-wheeler was 30 %. After 10 loads, ruts deeper than 10 cm were observed on 17 and 5 % of transects for the 8- and 10 wheeler, respectively. After 20 loads, ruts were observed on 30 and 15 % of transects for the 8- and 10 wheeler, respectively. 80 % of the variation in rut depth could be explained by the interaction between the number of loads, machine configuration and measured soil bearing capacity. The difference in rut development was slightly larger than what could have been expected from the respective forwarders ground pressures. This can be partially explained by the belts used. The thinner ribs on the 8-wheeler's belts led to a quicker break-down of the harvest-residue layer in the strip roads than the wider plates on the 10-wheeler.

Keywords: Ponsse Buffalo, 10-wheel forwarder

SEASONALITY OF WOOD SUPPLY OPERATIONS IN COASTAL NORWAY

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Abstract: Historically, seasonal variation in harvesting and transport has been driven by numerous factors. After a considerable development effort to reduce this variation, climate change is driving new weather patterns and with them, new challenges to supply operations. In this context, Norway is an interesting region with mountainous terrain combined with a cold coastal climate. The first goal of the study was therefore to quantify the effect of temperature, precipitation and snow on production and transport pace for a supply organization. The work started with a complete mapping of the management processes for roundwood harvesting, truck transport and shipping. After this, daily harvesting production and truck transport reports were collected for 2013-2017 together with weather data from regional climate stations, together with vessel records for 2015-2017. The results quantify the interactions between the weather variables and their effects on the re-location of harvesting operations with corresponding effects on harvesting production, truck and shipping transport at the organizational level. The mechanisms and restrictions underlying the management processes are also supported. The study constitutes the Coastal part of the EU Era-Net MultiStrat project (Multimodal strategies for resilient wood supply). Together with parallel studies are done in Northern Sweden (Sub-Arctic Region) and Austria (Continental Region) the project continues with tests of alternative mitigation strategies for achieving more even wood supply flows to regional forest industries.

Keywords: forest operations, weather data, production pace, transport pace

1. Introduction

Seasonal variations in wood supply are most often driven by the operating environment. At the same time reduced volumes in roadside, terminal and mill inventories places higher demands on coordination between wood purchase, harvesting and transport. This goal of this study was to quantify seasonal variation in production and harvesting for a forest owner association in coastal Norway. The study is a part of the Norwegian contribution to Era-Net MultiStrat (Fjeld et al. 2017, Westerlund et al. 2018).

The study started with a general mapping of demand and supply risks together with wood supply management processes. After this introduction, the work continued with analysis of three years of production and transport reports (2014-2016). The accumulated weekly production and transport volumes were used to calculate a weekly pace relative to the annual average (percent). Weekly roadside stocks were calculated as the accumulated production minus the accumulated transport. For each harvesting contract transport lead times per assortment were calculated by two methods; from first production report to last transport report (LTstart) and from last production report to last transport report (LTfinish). Daily weather records during the study period included temperature, precipitation, and snowpack from surrounding weather stations at varying elevations. Analysis methods used for the results presented are limited to regression analysis.

2. Results

According to the mapping of management processes, common weather patterns are met with a set of standard patterns for capacity allocation. These patterns are to a large degree governed by terrain and road bearing capacity. Frost and snow at medium and higher altitudes provide stable production reserves throughout winter and spring. Allocation of production capacity to lower altitudes is possible either during particularly cold periods or during summer dry periods. Otherwise, production is possible to maintain during intervening warm and wet periods in areas with thin soils over bedrock. For coastal Norway, the seasonal supply patterns are characterized by a mid-winter high season and lower summer/autumn season. Given that mill demand is relatively constant, transport managers seek to maintain an equivalent transport pace (m^3) without exceeding transport capacity limitations (m^3km). The resulting variation in production pace is therefore greater than variation in transport pace (Fig 1).

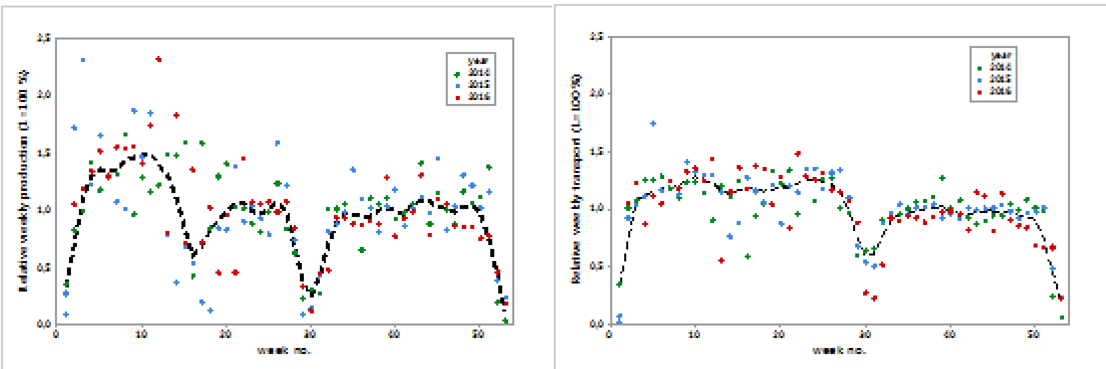

Figure 1. Seasonal variation in weekly production pace to roadside (left) and weekly truck transport pace from roadside (right)

This leads to a corresponding seasonal variation in transport lead times. For sawlogs, lead times peaked both just before summer holidays. For pulpwood, the peak coincided with the transition to the autumn low supply season (Fig. 2). Typical lead times varied between 10 and 45 days, depending on assortment and calculation method.

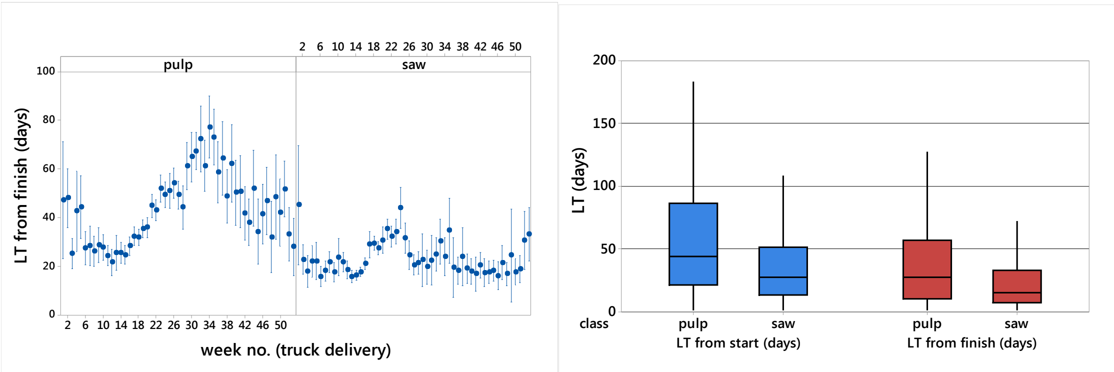

Figure 2. Seasonal variation in transport lead time (left) and box-plots for lead times per assortment (right)

Given the considerable variation in production pace, these were checked against weather data. A simple plot of production pace and temperature (summer and Christmas holidays excluded) shows the highest production at sub-zero temperatures, decreasing to a minimum production between 5 and 10 degrees, increasing slightly thereafter as temperatures rose towards 15 degrees. Structured interactions between temperature, precipitation and snowpack were significant ($p<0,001$) and together explained thirty percent of variation in weekly production pace. The individual effects of temperature, precipitation and snowpack alone were not statistically significant. The interactions are structured to follow a simple logic regarding their effect on bearing capacity and site availability where: 1) precipitation during sub-zero temperatures contributes to the snowpack enabling access to mire sites at medium and high elevations (winter), 2) low precipitation during higher temperatures provide periodic drying and access to silt and clay areas at low elevations (spring/summer) and 3) rainfall at low temperatures constitutes the worst case scenario with reduced bearing capacity on most site types during periods with limited evaporation and drying (autumn).

Variations in transport pace were limited due to mill demand, but were also checked against weather data. Within both high- and low seasons, a linear reduction of weekly transport pace was observed with increasing precipitation. However, average truck transport distances also increased during periods of low production pace. Forty-five present of the weekly variation in transport distance was correlated with the variation in road-side stocks (Fig. 3).

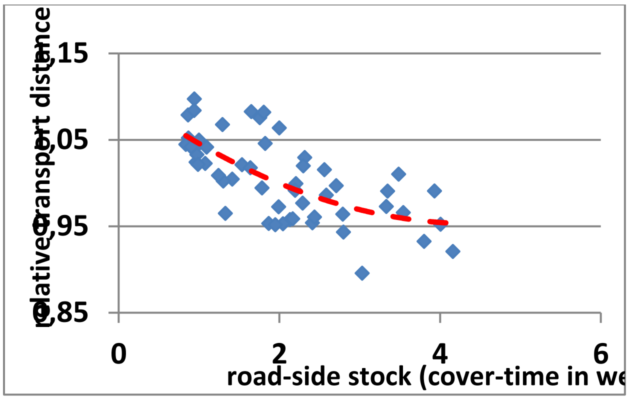

Figure 3. Relative variation in average truck transport distance (y-axis) with varying levels of road-side stocks (x-axis)

3. Discussion

In summary, the study provides a quantitative mapping of seasonal variation in production- and transport pace typical for a boreal coastal region. Decoupling production- and transport at roadside stocks enables a relatively even supply pace to customer mills, with the observed consequences for variation in roadside stocks and transport lead times. As reduced roadside stocks during low production periods were also associated with increased average transport distance to mills and terminals, these trends can reflect both transport policy and site availability restrictions. However, the particularly long transport distances during periods of low roadside stocks are more related to accessing sufficient wood for maintaining supply flows.

The general trends shown are common knowledge for many managers within the supply chain. At the same time, quantitative analysis of weather parameters was a useful exercise for structuring the effects of regional weather conditions on supply challenges. The driving factor for variations in supply, of course, starts with roundwood prices and the forest owner's willingness to sell wood, as examined in numerous econometric studies. This study has focused more on quantifying the residual short-term variations in wood supply within a price period. The results are therefore interpreted as an expression of the supply organizations success in managing operations to maintain both contractor capacity utilization and agreed flows to customer mills.

An interesting aspect of the weather-related effects on production pace is that in both the short-term analysis shown here (2014-2016) and a previous longer term analysis (2004-2013), the primary variable associated with production variation was temperature eight weeks prior to harvesting. A number of alternative time lags were tested but in both studies an eight week lag provided the highest coefficient of determination. This is possibly linked to the forest owner's perception of what constitutes "suitable operating conditions" for harvesting. The eight week lag may be close to the typical time necessary to locate contractor capacity to a newly-established harvesting contract. Otherwise, approximately 10 % of the association's annual volume is harvested by the forest owners, themselves. On an annual basis this represents a marginal volume, but contributes to production reporting peaks during the high season.

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MODELING SEASONAL BEARING CAPACITY FOR PRODUCTION SCHEDULING IN NORWAY

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Abstract: Stable wood supply to Nordic forest industries is dependent on scheduling of harvesting sites according to their bearing capacity. For CTL-harvesting numerous field-classification indexes are available. To improve planning precision and efficiency new combinations of more accessible digital terrain data are being tested. The goal of the study was to compare the ground damage risk predicted by digital vs. fields-based classification. Data was collected from 90 terrain profiles from 3 forest owner associations (30 profiles/FAO) with ground damage from adjacent harvesting sites. Digitally-sourced data included quarternary deposit maps and depth-to-water models from LiDAR-based terrain mapping. The corresponding field data included classification of soil texture, moisture, block-coefficient, soil penetration resistance and soil moisture content at varying depths. Forty percent of the variation in ground damage could be explained by the interaction between block-coefficient and penetration-resistance. Based on both data sources the study presents a combined model using on-line weather models to provide a updating classification of bearing-capacity as the harvesting season progresses.

Keywords: weather modelling, precision, ground-damage

A SPATIALLY EXPLICIT TIMBER HARVESTING AND TRANSPORT MODEL

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Abstract: Efficient and sustainable forest management relies on a well-designed network of forest roads that are sufficiently dimensioned for large vehicles. To ensure the cost-effectiveness of road maintenance and enhancement measures, areas with satisfactory forest accessibility must be discriminated from areas where economic wood production is not possible. Forest accessibility from the road network is often assessed using average values such as road densities or simple spatial descriptors such as buffers. However, these methods do not take into account heterogeneous terrain or soil properties. Moreover, both the extraction of wood to a nearby road and the on-road transport contribute to the total timber production costs; as a consequence, information on the whole logging process should be used to find combinations of possible harvesting techniques and transport routes. We present a model that uses existing area-wide data (slope, soil bearing capacity, obstacles, forest) to allocate the most suitable harvesting technique – cable, ground-based or aerial systems – to every forest parcel (pixel) and to identify the corresponding landings on a road. Apart from the detailed analysis of possible cable lines, we focus here on the assessment of ground trafficability. In a second step, the best transport route out of the forest is determined using a topological road network. For each forest parcel, the corresponding harvesting and transport costs are then estimated. Using this information, the most economic harvesting technique and transport route can be found and the suitability of every forest parcel for economic wood production can be assessed. In addition, the model allows to calculate timber volume flows along the road network if combined with spatially explicit information on timber stock. Our study area is the entire forested area of Switzerland (41'000 km2, of which 13'000 km2 forest) and comprises steep and flat terrain. The model results can be compared to the currently practised methods; they also help identify areas where economic timber harvesting is possible, areas that are currently unsuitable for economic wood production, and areas with excessive accessibility. This information facilitates road network planning and management.

Keywords: forest road, network analysis, timber harvesting, timber transport

1. Introduction

Efficient and sustainable forest management relies on a well-designed network of forest roads that are sufficiently dimensioned for large vehicles. To ensure the cost-effectiveness of road maintenance and enhancement measures, areas with satisfactory forest accessibility must be discriminated from areas where economic wood production is not possible. Forest accessibility from the road network is often assessed using average values such as road densities or simple spatial descriptors such as buffers. However, these methods do not take into account heterogeneous terrain or soil properties. Moreover, both the extraction of wood to a nearby road and the on-road transport contribute to the total timber production costs; as a consequence, information on the whole logging process should be used to find combinations of possible harvesting techniques and transport routes.

We present a model that provides spatially explicit information on the suitability of forest areas for economic timber harvest. The model can be used to analysethe entire area of Switzerland (41'000 km^2*, 13'000 km^2 of which are forested*). It uses a given road network, together with existing raster data describing the characteristics of the study area.

2. Data and Methods

In the Swiss National Forest Inventory (NFI), information about the forest has been recorded for more than 30 years(Brändli, 2010). The collected data include the forest roads (for trucks) in the entire forested area in Switzerland, together with roads connecting forest roads to main (usually cantonal) roads. Since the dataset includes information on road width and carrying capacity, roads suitable for specific vehicle categories can be distinguished(Müller et al., 2016). This is important because the density and spatial distribution of forest roads defines hauling distances and transport lengths,while the roads' dimensions affect the number of trips necessary for wood transport.

Our model includes three main harvesting methods: ground-based, cable-yarding(two maximum lengths, uphill/downhill) and aerial (helicopter) systems. It uses existing area-wide data describing terrain, soil properties, obstacles, and forest (at a resolution of 10 m) to allocate the most suitable harvesting techniqueto every forest pixel and to identify the corresponding landings on a road. In a second step, the best transport route out of the forest and to a collecting point is determined in a network analysis, using the topological NFI road dataset. Collecting points are defined on the nearest high-capacity road that can be used year-round by a 40-ton truck.

For each forest pixel, the corresponding harvesting and transport costs are then estimated. Using this information, the most economic harvesting technique and transport route can be found and the suitability of every forest pixel for economic wood production can be assessed.

A detailed description of the model can be found in Bont et al. (2018). The code was adapted to make the use of large country-wide rasters possible. Furthermore, we analysed ways of including surface roughnessin the assessment of ground trafficability.

3. Analyses and Results

Our study area is the entire forested area of Switzerland (13'000 km^2) and comprises steep and flat terrain.Harvesting options and on-road hauling routes are first analysedseparately. The identification of trafficable areas takes into account slope and soil properties, while the analysis of potential cable roads integrates information on terrain and obstacles (such as buildings or railroads). For the identification of the best hauling routes, travel distance as well as the roads' weight limits are accounted for. Subsequently, the best harvesting option and the best transport route can be determined as well as the best combination of the two.

The model output consists of various maps: the most suitable harvesting method, as shown in Figure 1; harvesting costs; hauling costs; and a suitability map based on combining these results and classifying them. The model results can be compared to the currently practised methods; they also help identify areas where economic timber harvesting is possible, areas that are currently unsuitable for economic wood production, and areas with excessive accessibility. In addition, the model allows to calculate timber volume flows along the road network if combined with spatially explicit information on timber stock. All this information facilitates road network planning and management.

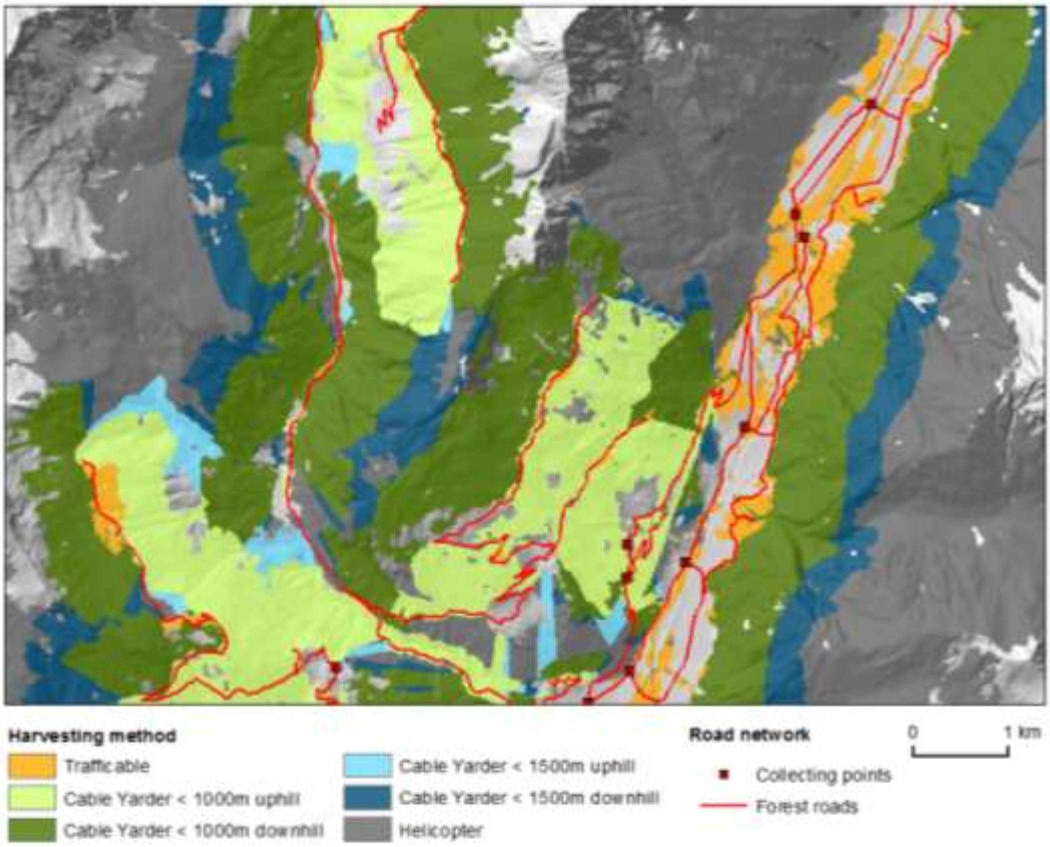

Figure 1: Harvesting methods for a densely forested, high-relief area in southern Switzerland.

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FORESTMAP: QUICK AND COST-EFFECTIVE INTEGRATED WEB PLATFORM FOR FOREST INVENTORIES

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Abstract: *ForestMap is a game-changing web tool to obtain forest inventory reports remotely. It estimates all relevant variables included in a professional forest inventory through combination of pre-processed remote sensing data and powerful predictive models. ForestMap intuitive interface allows anyone to automatically generate forest inventories of a chosen area without the need of field work and unnecessary delays. ForestMap is a solution that delivers accurate, quick and cost-effective forest inventory reports to anyone, anywhere*

Keywords: forest inventory, wood mobilization, app, LiDAR, remote sensing

1. Introduction

Wood-based industries, forest consultants and private owners need timely and reliable data of the state of the forest in order to adopt informed decisions in forest management. Traditional forest inventories are critical in forest management yet are expensive, laborious and time-consuming. A delay and/or inaccuracy in forest inventory reports could translate into large economic losses and into biased management actions.

In 2015, the EU had circa 182M hectares of forests and other wooded land (41% of its total area) (Eurostat 2017). Managing and monitoring forest are critical tasks to achieve the principal guidelines of the forest strategy to 2030. The strategy highlights that forests are important for rural development, forest-based and bioenergy industries, the protection of biodiversity and the fight against climate change and sets an objective for 2020:

to ensure that all EU forests are managed according to Sustainable Forest Management principles.

to increase the mobilisation of wood resources.

ForestMap will have a positive impact for a major mobilisation of wood resources. It is time to adapt the critical labour of forest inventorying to the new technologies that provide reliable and quick results for a fraction of the price. It can solve the needs of wood working industries, forest consultants and private owners (Growth, 2018)

2. State of the art: Current Solutions to Perform Forest Inventories

Wood related companies, forest consultants and private owners require information about the state of their parcels to enhance forest management and increase economic, environmental or social benefits from forests. Currently there are two different approaches to make forest inventories:

The traditional methods based on human workforce and field sampling: The traditional approach consists on a systematic collection of data and forest information on representative management units (plots). The sampling is statistically designed based on the desired bias and involves multiple measurements of a tree. In order to get accurate inventories, forest consultants need extensive field work and trained specialists. Even for small parcels and reduced forest areas, a high number of field plots are needed to get an accurate bias so this method is expensive and time consuming.

New technologies based on mathematical models applied to remotely acquired data: In contrast to traditional methods, remote sensing enables the acquisition of forest information without the need of field work but using aircraft-based sensors able to detect and classify different land uses including forest.:

LiDAR (Light Detection and Ranging) is a remote method that uses light in the form of a pulsed laser to measure ranges (variable distances) to the ground. Light return, combined with other data recorded by the airborne system, generates precise and three-dimensional information about the measured surface. The impact of the laser beam upon different surfaces (tree crowns, trunks, leaves, the ground, etc.) provides a three-dimensional data set in the form of a cloud of points dispersed into the territory (Fig. 1). Unlike traditional methods, LiDAR is well suited to perform inventories on small parcels with small bias (<15 %).

Medium-to-high spatial resolution multispectral satellite data have the advantage of covering every country. The dimension of pixels of these images ranges from 30x30m (LANDSAT 8 OLI;) to 10x10m (Sentinel 2). However, the characteristics of satellite data limits the accuracy that models can achieve. Nonetheless, satellite imagery can be used to identify species and to detect recent changes on the forests, complementing LiDAR data in these aspects.

3. New solution: Automated forest inventories based on remote sensing technologies

ForestMap is an e-commerce platform that allows users to make reliable and real time on-line forest inventories of a specific area in a rapid and simple way thanks to remote sensing (LiDAR) and pre-processing systems without requiring additional field validation campaigns.

Figure 2 Steps to purchase a forest inventory report for a chosen area. The platform retrieves the necessary information and applies the most convenient models through our implemented algorithm. The platform works in the background to deliver a forest inventory report minutes after payment.

Through the use of pre-processed LiDAR data on the platform, a refined algorithm is able to fit the best-suited model for a variety of tree species of commercial importance and provide a forest inventory report with acceptable bias (<15% observed vs. predicted) on forest wood volume in small areas. The platform guides the user through three simple steps to elaborate and deliver forest inventories from one to thousands of hectares: ① area selection, ② payment and ③ report reception. (Fig. 2) Through a few interactions users can perform reliable forest inventories of their own plots and receive the results within minutes in their account in a convenient pdf file.

The process of purchasing a forest inventory is conveyed into 3 easy-to-follow steps:

Step 1 – Area selection: ForestMap relies on secure protocols to manage user's information and transactions and is designed to facilitate the end-user interaction. The platform places the user in front of a map visor (Fig. 3) where he must define the area to be inventoried, choosing one of three input methods:

drawing the boundaries through a geographic data viewer

uploading a custom geo-referenced shape file

inserting the cadastral reference

These methods are designed to speed-up plot selection in case that plot contours are too small or convoluted.

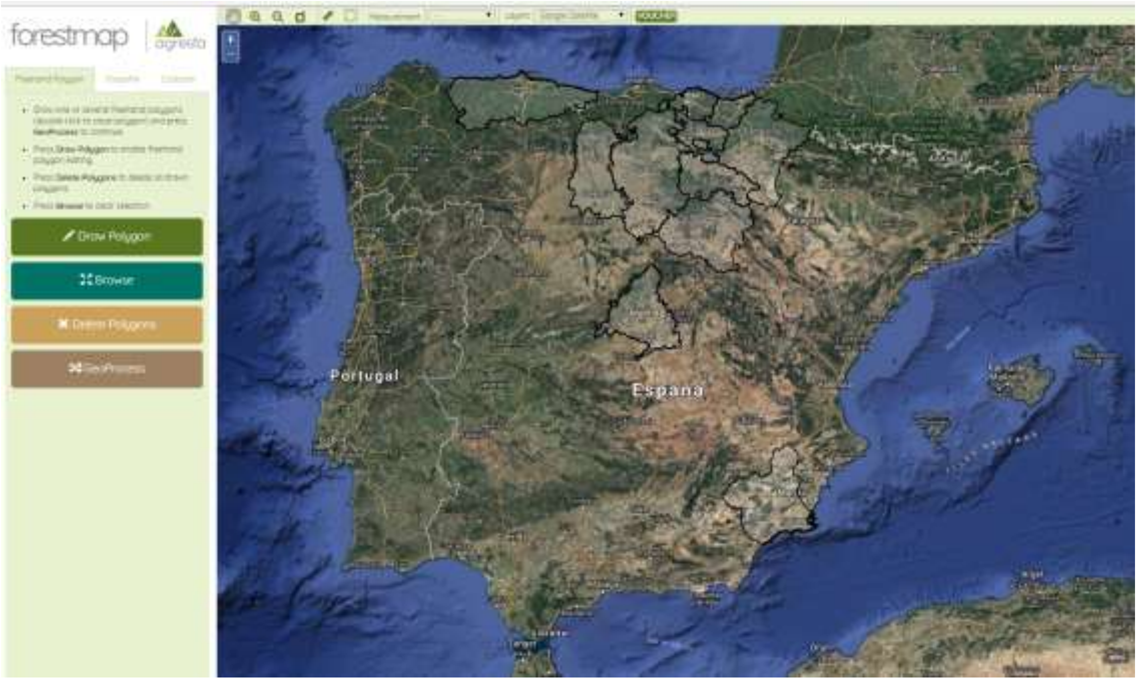

Figure 3 ForestMap´s visor

Step 2 - Payment: The inventory is automatically delivered upon payment. The system provides the customer with a list of options to further define the plot of interest to adjust the forest inventory variables e.g. number of trees, dominant height, basal area, volume of wood and stocked CO_2. To date, customers can only select some Spanish regions for reporting and the web still lacks different user plans for different type of users.

Step 3 – Report reception: The platform supports a member area used by the clients to manage their account, user data and preferred payment methods. Once the report is generated (minutes even for large areas (>500ha) ForestMap will notify the clients through a link to the folder "Available downloads" in their member area. There, the client finds the final forest inventory report in a compressed format.

Main advantages of ForestMap compared to traditional methods:

Forest inventory reports must be cost-effective as they are the key for success in a business with very tight margins. However traditional methods are costly and fail at obtaining reliable estimations in a quick way due to the human workforce needed. That is specifically true when conducting inventories in multiple small parcels in which remote methods provide the best results and become the best value for money.

Current remote forest inventory solutions just provide a set of data that indeed must be analyzed and interpreted by an expert in the field. ForestMap is able to provide reliable forest inventories without requiring additional field work and knowledge giving its users the relevant information.

The avoidance of additional field measurements needed enables a very rapid response from our platform, drastically reducing report delivery times and costs.

The simplistic yet operational design of the platform require minimal interaction with the client and facilitates multiple input methods making it easy-to-use even for the less technologically skilled clients.

There is a pilot projet website of ForestMap running for several regions in Spain: http://forestmap.es/en/

4. Who we are

Agresta S.Coop is an environmental company (SME), established in 2000, and specialized in forestry, natural resources management and the applications of new technologies to the environment. The legal figure is cooperative SME, where most of the workers are company partners and the decision making mechanism is carried out by a General Assembly.

Agresta works towards the improvement of the forest territory by means of innovation in a cooperative business model. The aims of the business are to produce excellent forestry services, to provide good terms and conditions for employees, to be fair to suppliers, to provide returns on investment for investors, to support local communities and to respect the environment. The core values of the company are democracy, participation, equality, equity and solidarity.

Agresta counts on a multidisciplinary team expert in GIS, GPS and remote sensing. The company is established all over Spain with 10 offices and during the last years has been working on different international projects, specially related to forest inventories with LiDAR technologies.

During the last seven years our work has been related to LiDAR and remote sensing technologies. In these projects Agresta has developed a tool to identify single trees through the return of the laser beam after measuring the main dendrometric variables of localized trees. Agresta is also working in the inventory and cartography of forests using LIDAR technology. The team has developed software that process LiDAR information in large areas. It has also developed methodologies of analysis of Fire risk at Landscape-level and Riverbank conservation state.

The main products and services can be summarized as follows: Forest inventories, Forest management, Use of forest resources-energy (forest biomass), LiDAR technology applied to forest Carbon consultancy, Geographic Information System & GPS, Land planning, Natural Environment Engineering, Environmental impacts, Forest Property

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FACTORS AFFECTING DOZER PRODUCTION RATE FOR CONSTRUCTING FIRELINES IN WILDLAND FIRES IN SPAIN

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Abstract: *Dozers are being employing for fireline constructing during wildfires attacks. This operation is spread all over the world, and in Spain, it has been applied from the 60´s. The dozers performance is increasing importance in suppression operations every year in Spain. In August 2017, a large wildfire took place in Castilla-La Mancha (Spain), that burnt 3,217 ha. Fourteen dozers (152-240 HP) were employed in suppression operations and constructed 82 km of firelines. Dozers were followed by onboard GPS devices. A mean productivity of 0.79 ha/day per machine was reached. Results pointed at a maximum rate of 1.49 ha/day. A in-depth results was the maximum rate of 300 m/hour. Our measured and confirmed performance limits (thresholds) in Yeste reinforce that dozers do excel when working in areas of steep slopes. Additional work should be done towards the development of a table of dozer performance implementing firelines regarding slope steepness and fuel models from data of numerous fires.*

Keywords: dozer, wildland fire suppresion operations, firelines construction, production rates

1. Introduction

In the wildland fire occurred in Yeste (Albacete) between July 27 and August 9, 2017, the largest deployment of heavy equipment teams was carried out in a wildland fire in Castilla-La Mancha since the fire of the Riba de Saelices of 2005 in Guadalajara, where 12.874 ha were burned and 11 firefighters died. In the present fire a Heavy Equipment Specialist Unit was implemented, as provided by the Incident Command System of the Forest Fire Service of Castilla-La Mancha Region (SMEIF), for the management of operations with Heavy Equipment, being named a person in charge of this Unit by the Incident Commander and under the supervision of the Operations Chief.

This paper aims to evaluate the quality and efficiency of the service provided by the dozers of the heavy equipment teams during the suppression of this fire, by compiling all the necessary information to establish improvement proposals for the Operative Service of Forest Fires in Castilla- La Mancha (hereinafter referred to as SEIF), while at the same time looking for an improvement of security and work performance based on the implementation of an optimal model of training and organization that allows a coordinated and efficient management of resources. In this large wildfire fourteen dozers were deployed (Type CAT D6-D7 and Komatsu D65-D85, from 152 HP to 240 HP and from to 3.7 m to 4.5 m angledozer blade lenght) and one backhoe loader (Type Case 580L, 71 HP). Dozers were followed by onboard GPS devices (SPOT GEN 3) that recorded position and time each 5 minutes. This information and observations made by strike team leaders and dozer bosses were analyzed to extract useful and relevant results.

In July 1994 there was a fire in the municipality of Yeste that burned more than 14,000 ha, in July last another forest fire affected more than 3,200 ha in the municipalities of Yeste, Molinicos and Riópar (Albacete, Spain). In both cases critical adversities took place: the low relative humidity, the long temporary drought, the absence of rain before the fire and the high combustibility of the vegetation composed mainly of a natural regeneration of *Pinus halepensis* (Aleppo pine) with very high densities that hinders in excess the work of suppression by the different intervention units of the SEIF.

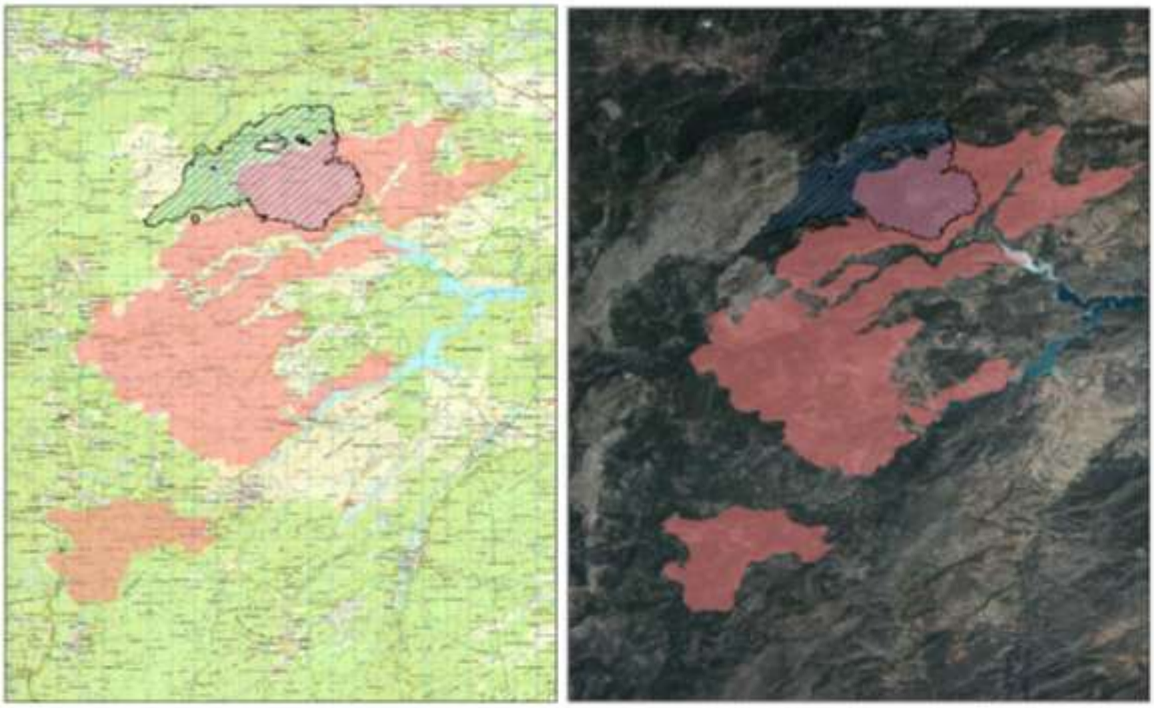

Figure 1: Comparison of surfaces affected by fires of 1994 (red) and 2017. Source: Analyst Unit of Wildland Fires in Castilla-La Mancha (UNAP)

During the days that the wildland fire remained active and out of control, the atmosphere situation was marked by conditions of stability and dry atmosphere, caused by the affection of the continental Sahara air and the high pressures that dominated the Iberian Peninsula, only altered by an episode of advection of the SW and relative losses of thermal origin, which were formed by the heating of the air closest to the earth's surface.

As a result of this situation, the wind with main domain of component W and NW, increased its module, favored in turn by local winds, situation that was what caused that the afternoon of day 28 and 30, the fire had a behavior of higher intensity and higher propagation speeds, estimated around 30-35 m/min.

This situation of meteorological risk described in the previous section, together with the abrupt topography and steep slopes of the wildland fire zone, posed a scenario that hindered in excess the work of extinction by the different intervention units of the SEIF. Figure 2 shows the steep slopes, which in many phases of suppression coincided with the perimeter of the fire.

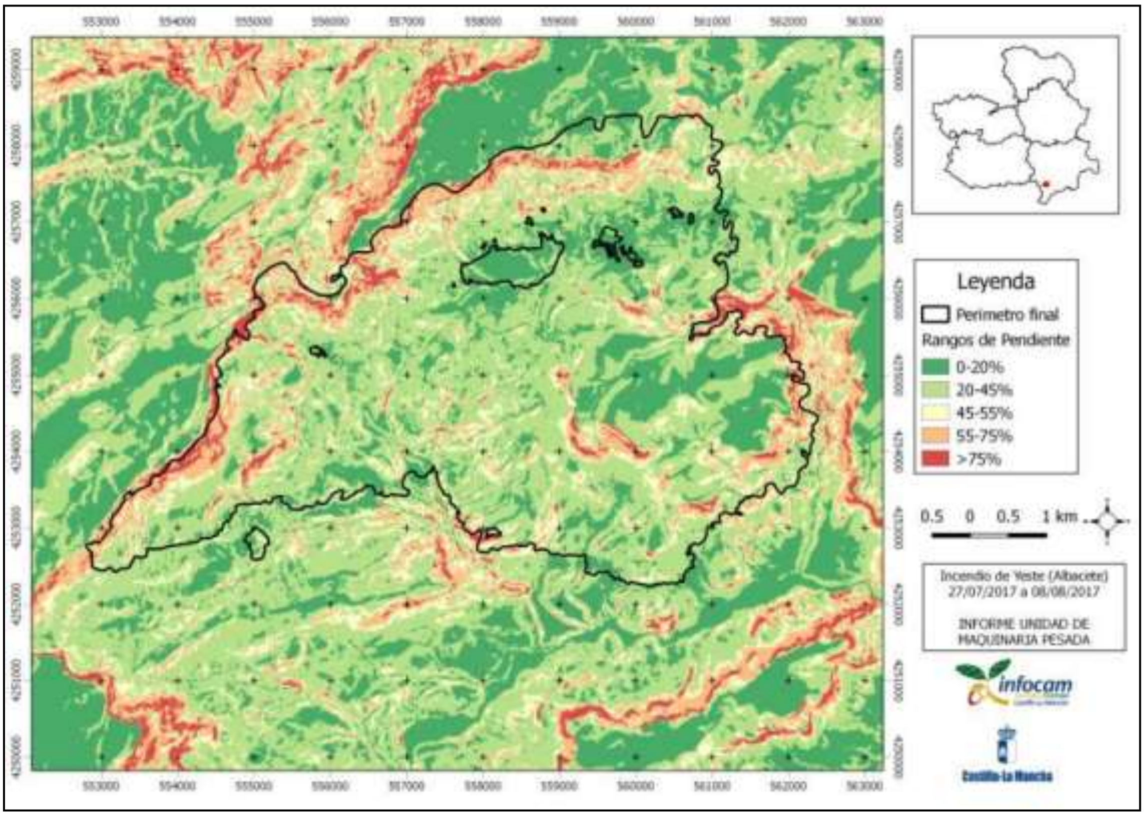

Figure 2: . Map of slopes. 17. Source: UNAP

This fire spread followed a topographic behavior, that is following positive gradient slope with phases in which the propagation was dominated by wind. Its detection of the fire took place at 11:18 am on July 27, 2017, affecting the fire to an approximate area of 3,217 ha until it was stabilized on August 1 2017, at 20:00 h. the control of the fire was declared on August 4 and the final extinction on August 9, 2017. There were no personal or material damages to be regretted despite the fact that several small villages had to be evacuated.

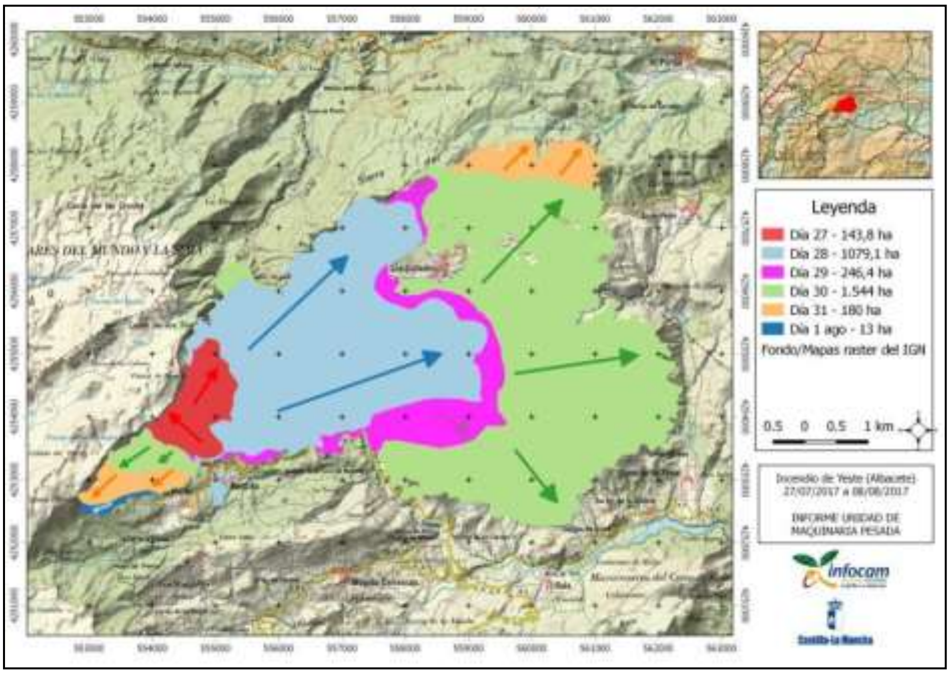

Figure 3: Map of isochrones, main propagations and area affected by fire day.

As regards , the fire mainly affected young and high-density pine stands (*Pinus pinaster* and *Pinus halepensis),* which constitute a type 4 fuel model of the Rothermel classification, which is associated to high fire spread and intensities. Figure 4 show the models of fuels and the areas affected by fuel strata according to information from the III National Forestry Inventory (IFN3).

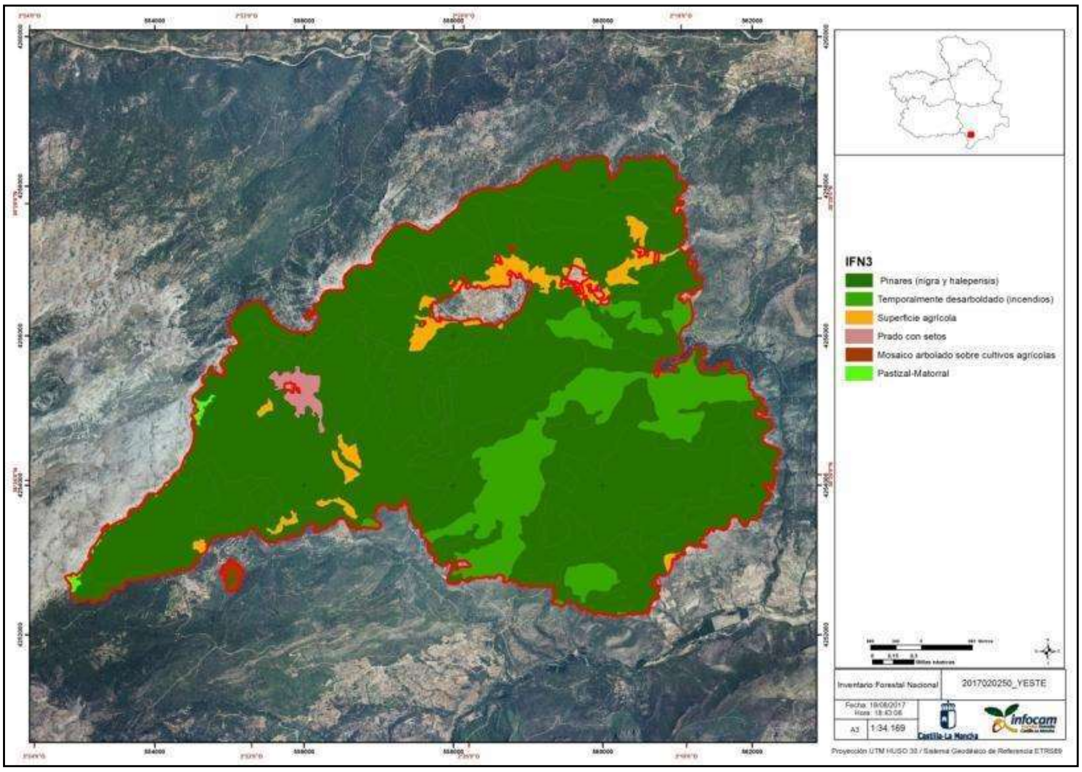

Figure 4: Map of Fuels. Source: UNAP.

2. Strategies and tactics

In the forest fire originated on 27th July , 2017 in the municipality of Yeste, the strategy was fundamentally conditioned by three factors that determined the operations finally executed: topography, fuels (vegetation) and threats to small villages.
In this way, the main strategy was based on defensive maneuvers, to protect villages: Los Collados, La Parrilla, Torre Pedro, etc. taking advantage of the forest trails, the natural discontinuities (mainly rocky, streams and agricultural plots) where the slopes of the terrain and the compactness of the soil allowed the heavy equipment to have effective working capacity for firelines.

The maximum number or dozer working at same time was 15 (1st August), an unusual and outstanding equipment. In total 74 labor days were accumulated during fire operations. It is important to remark that Castilla la Mancha Region covers almost 80 thousands km^2 and the total available dozer are 17.

As for the tactics developed by dozers, they relied heavily on indirect and parallel attack generating discontinuities in the fuel. The direct attack was reduced to works of consolidation of perimeter in Unit SE and in the NE Unit named "La Parrilla" on July 31, taking special relevance the indirect attack through the execution of contingency plans for the defense of the villages and safeguarding the critical points that were at risk to be reached by the front of flames, which would complicate the situation and fire suppression operations. Parallel attacks were also carried out with heavy equipment with support of technical fire maneuvers (technical fire and definition of perimeters), opening and improvement of accesses, arrangement of roads, and execution of logistic platforms and turn around areas, passing bays and security zones, obtaining very good results.

Figures 5, 6, 7, 8: Top left, Indirect attack in wooded areas. Top right, Indirect attack shrubs areas. Bottom left, attack in parallel with technical fire maneuvers. Down right, direct attack.

	
Figure 9: Build of new access with dozers.	Figure 10: Dozer firelines with logistic platforms and turn around areas and passing bays.

During the days 27th and 28th July, 2017 Phase 1 named phase of the first deployment of Heavy Equipment in the fire took place. Equipment teams were mobilized however did not intervene in the operations during these days motivated by the initial complication to access the rear area (or tail) of the fire. This incidence could be resolved in the following days (Phase 2), largely due to the search for alternatives by the Heavy Equipment Specialists Unit. Finally, in a Phase 3, the teams remained in preventive surveillance from 5th to 8th August.

Of the 3 phases described based on the development of the fire and the plans of operations, this report will focus on Phase 2, since it is the phase that encompasses from July 29th to August 4th, 2017, because these days in which it has most of the equipment deployed and where practically all the control lines built were made .

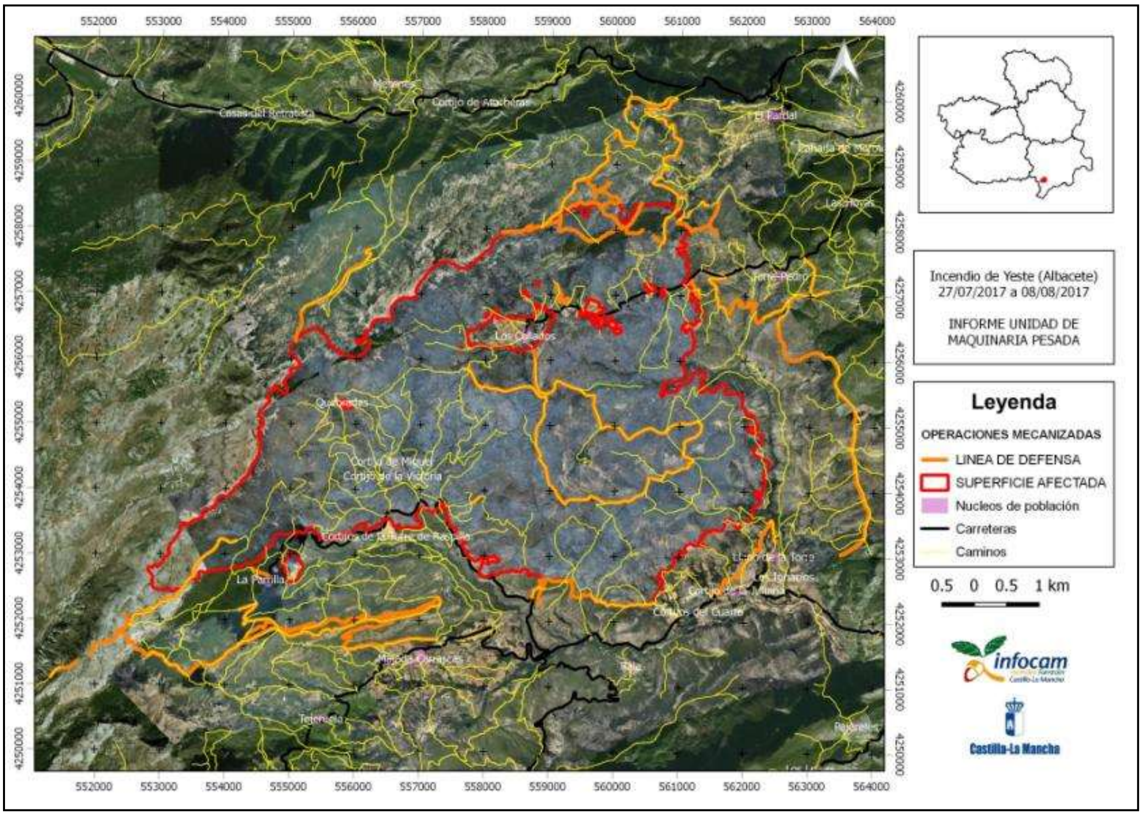

Figure 11: Map of mechanized operations in Yeste Fire (Albacete, Spain).

3. Measurements and production rates

Slope is one of the most relevant feature afections fire spread and work performance. From the analysis of the data collected by the GPS location systems (dozer routes), the following results of slopes have been obtained for each machine shown in Table 1.

	Slope (%)			Slope in absolut value (%)		
Code	**Average**	**Up**	**Down**	**Average**	**Maximun**	**Minimun**
B-LOADER	10,29	13,18	5,96	10,29	13,18	5,96
M12	1,85	36,06	-35,89	8,82	36,06	0,00
M14	0,79	39,32	-44,56	8,63	44,56	0,00
M15	0,78	47,80	-52,21	8,51	52,21	0,00
M21	1,79	43,52	-18,63	10,14	43,52	0,35
M22	0,15	39,33	-42,28	9,46	42,28	0,00
M23	-2,72	37,71	-68,99	6,59	68,99	0,00
M24	1,61	65,46	-34,47	9,30	65,46	0,00
M25	7,53	43,91	-18,87	9,68	43,91	0,00
M31	-0,06	32,97	-37,30	11,07	37,30	0,00
M34	-0,06	40,95	-38,22	11,86	40,95	0,00
M44	-11,70	43,93	-76,99	5,17	76,99	0,00
M53	6,39	42,89	-24,18	9,84	42,89	0,00
M55	2,64	38,17	-24,11	8,74	38,17	0,00
TOTAL	**1,38**	**65,46**	**-76,99**	**9,15**	**76,99**	**0,00**

Table 1. Percentage of average slope, maximum and minimum per machine.

The previous table shows the total percentages that consider the positive (up) and negative (down) slopes; and the percentages in absolute value that do not distinguish between negative and positive slopes. The average, maximum and minimum slopes were considered for the two percentages.

Therefore, from Table 1 it can be seen that on 07/31/2017 the "M24" machine exceeded a maximum working slope in the climb that was close to 65%, and the machine "M44" exceeded a maximum slope in close descent. to 77%. In the total of mechanized operations carried out, an average slope of 1.38% was reached, considering the positive and negative slopes (ups and downs). If the slope is taken in absolute value, the average percentage of slope would be of 9.15%.

3.1 Production rates of fire lines

For the preparation of this paper, measurements have been made of the lengths and widths of all the control lines that were built during the period between July 29th and August 4th , 2017, as well as the extension of roads and forest trails that were executed by heavy equipment during these days. After the processing of the data obtained in the measurements, it has been obtained that heavy managed to build 82.293 m of control lines with an average width of 5,64 m, which translates into 46,39 ha of surface treated. Mechanized operations were analyzed individually and grouped into geographical sectors following the way of organizing suppression teams during the fire.

The results of these measurements are detailed below by day of intervention (Table 1) and by Units of work (Table 2):

Date	Length (m)	Area (ha)	Nº Dozers	Dozer Code
29/07/2017	8.321	4,10	3	M12-M14-M15
30/07/2017	18.486	7,88	8	M12-M14-M15-M21-M23-M24-M31-M53
31/07/2017	23.808	15,44	13	M12-M14-M15-M21-M22-M23-M24-M25-M31-M34-M44-M53-M55
01/08/2017	15.746	9,41	15	M12-M14-M15-M21-M22-M23-M24-M25-M31-M34-M44-M53-M52-M55-BLOADER
02/08/2017	9.076	5,64	6	M12-M14-M15-M24-M25-M53
03/08/2017	6.398	3,60	4	M12-M14-M24-M53
04/08/2017	459	0,32	2	M12-M14
TOTAL	**82.293,36**	**46,39**	**15**	

Table 1. Measurements of mechanized operations per day.

Unit	Lenght (m)	Area (ha)	Nº Dozers	Code Dozers
CENTER	11.469	4,19	1	M15
E	15.344	10,08	6	M12-M14-M15-M22-M23-M44
NE	18.107	13,72	6	M12-M14-M15-M22-M23-M55
NW	2.262	1,20	2	M12-M14
SE	5.631	3,58	3	M24-M31-M34
SW	29.480	13,63	11	M14-M15-M21-M24-M25-M31-M34-M53-M44-M55-BLOADER
TOTAL	**82.293,36**	**46,39**	**15**	

Table 2. Measurements of mechanized operations per geographic zone.

From the analysis of the data obtained, it can be deduced that the period of greatest activity of heavy equipment coincides from July 30th to August 1st , 2017. In this period, more than 70% of the work was carried out, acting at full capacity with 8, 13 and 15 machines respectively (14 dozers and 1 backhoe loader). During these 3 days of intervention, more than 58 km of control lines were built, which means an area of approximately 32.73 ha.

During the days July 29th ,August 2nd and 3rd, 2017, an average of 4.3 machines were working in front of the 12 teams per day. As result of these 3 working days, more than 24 km of control line opening and an area of approximately 13.34 ha had been obtained.

From 20:00 p.m. on August 1st , the fire was stabilized, with the final control taking place on August 4th at 9:00 p.m. For this reason, it is because of the demobilization of the vast majority of teams between August 2nd and 4th that, as of this date, only 2 dozers remain in the fire (M12 and M14) in a "preventive" situation until its withdrawal from the fire on August 8th. The Incident Commander would declare the extinguishment of the fire at 5:48 p.m. on August 9th , when all the heavy equipment teams were at their destination bases.

In reference to the Sectors in which there was intervention of heavy equipment, it is worth mentioning the Sectors SW, NE and E with more than 80% of the total work performed during the intervention of the heavy equipment in this fire. In contrast, there are the NW, SE and CENTER work sectors with almost 20% of the work carried out.

Finally, it should be noted that the percentage of new construction control lines has been analyzed with respect to the total work performed, obtaining a result of more than 21 km of new construction control lines, which represents 26% of the total length executed, that is, every four kilometers one would be of new construction. In terms of the surface area executed, the results are even greater, obtaining in these new construction lines an area of approximately 17.08 ha, which would represent 37% of the total surface area built.

3.2 Production rates of fire lines per machine

From the analysis of statistical data, the following work performances have been obtained for each Heavy Equipment:

Code	Lenght (m)	Area (ha)	Time (nº days)	Rate (ha/dia)	Time (hours)	Rate (ha/hora)
M12	16,43	7,14	6,00	1,19	96,00	0,07
M14	18,63	7,90	6,00	1,32	96,00	0,08
M15	20,77	7,81	6,00	1,30	96,00	0,08
M21	6,64	1,99	3,00	0,66	48,00	0,04
M22	10,29	4,11	2,75	1,49	44,00	0,09
M23	10,23	4,06	3,00	1,35	48,00	0,08
M24	7,74	2,74	5,50	0,50	88,00	0,03
M25	4,05	1,21	2,50	0,49	40,00	0,03
M31	5,83	2,35	2,75	0,86	44,00	0,05
M34	4,08	1,60	3,00	0,53	48,00	0,03
M44	3,04	0,95	2,00	0,47	32,00	0,03
M52	0,00	0,00	0,00	0,00	0,00	0,00
M53	9,30	2,82	5,25	0,54	84,00	0,03
M55	4,00	1,59	2,00	0,80	32,00	0,05
B-LOADER	0,26	0,10	0,25	0,42	4,00	0,03
AVERAGE	**8,09**	**3,09**	**3,33**	**0,79**	**53,33**	**0,05**

Table 3. Production rates of lines (dozer and backhoe loader).

For the calculation of the production rates per working days, the time of the displacement to the fire and return to base of origin has been discounted, in addition to the time that the machine remained in a waiting situation and preventive surveillance.

For the calculation of the performances per hour of work has been taken into account an effective time of 2/3 of the total time of permanence in the fire, considering as time not effective the one destined to rest, eat and refuel machines, relays of machine drivers and dozer bosses, breakdowns and maintenance of the work team, etc.

As conclusions of the data reflected in Table 3, it can be deduced that the work performances oscillate between 0.03 ha/hand 0.09 ha/h. Assuming an average line width of 3 meters (the length of the thrust blade with angledozer movement in medium dozers is between 3.7 and 4.5 meters without taking into account the angle) the work performances would be between 100 m/hand 300 m/h, average production rates in line with the slopes and existing fuel models in the work areas. In addition to these data it is clear that there is no clear relationship between work performance and time of intervention in the fire, for example, M22 and M23 machines reached high performances in just 3 days of intervention in the fire, however other machines with greater allocation time obtained much lower production rates.

4. Conclusions

The production rates implementing firelines in Yeste large wildfire is between 100-300 m/h, this is a normal production rate for the steep slopes and fuel models existing in the area.

In the fireline construction that we are reporting here the steepness in slope where above the maximum threshold in the exiting literature, our measured threshold is set as 65% when up-slope (while the maximum established in the literature is 55%) and 77% when down-slope (maximum established in the literature that is 75%). Our measured and confirmed performance limits (thresholds) in Yeste reinforce that dozers do excel when working in areas of steep slopes. Additional work should be done towards the development of a table of dozer performance implementing fire lines regarding slope steepness and fuel models from data of numerous fires.

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THE POTENTIAL OF A WEIGHT DETECTION SYSTEM FOR FORWARDERS USING AN ARTIFICIAL NEURAL NETWORK

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Abstract: *To manage forest processes, information about the amount of timber that passed through different processing steps within the timber supply chain is essential. This information can be used both to keep the overview of the amount of timber already produced for initiating further activities and to clear accrued operation expenses promptly. When felling operations have been supported by or carried out exclusively through manual working steps, information sources like harvester protocols are either not available or lack sufficient accuracy for their proper use. To solve this problem in cut-to-length logging, a weight-detection system can be integrated into the loading process of the logs as single stems or stem bundles. This system can be used for estimating the timber volume moved, thus closing the information gap without further interactional effort. Unlike common crane scales, which are not available for every type of machine, the method presented here for a weight-detection system is universally applicable in modern crane types.*

In the first step of the development stage, loading processes during the work task of the forwarder are detected. Using an artificial neural network and data provided by the sensor set of a modern crane, the weight of the load in the grapple can be estimated based on the position of the grapple and the hydraulic pressure of the boom cylinder during these loading processes. The accuracy error of only 10% of the volume moved after initial training of the neural network demonstrates the potential *of this system. By obtaining more training data through further measurements, an accuracy error of less than 4% is expected. For decision making within the forwarding process, this technique can therefore be a reasonable solution for short-term and extensive implementation of the smart forwarding processes that are currently being established in the Forwarder2020 project.*

Keywords: forest management, process management, crane scale, weight detection, neural networks, Forwarder2020

1. Introduction

The logistical management of the timber supply chain offers high optimization potential to the forest industry (Heinimann 1999). Mainly due to the wide variety of forest actors' internal structures and their functions within the timber supply process, the information flow within the timber supply process can easily be interrupted, leading to unnecessary time delays which hinder the possibility of making adapted strategic economic decisions (Bodelschwingh 2006).

The main indicators exchanged in the information flow, particularly concerning the volume or weight of the moved or processed timber, are the characteristic numbers for a wide range of single processing steps. Consequently, various manual and automatic volume and weight measurement systems have been established in the past decades, for example to calculate own performance, gather information for process managing purposes in forest enterprises or answer scientific questions. Depending on their scope of application, the measurements may follow strict regulations if their estimated values have a legally binding character such as compliance with formal trade practices or safety regulations (European Parliament and Council of the European Union 4/29/2015) or, with lower accuracy, may simply serve as volume estimating assistance. For each objective, the desired accuracy or the possibility of official calibration of the measuring system can be crucial for its use. This classification of different systems, which can be given by official testing laboratories under national laws, considers national and international trade regulations and is often required for their accredited use by forest administrations (Landesbetrieb Landesforsten Rheinland-Pfalz 10/26/2017; Petty and Melkas 2013; ForstBW 2013).

2. Aim of development

When focusing on the automatic estimation of the timber volume moved during forwarding work in cut-to-length (CTL) operations, the volume information is not always available without supplementary equipment (Manner 2015). This emphasizes the as yet unsolved information deficit problem also presented in Bodelschwingh

2006. As an alternative solution, Manner (2016) suggests filling this information gap with additional data from harvester protocols and spatial information (ibid.). While not every felling operation is necessarily fully mechanized, direct measurement of the volume or weight while loading, unloading or measuring the weight being moved by the forwarder as loaded weight should be strived for in order to guarantee the highest coverage of CTL logging process variations.

Additional mounted crane scales, as used for the John Deere TimberLink™ system (John Deere 2014) or the PONSSE load optimizer (PONSSE 2018), currently provide common, highly accurate solutions that can also meet official measuring standards (i.e. ForstBW 2013). A case study conducted by Petty and Melkas (2013) in Finland showed the accuracy of these systems, where over 99% of the measurements tested achieved the in Finland required 4% weight tolerance with the use of six different scale manufacturers. This study even showed higher accuracies than previous measurements, further underlining the higher accuracy of crane scales based on hydraulic pressure as compared to strain gauge measuring principles (ibid.). As a functionality of most crane scales (Sebulke 2016; ForstBW 2013), it is possible for these systems to work in different measuring modes (automatic to static in mid- to high accuracy), and thus can also be used for continuous measurements with a lower accuracy during regular work or in semiautomatic mode, for example loading swap trailers (Korten and Kaul 2012).

Regarding dispositive issues in the supply chain, these products can, on the one hand, potentially meet requirements thanks to these different measuring modes because the automatic measuring mode does not influence the driver in his working behaviour and hence his work productivity. On the other hand, due to the additional costs of the extra modules which need to pay off directly for the user, these products are currently not extensively distributed in equal measure and are consequently only partially available for information exchange without high accuracy requirements.

The use of modern cranes enables a new possibility to access weight or volume information without additional equipment costs and offers the potential of establishing an informal source of information about the timber volume moved for comprehensive purposes.

With the crane's already equipped internal sensor set, accessible through the controller area network (CAN), it becomes possible to derive the lifted weight directly by calculating the force needed and the position of the crane. Although the movement of the crane as well as the oscillating movement of the lifted logs create a constantly changing weight value, weight estimation using dynamic payload detection, for instance as described in Hindman (2008), is possible. In this first study, this approach, including the use of two different artificial neural networks was tested on an old crane which had been manually equipped with the relevant sensors of a modern crane. The collected data was evaluated in a post-process to present the feasibility of this approach and the technical potential of the system.

3. Material and methods

3.1 Detection of loading cycles

For an automatic recording of log loadings, the individual loading cycles during the work task have to be detected and differentiated. Within one individual loading cycle, especially during the period when the log is picked up, it is possible to estimate the current mass of the grapple content. The identification of loading cycles can be achieved by a separate neural network (NN), which requires the joystick signals as well as the absolute position of the grapple as input data. The delivered output data is a vector specifying whether the grapple is currently loading a log or not. Individual loading cycles that correspond to a complete loading phase from the complete cycle data are thus generated. The network was trained using data from previous measurements and the accuracy was thoroughly examined through visual confirmation of the measurements evaluated (Geiger and Geimer 2017).

3.2 Theoretical functionality of weight detection

To enhance the project viability and to reduce implementation requirements, the number of sensors necessary to accurately generate reliable projections on the mass of the timber log under different loading conditions was minimized. In theory, precise knowledge of the grapple's positional data during a loading cycle as well as the time series of the pressure in the hydraulic cylinder is sufficient to develop a log balance. The position of the grapple is calculated using a kinematical model from the individual displacements of each hydraulic cylinder. This displacement was recorded in a laboratory using laser distance sensors. For the hydraulic pressure, only the inner boom cylinder was equipped with a pressure sensor. This sensorial data during the cycles along with the crane control signals were then pre-processed and used by the NN to estimate the payload mass.

3.3 Calibration and peripheral sensor preparations

The pressure sensor and position sensors were calibrated as they were mounted onto the machine. The positional sensors were parameterized using the minimum and maximum positions of the respective hydraulic cylinders. Furthermore, the forwarder had to be prepared specifically for the accurate recording of the laser signals. The swivel angle was recorded with a draw-wire sensor and its end was attached to the crane pillar. All analogue sensor signals and CAN signals (joystick signals) were recorded with a Micro Autobox.

3.4 Testing procedure

Before generating the data for the NN, appropriate logs had to be chosen to effectively represent the possible mass spectrum encountered in the forest during real operation. As such, ten logs with different masses were selected and recorded, while the tree trunks were simultaneously numbered. Prior to the actual test cycles, static measurements were taken to review the behaviour of the sensors under test conditions and to verify the functionality and plausibility of the individual sensors.

For each test cycle, the logs were loaded in random order and in a random combination of multiple- or single-log grappling. During these cycles, the logs were placed at random locations that the driver had designated beforehand. The driver was advised to emulate the position of tree trunks in the forest and place the majority at medium distances, but at times also pick up logs from a closer or further distance.

3.5 Data interpretation by the neural network

Data preparation for the NN was automated based on the previously implemented cycle recognition. However, to limit the size of input data, only the seconds around the moment when the grapple picks up the log were considered relevant input data. During the data preparation, the signals were filtered to remove white noise.

The pressure signal was treated differently: by filtering the original time series with varying window sizes, different resulting time series were generated. These varying windows sizes resulted in low- and high-frequency pressure signals that served as input data for the NN. Following the data preparation, subsequent time series were generated as input data:

(1) pre-processed pressure sensor signals, (2) positional data on the grapple, and (3) joystick signals.

The resulting time series for each loaded log were then divided into sections of equal size. Each section was represented by statistically derived indicators (e.g. mean, minimal and maximal pressure value of that section). The resulting data matrices of the respective masses of the logs were fed into the NN as a solution vector for each loaded log or as a combination of logs.

4. Results and discussion

As the accuracy of the results of the NN compared to its ideal output is directly proportional to the accuracy of the later assigned weight of the logs, this output can be directly used to evaluate the first test of this approach.

Figure 3 thus shows the normalized results of the NN for the different data sets of training data, validation data, test data as well as all data combined. Each graph displays the normalized target and output of the NN, given that the input data is normalized as well. Therefore, an optimal result of the NN matches the ideal output, visualized as the red, dashed line.

Figure 3: Results of the neural network

The results of the test data set indicate a very high accuracy of the presented method. Almost all of the input cycles, displayed as blue dots, are remarkably close to the ideal output. Although a sensor fault occurred during the measurements, the highest deviation in the test data is 24.2 %. Considering all test data, the mean accuracy is 9.1 %, which means that log masses can be measured correctly during the dynamic working process of a forwarder.

Higher accuracies on the predicted mass for the timber logs would be achieved by increasing the amount of input cycles, and thereby reducing the influence of outliers on the algorithm. The results presented, observed from the NN, suggest that the velocity and acceleration of the grapple arm movement, as potential disruptive factor for the training-effect of the network, play a minor role.

Therefore, this method is a promising and cost-effective way to accurately and reliably determine the mass of timber logs using a minimal number of sensors combined with a sophisticated neural network.

Summary

As for the objective to create a comprehensive tool to close the information gap of the timber volume processed, the current results offer a wide range of application possibilities in the forest industry, especially for lower-accuracy data collection. The implementation of this system as a post-processing application or as a potential real-time detection system in the prototype forwarder of the "Forwarder2020" project seems possible as a potential weight-detection system for future needs (HSM Construction 2016). The aimed requirements of less than 4% (conventional crane scale equivalent) on a legally non-binding base are expected to be met with further development and additional training data from future field testing.

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THE EFFECTS OF COVERAGE ON LOGGING RESIDUE MOISTURE CONTENT AFTER STORAGE

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Abstract: In Sweden the large users of biomass for energy pays for the biomass based on delivered energy content. Thus, the moisture content of the biomass has a large impact of its value and suppliers strives to deliver as dry material as possible. As the deliveries to customers are strictly demand driven, suppliers have to store biomass until demanded during winter. Traditionally logging residues are dried on the cut-block for one summer and thereafter forwarded to a landing and stacked. These logging residue stacks are covered using a waterproof paper to avoid remoistening of the residue during the period they are stored on the landing. There is a fear that the drying process for logging residues will be affected by recent changes in planning and execution of harvesting and forwarding work. These changes are motivated by an effort to reduce ground damage caused by these operations, and might in some cases lead to residues not being dried on the cut-block and in other cases stacks might be placed in less suitable locations than before. Thus, it has become of interest to know if drying can be improved by minimising the influence of ground moisture on the moisture content of logging residues. An experiment was designed where the effects of 1) breaking the transport of ground moisture into the biomass, and 2) covering the residues, were studied in a factorial design. In both cases ordinary Walki biomass cover paper was used. The experiment was replicated on 3 sites across southern Sweden. On each site four stacks of residues were placed on a landing, and treatments were 1) No cover, 2) Covered, 3) No ground contact, and 4) Covered with no ground contact. Results after 8 months of storage (based on two sites) show that moisture content were 41% in uncovered stacks (treatment 1), 40 % in treatment 2 and 3, and 32% in treatment 4. While the stacks in treatment 1 and 4 had a homogenous moisture content throughout, stacks in treatment 2 and 3 had a significantly higher moisture content in the upper part of the stacks. Traditional coverage of residues was not a profitable option on any of two sites due to the insignificant improvement of moisture content. Treatment 4 is on the other hand profitable and provides a drier high-quality material with the extra benefit of a homogenous moisture content throughout the stack. However, our results have to be treated with care since they are based on only two sites. The last site in the experiment will be measured in late February.

Keywords: Biomass, Quality, ground moisture

1. Introduction

In Sweden the large users of biomass for energy pays for the biomass based on delivered energy content. Thus, the moisture content of the biomass has a large impact of its value and suppliers strives to deliver as dry material as possible. As the deliveries to customers are strictly demand driven, suppliers have to store biomass until demanded during winter. Traditionally logging residues are dried on the cut-block for one summer and thereafter forwarded to a landing and stacked. These logging residue stacks are covered using a waterproof paper to avoid remoistening of the residue during the period they are stored on the landing (Lehtikangas and Jirjis 1993; Jirjis 1995).

There is a fear that the drying process for logging residues will be affected by recent changes in planning and execution of harvesting and forwarding work. These changes are motivated by an effort to reduce ground damage caused by these operations. This might in some cases lead to residues not being dried on the cut-block (Nilsson et al. 2013) and in other cases stacks might be placed in less suitable (wetter) locations than before. Thus, it has become of interest to know to what extent ground moisture by itself and in combination with conventional covering affect the moisture content of stored logging residues.

An experiment was designed where the effects of 1) breaking the transport of ground moisture into the biomass, and 2) covering the residues, were studied in a factorial design.

2. Material and methods

The experiment was replicated on 3 sites across southern Sweden; Nybro, Remningstorp and Årstad. In all cases ordinary Walki biomass cover paper was used to cover the material or to break the ground contact. On each site four stacks of residues were placed on a landing, and treatments were 1) No cover, 2) Covered, 3) No ground contact, and 4) Covered with no ground contact.

3. Results

Results after 8 to 10 months of storage show that moisture content developed differently in Årstad compared to the other two sites. In the site at Årstad, the uncovered stack (treatment 1) had a moisture content of 59% which was not significantly different from the 62% in treatment 3, however treatment 2 and 4 were significantly drier with a moisture content of 53 and 55 % respectively. Only the uncovered stack in Årstad had a homogenous moisture content. Stacks in treatment 2 and 3 had a significantly higher moisture content in the lower part of the stacks, while the opposite was true in treatment 4. In the two other sites moisture content was 40 % in treatment 1, 2 and 3, and 32% in treatment 4. While the stacks in treatment 1 and 4 had a homogenous moisture content throughout, stacks in treatment 2 and 3 had a significantly higher moisture content in the upper part of the stacks.

4. Discussion

Traditional coverage of residues was not a profitable option in the Nybro or Remningstorp sites due to the insignificant decrease in moisture content. However, in the Årstad site traditional coverage was a very profitable option. Treatment 4 was on the other hand profitable in all sites and provided a drier high-quality material, which at the Nybro or Remningstorp sites had the extra benefit of a homogenous moisture content throughout the stack. Nurmi and Hillebrand (2001) reported that coverage of residues did not have much effect as long as the weather was dry, this can explain the increased value of covering the residues at the wet site in Årstad compared to the other sites that were dry. This enhances the opinion of practitioners in dry areas that covering residues should be done more as a insurance against getting wet residues in case of unusually long periods of rain than as a measure that always reduces moisture content after storage.

Breaking the ground contact to reduce moisture absorption from the ground was not a successful method to reduce moisture content unless the logging residue stack was covered.

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SKYLINE TENSION MONITORING OF CABLE YARDING SYSTEMS IN THE ITALIAN ALPS

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Abstract: The cable yarders represent one of the most common system for steep slope forest operations in the Alps. This system is based on the use of tensioned skylines, which should operate continuously under a specific Safe Working Load (SWL) in order to guarantee a proper safety level for the forest operators.

The aim of this study is to analyze the operative skyline tensions in real harvesting sites, working with different cable systems and rigging configurations, identifying the frequency of the overcoming of the SWL and the main factors influencing the peak tensions and the dynamic amplification.

The analysis was conducted on 12 different cable lines in the North-Eastern Italian Alps, equally distributed between single-span and multiple-span configurations, monitoring totally 502 work cycles. The surveys interested 11 different cable yarders and 10 different logging companies.

The data collection was based on a high-frequency tensiometer, for the skyline tension monitoring, and on a machine-control-unit (based on a camera and an inertial measurement unit integrated with a GNSS sensor), installed on the carriages, for the time study and the special event detection. Each cycle load was measured at the landing. The line and corridor profiles were extracted from a digital elevation model derived from Lidar data and using the GPS position of the support elements. The data analysis was based on the synchronization of the full set of data and the use of statistical software for the descriptive statistics and the development Mixed Effect Models for the significant variables detection.

The results showed that more than 53% of the cycles observed exceed the SWL. The most critical conditions were recorded in the single-span configurations where more than 73% of the cycles exceeded the SWL and 3% of the cycles overcame the endurance limit of the skylines, generating a potential decrease in the lifespan of the ropes and potentially increasing the risk for the operators.

Keywords: Cable yarder, Cable tension, Alpine region, Safe Working Load, Mixed Effect Models

ENERGY EFFICIENCY OF SMALL AND MEDIUM-SIZED ENTERPRISES IN WOOD PROCUREMENT: A CASE STUDY OF STORA ENSO IN FINLAND

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Abstract: Stora Enso is committed to the continuous improvement of energy efficiency. At the Group level, the target is to reduce electricity and heat consumption by 15% by 2020 compared to 2010. Stora Enso Wood Supply Finland (WSF) was certified to the ISO 50001 Energy Efficiency Management System Standard in 2015. At Stora Enso WSF, our goal is to improve energy efficiency by -4% by 2020 from 2015. Improving the energy efficiency of our wood procurement entrepreneurs is currently one of the main focus areas on energy efficiency development at Stora Enso WSF. Nowadays, we have 33 logging and 34 timber-trucking enterprises which harvest timber to roadside landings and further transport timber to mills. In order to clarify the state of the art of energy efficiency in the business of wood procurement entrepreneurs at Stora Enso WSF, logging and timber-trucking entrepreneurs were interviewed in November and December 2017. Both 25 logging and 25 timber-transportation entrepreneurs were interviewed. The study results reported that 52% of the logging entrepreneurs and 72% of the timber-trucking entrepreneurs interviewed underlined that by enhancing more energy efficiency they are able to improve profitability in their enterprises. Logging entrepreneurs evaluated that the most essential issues related to energy efficiency in their business are good skills, motivation and attitudes of forest machine operators, as well as the size of logging areas and the sufficient levels of standing stocks, the density of harmful undergrowth and long forwarding distances at harvesting sites, the large number of timber assortments harvested, and the technical usability of machinery. Correspondingly, timber-trucking entrepreneurs estimated that the most significant priorities for energy-efficient transportations are the fuel efficiency of timber trucks, the utilization of maximum weights (68 & 76 t) in trucks, the cross-cutting length of timber, a good planning of driving routes, driving distance from timber storage to the destination (i.e. to mill or terminal), the share of driving with empty truck, and superior skills, motivation and attitude of truck drivers. Most of the entrepreneurs interviewed (92% of the logging entrepreneurs and 72% of the timber-trucking entrepreneurs) forecasted that energy-efficiency issues will focus on their business in the coming years. Furthermore, for instance, 76% of the logging entrepreneurs and 84% of the timber-trucking entrepreneurs predicted that when they invest in new logging machinery and truck fleet in their enterprise, the energy efficiency of machines and trucks will be emphasized in their future investments. Our study concluded that the excellent attitudes and motivation of entrepreneurs and machine operators and timber-truck drivers towards energy efficiency and the skills of operators and drivers play a significant role when we are improving the energy efficiency in wood supply chain at Stora Enso WSF.

Keywords: ISO 50001, small and medium-sized enterprises (SME), wood procurement, harvesting machinery, timber-truck fleet.

DEBARKING HEADS, A POTENTIAL SOLUTION TO MODERN FORESTRY CHALLENGES IN EUROPE?

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Abstract: Modern forestry is increasingly confronted with challenges that appear with intensive forest management and the progression of the effects of climate change. The forestry sector is able to react to the changing conditions by adapting management plans, forest structure or planting tree species with a higher stress resistance. However, during stand management activities, silvicultural treatments and harvesting operations can have an impact on the further development of the remaining forest ecosystem. In this regard, key challenges in modern forestry are i) decreased soil fertility in stands with poor nutrient stock or supply and ii) the spreading infestation of pests (e.g. spruce bark beetle, *Ips typographus*) supported by more frequent stress situations through climate change, or poorly structured forest stands.

In Germany, the most widely used harvesting system for thinning operations is a single-grip harvester used for felling and processing trees followed by a forwarder for timber transport from the machine operating trails to roadside. In a research project, debarking rollers and other modifications designed for Eucalyptus harvesting heads were tested on commonly used harvesting heads for the first time, to assess the possibility of adding debarking to fully mechanized forest operations under Central European conditions. As a high nutrient supply can originate from tree bark and debarked logs cannot serve as breeding habitat for bark beetles, debarking provides a solution to address the above-listed challenges and offers additional benefits.

Different field tests, with varying tree species, diameters, and age classes, were established within German state forests in Lower Saxony and in Bavaria. These tests were also repeated in both summer and winter seasons to evaluate the influence of associated tree sap flows on debarking quality. To assess debarking ability originating from head modifications, measurements of the debarking percentage were performed with newly developed photo-optical evaluation software and a terrestrial LiDAR. Within the study design, three different harvesting heads were modified to assess the different mechanical characteristics and setups. For the first time, two of the modified harvesting heads were also tested within spruce bark beetle infested stands to evaluate the performance and potential benefits under those specific and exceptional conditions.

The results demonstrate that especially for summertime operations, simple modifications on harvester heads are able to provide an average debarking efficiency of up to 90 percent depending on the modifications. In-stand bark removal showed several key advantages such as: lowered probability of pest propagation, higher nutrient content remaining on the forest floor, lowered mass of stems during transportation, less ash residue and fine dust outtake at thermal use, etc. Another key finding is that a negatively affected sap flow, through wintertime operations or during pest infestations, resulted in a considerably lower debarking efficiency. Considering operational performance, since a debarking process often requires the stem to be fed through the harvesting head on multiple occasions to remove bark, harvesting productivity was reduced by approx. 30% compared to productivity measured with conventional harvesting heads. Further alterations to the harvesting heads along with refinement of work procedure could help mitigate this productivity decline.

Keywords: debarking, debarking percent, debarking harvesting heads, mechanized forest operations, European forestry

INFLUENCE OF MOISTURE CONTENT ON OXYGEN CONSUMPTION OF WOOD CHIPS – DETERMINATION OF THE STORAGE-STABLE MOISTURE CONTENT

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Abstract: Wood chips are an important renewable energy source, since they can be used for heat and power production independently from sunshine and wind. The storage of wood chips is a central step in the biomass supply chain, as it compensates for temporal differences in production and consumption. Typical storage-related problems are dry matter and energy losses due to microbial activity in fresh wood chips. Dry matter losses can be reduced, when the chips are technically dried before storing. Technical drying, e. g. with waste heat from biogas plants, is often applied to reach moisture contents (MC) suitable for small- and medium-scale wood chip heatings. However, the chips are frequently dried to very low MC, which might lead to a waste of energy and time and can also be adverse for the heating systems. Moreover, no additional positive effect on storage is expected when chips are overdried. But the storage-stable MC of wood chips has not been investigated intensively and is therefore not yet exactly determined. According to literature, it is in a range between 15 w-% (Kollmann 1951) and 30 w-% (ÖNORM 1998). The purpose of our study was to determine as accurately as possible the threshold of MC where microbial activity starts. Thus we can recommend drying just below this critical point.

Keywords: solid biofuels, storage stability, dry matter loss, moisture content, oxygen measurements

Open-stored spruce chips from forest residues (crown material) and from energy roundwood (delimbed stem sections of low quality or small diameter) were conditioned in a drying cabinet at 60 °C to MC between 3 and 32 w-% (moisture mass fraction on wet basis). Then they were filled into 10 liter buckets which were sealed air-tight. The buckets were stored for 48 hours, one batch at approx. 20 °C (room temperature), a second batch at 33 °C. Subsequently, the remaining oxygen concentration was measured by sucking the air in the buckets through a valve to an oxygen sensor. A decrease in oxygen concentration compared to the initial oxygen concentration of 20.9 Vol-% (ambient air) indicated microbial activity and therefore dry matter loss. The dry matter loss was stoichiometrically calculated. In total, 96 samples of each assortment were investigated within a period of three months.

The results show that MC of wood chips and oxygen concentrations inside the buckets after 48 hours were significantly correlated for both assortments: with increasing MC the oxygen concentrations decreased. Higher storage temperature caused faster oxygen consumption. Even very low MC (< 10 w-%) led to a slight oxygen depletion, which might be caused by chemical auto-oxidation processes that can be observed especially for wood pellets (Kuang *et al.* 2009). Regression analysis showed that the best fitting was reached by polynomial regression for both assortments and storage temperatures. Therefore, the point of storage-stability depends on the definition of the acceptable dry matter loss. If this threshold is, for example, defined as 2 % per year, the stoichiometrical calculated oxygen concentration in the buckets must be at least 18.2 Vol.-%, which means, that the moisture content should not exceed 21.7 w-% (storage temperature 20 °C) or 17.7 w-% (storage temperature 33 °C) for energy roundwood chips (Fig. 1).

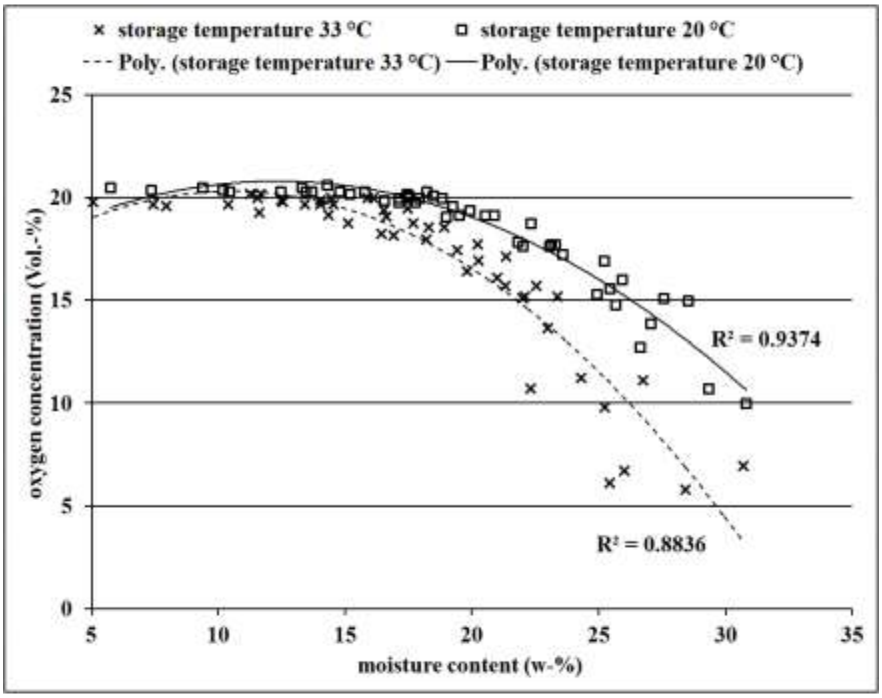

Fig. 1: Polynomial regressions of moisture content of the energy roundwood chips and oxygen concentration in the 10 liter buckets after 48 hours of storage at 20 °C and 33 °C during the 3-month-experiment.

For forest residue chips the correlation was weaker, since the storage period of the wood chips before sampling seemed to influence the microbial activity. Samples that were taken during the first 6 weeks of storage led to faster oxygen depletion than samples taken later. The reason for this could be the high proportion of needles in the forest residue chips which contain many easily available nutrients for microbial growth and accelerate dry matter losses especially in the beginning of the storage (Hofmann *et al.* 2017). Therefore, an extrapolation to one year would probably lead to an overestimation of the dry matter loss. However, during week 7 to 12 the regression line of the forest residue chips was very similar to the overall regression line of the energy roundwood chips.

Final analysis of the data and interpretation of the results are still in progress.

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PRODUCTIVITY, SETUP TIME AND COSTS OF A WINCH ASSISTED FORWARDER

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Abstract: In fully mechanized cut-to-length timber harvesting operations, the forwarder represents the limiting machine in steeper terrain in terms of trafficability. In order to operate also on steep terrain and on soft soils with low traction they can be equipped with traction winches. The objective of this study was to investigate setup time, develop a productivity model and calculate extraction costs for the winch assisted forwarder John Deere 1110E. The productivity model is based on 75 observed cycles within 18 skid trails. The study was carried out in three different stands using detailed productivity and process analyses. Factors, which influence machine productivity, are piece volume, inclination, distance during loading activities and extraction distance. With an average observed piece volume of 0.10 m3 and an average load volume of 9.25 m3, the winch assisted forwarder reached a productivity of 13.7 m3/PSH15. By an annual utilization of 1,900 hours and system costs for the entire machinery of 110.68 €/PSH15, forwarding costs 8.06 €/m3. The detailed time and motion study showed different possibilities for mounting the cable depending on operation direction, terrain, passability through the stand and availability of the harvester. Average setup time for the cable operating downhill was 21.6 minutes, which additionally caused costs of 1.03 €/m3. This study has been already submitted to Journal of Forest Research.

Keywords: winch assisted forwarder, extraction, productivity, setup time, steep terrain harvesting

THE IMPACT OF WEATHER CONDITIONS ON FUEL CONSUMPTION OF COMMINUTION AND TRANSPORT OF WOOD RAW MATERIAL IN ESTONIAN CONDITIONS - A CASE STUDY

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Abstract: Estonia has ratified the Paris Agreement on Climate Change and contributing the EU commitment to a 40 percent reduction in emissions by 2030 compared to 1990. Long-term Development Programme for the Estonian Energy Sector up to year 2030+ has targeted even more ambitious goal for Estonia – by year 2050 the GHG emissions should decrease by 80% compared with the year 1990. Achieving these goals requires a significant increase of use of wood as a renewable energy source. In this situation the efficiency of production and logistics of wood fuels is becoming essential. Among different factors influencing the production and transport cost of wood fuels is the air temperature. During last years, the winters have been mild and due to that the local transport of wood fuels has taken place on soft and unfrozen soils. But higher temperature has created more favourable conditions for processing of raw material. As the data for previous cold winters is also available, the goal of the case-study was defined - to analyse the impact of precipitation and air temperature in winter to the price formation of comminuted wood fuels in Estonian conditions. The main attention was given to fuel consumption.

The initial data from SLG Energy Lõuna company covered 7 different types of chippers (Jenz HEM 561, Jenz HEM 582, Jenz HEM 700, Heinola 910ES, Bruks 805CT, Doppstadt DH 910, Doppstadt DH 608) and 5 trucks (Volvo FH 460, Volvo FH 500, MAN TGX, MAN TGA andMAN TGA). All machines were equipped with a GPS tracking device which records the route and the fuel consumption. During the study all costs and revenues related to the concerned machines were accounted. The data about the precipitation and air temperatures was got from the Estonian Weather Service.As a result of analysis of meteorological data and the data of the machines, the seasonal variation of fuel consumption was observed and the impact on fuel consumption was determined

Keywords: Trucks, wood chippers, forestry, costs

TERRAIN CLASSIFICATION FOR TIMBER HARVESTING AND FOREST ACCESSIBILITY

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Extended abstract*: Different terrain conditions influence the type of machines and harvesting systems as well as designing and construction of forest roads. Vehicle mobility is the ability of a vehicle to move in terrain while performing its primary mission, while terrain trafficability is its property to allow the passage of a vehicle, where terrain conditions show their influence. From the standpoint of planning harvesting operations and forest accessibility on a strategic level, terrain slope is the most critical field parameter that directly affects the selection of the harvesting system. This paper deals with terrain classification for forestry operations in the Republic of Croatia which expands across three central European biogeographical regions – Continental, Alpine and Mediterranean – and therefore has a very high level of forest diversity comprised of 11 out of 14 European forest types. Terrain classification was based on ten forest bioclimates where each was analysed regarding 1) slope classes, 2) soil erosion risk classes, 3) soil moisture regimes 4) terrain ruggedness index (TRI) and 5) ground obstacles – stoniness. The research was based on commercial state and private forests on totally 1,989,647 ha. Bioclimates were as follows:*

Subalpine dwarf pine forests
Subalpine spruce and beech forests
Mountainous fir, beech-fir and spruce forests
Sub-mountainous beech forests
Sessile oak forests of hilly terrain
Common oak and floodplain forests
Sub-Mediterranean mountainous beech and black pine forests

Sub-Mediterranean pubescent oak forests with hop-hornbeam
Sub-Mediterranean pubescent oak forests with oriental hornbeam
Mediterranean Aleppo pine and holm oak forests and maquis

Analysis showed various conditions in each bioclimate. The most commercial species in national forestry, such as common and sessile oak, beech and fir were accumulated in five bioclimates (2–5) and had specific terrain conditions.

Subalpine spruce and beech forests cover 34,232 ha of the researched area. Soil moisture regime is entirely automorphic, and 56.06% of bioclimate is on intermediately rugged terrain. 72.60% of bioclimate has 51–90% stoniness coverage on the surface and 60.91% of forests are on terrain slopes above 34%, while 27.13% of forests are on slopes above 51%. On 78.21% of the surface, there is a moderate risk of erosion.

Mountainous fir, beech-fir and spruce forests cover 185,762 ha of the researched area. Soil moisture regime is on 99.88% of the surface automorphic, and the most of the growing stock is on slightly and intermediately rugged terrain. The share of stoniness per surface is high whereas 56.82% of these forests contain 51–90% of ground obstacles. At 67.75% of the surface, terrain slope is above 21%, while the most growing stock (26.30% of area) can be found on terrain slopes between 34 and 50%.

Sub-mountainous beech forests cover 331,099 ha of researched area. Soil moisture regime is on 94.54% of the surface automorphic, and the highest share of the growing stock (101–400m^3/ha) is spread on a level, nearly level and slightly rugged terrain. Terrain ruggedness index showed slight changes regarding previously mentioned bioclimates and this change continues in term of ground obstacles. At 62.39% of the bioclimate share of stones on the surface is below 2%, however at 16.99% of forests stoniness is between 51-90%. Three slope classes prevail in these forests 1) terrain slopes between 11 and 20% at 75,891 ha of bioclimate, 2) terrain slopes between 21 and 33% at 100,874 ha of bioclimate and 3) terrain slopes between 34 and 50% at 79,822 ha of bioclimate. At 41.08% of forests risk of erosion is low, while at 54.29% the risk is moderate.

Sessile oak forests of hilly terrain cover 311,679 ha of researched area. Soil moisture regime is at 77.50% of the surface automorphic while at 22.07% of the area pseudogley soil types were found. Terrain ruggedness index shows that 71.63% of bioclimate is on level terrain and 74.58% of these forests contain up to 2% coverage of stones on the surface. Terrain slope ranges from 11–20% at 33.05% of the area and from 21–33% at 29.29% of forests, while 64,448 ha contain slopes above 34%. At 53.73% of the surface, soil erosion risk is low, but 39.82% show moderate erosion risk.

Common oak and floodplain forests cover 288,310 ha of researched area. The soil is highly influenced by the surface, underground and rainfall water and at 27.15% of surface amphigley soils can be found, at 26.70% of surface contain pseudogley soil,

while alluvial, epigleic, hypogleic and semigleic soil can be found at 29.61% of the surface. Analysis showed that 99.54% of the surface TRI is level without ground obstacles (99.54% of forests contain up to 2% share of stoniness). Terrain slope is at 92.84% of the area up to 10%, and at 97.83% there is a low risk of soil erosion.

Digital terrain model based on the input data will enhance planning of timber harvesting, forest accessibility (forest road route layouts) and stress the environmental aspect of given procedures in the highlight of terrain diversity, various stand conditions and different ways of forest management. The analysis was done on a national level, including almost 2 million hectares of state and private forests, of which 91.4% are commercial forests.

Keywords: terrain trafficabilty, bioclimates, planning, GIS

EVALUATION OF OPTIMAL CROSS-CUTTING METHODS FOR SINGLE-GRIP HARVESTERS IN CUT-TO-LENGTH WOOD HARVESTING OF BUTT-ROTTEN NORWAY SPRUCE STANDS

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Abstract:*The root and butt-rot fungus Heterobasidion annosum sensu lato (Fr.) Bref. causes severe damage to forests. When cutting butt-rotten forest stands by single-grip harvesters, it is extremely important that a decayed part of stem is cut away and the healthy log section of a stem is cut as much as possible to sawlogs. It can be presupposed that when a harvester operator cross cuts a lot of offcuts, stem processing time rises and cutting productivity reduces, while a sawlog removal and the production value of timber from the stand increase. The aim of the study was to develope the cut-to-length wood harvesting method by clarifying the optimal cross-cutting methods for diverse Norway spruce (Picea abies (L.) Karst.) stands damaged by butt rot. The time studies were carried out and the profitability calculations of the value of timber at a roadside were drawn up. The length of offcuts used was 50 cm in the study. Sounding of offcuts added significantly the stem processing time consumption of rotten spruce stems. Correspondingly, the avarage log percentages of the stems sounded were bigger, as well as the values of the stems sounded at roadside landings were higher than bucking the spruce pulpwood poles of 3 meters from the butt of rotten spruce stems. The calculations revealed that sounding of butt-rotten spruce stems with one to three offcuts is economically profitable if a diameter of butt rot on the surface of stump is small. On the other hand, when the diameter of butt rot is larger on the stump surface, it is more profitable to cross cut first a spruce pulpwood pole of 3 meters and after that to follow up the progress of butt rot in the stem.*

Keywords: *Heterobasidion annosum, decay, bucking, sounding, offcut, coniferous forests, Finland.*

SUPPLY POTENTIAL AND COST OF FOREST BIOMASS FOR THE SMALL AND LARGE-SCALE DEMAND SITES AT THE REGIONAL LEVEL IN FINLAND

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Abstract: Forestry digital systems are developing fast. Innovation in forest inventory, data transparency and software management are bringing the opportunity to make a significant decision-making and additional information for the forestry sector. During the last years, airborne laser-scanning has been utilized in Finland's forest inventory. Laser scanning forest data makes it possible to divide the source of wood by more accurate before cutting. In addition, the detailed data can be presented on the Internet applications, like the wood trade market service. The aim of the study was to determine how the results from forest airborne laser scanning can be utilised when analysing supply potential and cost of forest biomass to the corresponding demand sites at the regional level. The study scenarios were estimated for both small and large-scale industrial and energy demand sites. Supply potential of forest biomass was based on the latest laser scanning data, which was developed to separate alternative wood sources. The laser scanning results indicate the volume of roundwood and the forest energy potentials from small-diameter energy woods, stumps and logging residues. The cost of alternative timber sources was analysed for alternative demand sites at the regional level. There is willingness to use wood more extensively and precisely at the regional level for both small and large-scale user sites. By using airborne laser scanning method, the forest resources can be evaluated more effectively and more specifically for the forest owners and user sites point of views.

Keywords: forest biomass, supply, demand, laser scanning, cost

FITTING HEALTH AND SAFETY MEASURES TO NEEDS AND CONDITIONS OF ENTERPRISES

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Abstract: *Improving the health and safety situation in forestry is a permanent task for research, extension and advisory services, and enterprises. This is particularly true for micro and small enterprises that provideforest operations services. A concept to support enterprises to cope with their actual and individual health and safety challenges was developed by the interdisciplinary proSILWA team and is currently tested in Germany. It is a stepwise approach towards changing motivation, attitudes, values, behaviour, and work procedures aiming at establishing a more pronounced safety culture in forest enterprises. Based on a detailed assessment of the currenthealth and safety situation entrepreneurs and advisors embark on a dialogue to specify the individual needs for health and safety measures, to identify measures that will fit to the enterprise´s actual situation, and to prioritise activities.Measures that promise to be effective acceptable, and affordable are to be implemented. The key to success is that entrepreneurs act upon their own motivation and belief that the activities will be beneficial for the enterprise.*

Keywords: health and safety, micro and small enterprises, harvesting

1. Introduction

Improving health and safety in forestry isa permanent challenge for research, extension and advisory services, and forest enterprises. Even if reporting and statistics of accidents and work related illnesses is not satisfactory in many countries (Kastenholz 2014, Garland 2018) there is clear evidence that forestry work still ranges among the most dangerous occupations. The need to draw safety and health into the focus of research and extension is crucial since the situation in forestry has not sufficiently improved until today (Kastenholz et al. 2016). While extensive knowledge about accident and health risks, both in motor-manual and mechanized forestry work, exists and a comprehensive range of prevention measures are available (Kastenholz et al. 2017),in many enterprises the implementation of measures and actions to effectively improve health and safety is deficient. This is particularly true for the thousands of micro and small enterprises that provideforest operations services to forest owners and forest based industry companies. These enterprises are hard to reach and attract by academicexpertise, have limited management capacities,and have to cope with daily constraints by their operations and their economic situation (Kastenholz und Lewark 2005, Kastenholz et al. 2016). Recent inquiries in exemplary German enterprises show that they are often unable or unwilling to cope with the manifold technical, organisational and personal demands for a systematic implementation of health and safety measures that go beyond basic legal or contractual requirements. While entrepreneurs are generally well aware of the work-related risks there is considerable uncertainty of how and where to start with prevention activities (Kastenholz et al. 2017).

The project “proSILWA” was launched in 2016 with the goal of establishing safer and more health conscious work practices in micro and small forest service enterprises by drawing on exisiting evidence and measures available from different fields (Kastenholz et al. 2016). The project comprises an interdisciplinary team of forestry work scientists, psychologists and engineers who pooltheir knowledge and experience in order to develop a concept thatengages entrepreneurs in a process towards a more pronouncedhealth and safety culture. Results from the first project phase, which consisted of the analysis in twelve enterprises, were reported at the FORMEC Symposium 2017 (Kastenholz et al. 2017). The present paper will illustrate how research findings and methodology from the first project phase will be integrated in a consultancy concept and a business development process for micro and small enterprises.

2. Methods and process

2.1 Interdisciplinary approach

Health and safetyis the outcome of interrelated technical, organisational and personal measures that are applied in a specific situation of an enterprise and in specific operations. The analysis of each of these dimensions is subject to different academic disciplines and based on a variety of theories. In order to takea comprehensive approach to developinga concept for implementing prevention measures in forest enterprises,an interdisciplinary joint project was conceptualised. In the proSILWA team, forestry work scientists contribute their knowledge of the technical and ergonomic components of forest operations and related safety and health aspects. Psychologists focus on motivation, attitudes, and behaviour of entrepreneurs and workers, and work scientists with an engineering background provide a view on the organisation of the man-machine interfaces in forest operations. The diverse academic disciplines allow to assess the current situation and the specific prevention needs from multiple angles and contribute to a holistic image of the field in general and of specific companies.

2.2 Validated methods to assess the situation in exemplary enterprises

In order to understand potential deficits in health and safey and the resultingprevention needs, but also potential strengths and resources,the current situation in forest enterprises was assessed.Twelve enterprises from different regions in Germany were selected as a sample.These enterprises represent a wide range of activities and reflect the heterogeneousness of the contracting sector. The enterprises declared their willingness to cooperate throughout the project duration in analyses, field-tests of prevention measuresand in the evaluation of project results.

First, guideline -based in-depth interviews were conducted in all of these enterprises in order to assess the current status quo. The interview guideline comprised a wide range of topics that were compiled from elements of a variety of validated instruments, covering behavioural aspects, the organisation of health and safety, technical equipment, as well as the economical situation of the enterprise. The interviews were transcribed and run through extensive content analyses. This resulted in comprehensiveenterprise profiles for each individual company (see section 3.1).

2.3 Towards an effective prevention concept and a development process

The assessment of an enterprise´s situation and the illustrated presentation of the results form the basis for a mutual process by which entrepreneurs and consultants identify and implement prevention measures. Thereby a continuous improvement process is initiated towards an enhancedprevention culture in forest enterprises.

3. The proSILWA concept

The proSILWA concept is based on the assumption that forest entrepreneurs need support and advice to improve safety and health in their enterprise and in their daily operations. This was confirmed by the interviews with twelve exemplary entrepreneurs. While an awareness for health and safety risks generally exists, there is a considerable lack of implementation of appropriate measures to cope with these risks.

Furthermore, the concept acknowledges that each enterprise differs in terms of technological standards, competences,and attitudes of the entrepreneur and employees, economic constraints, relation to customers, and many other factors which drive or hinder effective prevention (see Kastenholz et al. 2017 for more details).Since micro and small enterprises generally lack management capacities and operate under severe time constraints, prevention activities need to be prioritised and implemented according to current needs and they must be appropriate to suit the specific situation of the enterprise. This leads to the core idea of the proSILWA concept: Prevention measures will only be effective and durable when they are implemented by the entrepreneur himself. This requires, that the entrepreneur understands how a specific measure will lead to benefits in terms of lower accident risks, better health for himself and the employees;

is motivated to actively engage in prevention activities;
is willing to communicate with his co-workers in an open and transparent manner;
is ready to spend time and financial resources on one or more measures;
considers prevention as a permanent task, and acts accordingly.

Based on these presumptions the proSILWA concept has been designed as a step-wise approach.

It starts with an assessment of the current health and safety situation and organisation in the enterprise.

Results of the assessment are communicated with the entrepreneur in a face-to-face dialogue.

The entrepreneur decides on prevention measures to be implemented, either with the support of a consultant or single-handedly (depending on the entrepreneur's decision).The effectiveness of a prevention measure is evaluated and evaluation results will lead to an updated prevention plan.

3.1 Assessment of the safety and health state of art

The first step of the proSILWA concept is a comprehensive assessment of the situation a specific enterprise currently operates in, of relevant physical and psychological risks, as well as of measures that are already being taken and their respective effectiveness. This initial step also comprises an evaluation of resources such as individual competences, motivation for change and job satisfaction. In the proSILWA project the assessment was carried out with a guideline-based interview (see section 2.2). The resulting content was extensively analysed qualitatively. In this pilot phase, findings were clustered in 13 analytic areas which could be allocated to the four commonly known dimensions of prevention: Technology, Organisation, Person and Situation (TOP-S).

In the *technology* dimension, the main focus is on the condition and ergonomics of the technical equipment and the willingness to invest in technical purchases and maintenance.Research aspects regarding the *organisation* are aimed at various topics that can be organised in the company in a certain way. This generally includes operational organization, but also occupational health and safety as well as company health promotion and operational mobility.With regard to the *person*, motivation and attitudes of employees and managers was analysed. In addition to job qualification and technical expertise, knowledge about issues of occupational health and safety and the practice of safety-conscious behaviour were relevant in this aspect. Moreover, the styles of management and communication in the company were assessed.In addition to these three topics, the *external situation* was assessed drawing on situational factors outside the company. These included communication with various external actors (e.g. clients, employer's liability insurance association, visitors to the forest) as well as economic conditions with regard to order volume and personnel recruitment, but also demographical factors and absence of illness.

In an expert rating carried out by the project team a score was assigned to each of the 13 areas. To assign the value 1 for one area would imply that no additional action would be needed – the task of the entrepreneur would be to maintain and consolidate the status. A value 5 reflects that the assessment indicates a crucial deficit in this area which requires immediate action.

The results of the assessment are illustrated in a spider-web, which shows at first glance where an enterprise's strengths or deficits lie. The illustration is shown in Figure 1 where - for the sake of example - the average values from twelve enterprises are displayed.

Figure 1: Illustratingtheassessment of the respective current situation in a forest enterprise (data represent the average of the score from 12 enterprises)

3.2 Dialogue to define prevention needs and potential activities

The second step is to feed back the assessment results to the entrepreneur. In the pilot phase this was done with an "enterprise profile", a written report containing the results of the analysis as well as the spider-web illustration. This was followed by a face-to-face dialogue of the entrepreneurs and an interdisciplinary project team of two to three. The dialogues in all twelve enterprises confirmed that for working with forestry contractors it is of utmost importance to discuss the results in extensive face-to-face conversations, even if the authors of the enterprise profiles took good care to write the report in a clear and straight language.

Using the spider-web illustration as a starting point for the dialogue has proven to be effective. The initial question "does this picture reflect your own impression of the situation in your business" led to an immediate and broad discussion about prevention needs with almost all of the participating entrepreneurs. In the course of this discussion it became clear that nearly all entrepreneurs participating in the pilot process found their own situation to be reflected accurately in the illustration and the enterprise profile.

This dialogue resulted in an agreement to initiate subsequent activities. Confirming the presumption that each enterprise has individual actual needs and an individual motivation to initiate prevention activities, different activities were planned for each enterprise. Measures taken were, among others:

carrying out a moderated health and safety workshop with all company members;

introducing safety equipment, such as radio-equipped helmets ;

providing fitness sports to cope with work-related physical strain;

conducting specific hazard assessments;

convening a meeting with clients to overcome safety related communication deficits between contractors and foresters.

3.3 Implementing prevention measures and evaluating the effectiveness

Supported by the project team, the enterprises participating in the pilot phase have started to implement the activities that were defined and agreed upon in the feedback dialogues. Since the project is still ongoing at this stage it can only be reported that all entrepreneurs involved in the project are keen and motivated to improve their efforts towards better health and safety.

3.4 Continuous development towards a safety culture

The goal of the proSILWA concept is to initiate a continuous development process towards a more pronounced culture of prevention in forest enterprises. This development circle, which is derived from widely-used quality management models, dictates that effective and durable prevention measures require permanent reflection and updates of action plans by the parties involved (Figure 2).

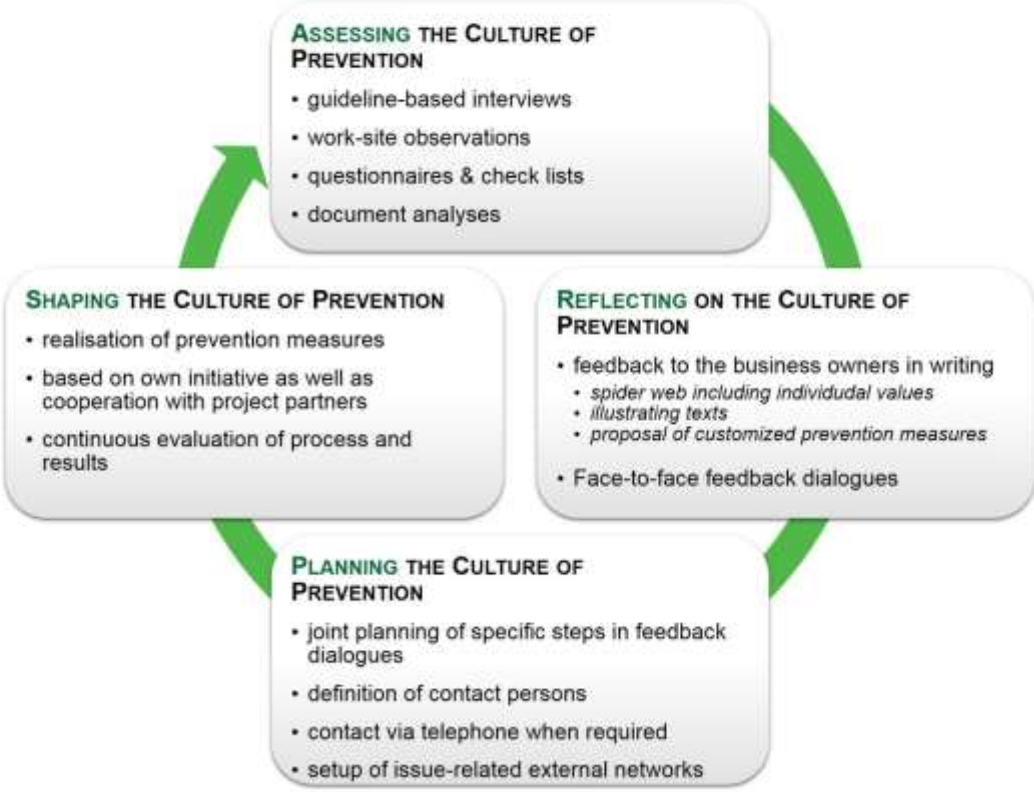

Figure 2: Continuous process towards a culture of prevention in forest enterprises

4. Conclusions and Outlook

4.1 Meeting actual and individual demand

The recent proSILWA project activities provide evidence that forestry entrepreneurs are motivated to implement prevention measures if they understand the general need to do so, if they recognise particular existing deficits and strengths, and if they are aware of regulatory requirements.External advice and support in identifying the most appropriate and best suitable prevention activities is a major supporting factor in order to initiate improvements.

4.2 A concept to reach micro and small enterprises

First evidence indicates that the concept presented in this paper meets the culture of the forestry service sector and the acceptance of forest entrepreneurs. A neutral assessment of the actual specific situation, a dialogue based on transparently reported assessment results, and last but not least a concept that aims at providing entrepreneurs with ownership of the activities, promises that prevention measures which have been identified and implemented in this process will be effective and durable. Forthcoming comprehensive evaluation studies will show whether this expectations will be met. However it can be stated that the key to success is that entrepreneurs act upon their own motivation and belief that the activities will be beneficial for the enterprise.

It should be emphasised that the core element of the proSILWA concept is communication. From the pilot phase, it is evident that there is a demand for more and better focused communication about health and safety needs within enterprises but also between enterprises and other actors of prevention. Therefore, the consultancy process needs to facilitate an open and trustful exchange that is prioritised on health and safety, and aims at actions thatlead to an improved prevention culture.

4.3Involve intermediaries

As stated before, forestry entrepreneurs need support in identifying prevention needs and appropriate measures, as well as in implementating prevention measures. Researchers and consultants, or consulting researchers, can moderate this process, like the proSILWA team demonstrates with it's project activities. But the implementation of a variety of prevention measures needs expertise which is available from various actors. For instance, technical measures can be implemented with the expertise of manufacturers, equipment traders, but also of institutions that test equipment, machinery and processes, like the KWF in Germany.

In addition to that, further actors are involved in prevention whohave a keen interest and/or an official role in improving safety and health in forestry.

In Germany, an important actor and partner in the process is the statutory accident insurance for agriculture and forestry (SVLFG) which has an official mandate for fostering prevention in the forestry sector.

Other actors are organisations that issue contractor certificates, like the proSILWA partner GGWL. Since they audit, among other criteria, the safety and health status in enterprises, this opens the opportunity to facilitate raising awareness for prevention needs and support the initialisation of a prevention process.

Contractor associations can facilitate the process by communication and raising awareness for the need of prevention.

The current task in the proSILWA process is bringing together these and other actors to define a mutual strategy for disseminating the proSILWA results and encouraging the widest possible incorporation into the forestry service sector.

4.4 Next steps to make proSILWA fit for a wide outreach

The project team is well aware that the methodology used in the pilot phase, consisting of in-depth guideline-based interviews and content analyses, followed by a series of dialogues will hardly be affordable for enterprises because of the high time demand. This procedure was ideal to pave the way for designing the concept using public funds but a wide application in the sector requires a more time efficient methodthat delivers the same quality of results. Therefore, the challenge for the proSILWA team now is to reduce the initial assessment and analysis effort for setting up the enterprise profile, so that this method can be widely applied in forestry practice.

The main conclusion from the first tests with exemplaryentrepreneurs in Germanyis thatthe proSILWA conceptis promising to pave a way towards an effective safety culture in forestry.

Acknowledgements

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HARVESTER ON-BOARD COMPUTER DATA – HOW CAN WE USE IT TO IMPROVE THE FOREST SUPPLY CHAIN IN GERMANY?

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Abstract: The on-board computer (OBC) of a harvester collects an immense amount of data concerning machine and engine performance as well as parameters of the harvested wood and machine positioning. The integration of this information shows great improvement potential of the forest supply chain in northern Europe. Conversely, due to the expanding use of close-to-nature forestry, more complex and multi-species stands are being managed in Germany. Because of the forest restructuring, the number of assortments is often increasing, while at the same time the volume per assortment is decreasing, thus ultimately making the planning effort more intricate. Operationally, this can add to further complications throughout the forestry supply chain, particularly when considering the different ownership structures. This complications can be further enhanced in the case of the most unsystematic and varying supply chains of the Forest owner associations.

In an attempt to address these shortfalls, the objectives of this study are to develop an information logistic process with the continuous and integrated use of harvester data to improve the efficiency of the Bavarian wood supply chain. Additionally, an economic evaluation system will be developed for the entire supply chain to increase decision-making capability for varying sizes of forest properties and enterprises as well as ownership structures. Finally, the newly created information logistic process will be validated in target enterprises with different structures.

To achieve these objectives, the current processes used at two differently structured companies (Bavarian State Forest Enterprise, Association of forest owners) will be described by expert interviews and workshops through business process reengineering. Particular focus will be directed at the following questions: Which stakeholder measures which data and what are the associated costs? What is the data flow, what does it entail, who are the parties involved and when does the transfer occur? Are there any deficits concerning the data availability? These processes will be shown as a model in data flow and activity diagrams using the

unified modelling language (UML) and the software ARIS BPM. Key performance indicators, relevant for the corporate management, will then be determined. Considering the findings from the analysis of the current processes and corresponding areas requiring improvement, target processes will be developed with the aid of simulation models and economic analyses. All stakeholders will be involved to achieve higher acceptance. In this phase of the project, the main questions are: Which data requirements can be fulfilled with harvester data? What do the interfaces between stakeholders present? How can the processes be downsized through the use of harvester data? What are the areas of tension between the stakeholders stemming from the changed processes and how can those be minimized? Subsequently, a multi-criteria decision analysis will occur to balance and rate the redesigned processes. Lastly, target processes will be implemented in enterprises to directly compare the theoretical and practical results. The relevant questions are: Are the economic effects of the simulation analysis similar to the ones we observed in practice? Are the best practices available in the literature applicable for forest supply chains?

Despite the early stage of the research project, we anticipate efficiency improvements of Bavarian forest supply chains. Main reasons for the improvements are hypothesized to be linked to costs savings and lower risks due to shortened lead-time, organizational improvements and more intense market and customer orientation. Overall, we expect a significant potential of harvester data integration in German forestry.

Keywords: harvester data, OBC, data integration, business process reengineering

DETERMINING CONDITIONS FOR REPLACING FOREST VEHICLES USING CASH FLOW ANALYSIS

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Abstract: *Previous research suggests that forestry practitioners, from both state and private companies, often approach replacement of existing forest machinery without prior business decision-making or without establishing economic criteria. As one of the main reasons for not conducting an analytical procedure of justification for machinery substitution is complex theoretical and practical approaches and mathematical procedures whose acceptance and implementation is not simple. Therefore, the procedures described and applied in this paper are considered more acceptable to practitioners in the process of replacing forest machines, assuming the disposal of relevant data and information. This paper presents the process of analysing the cash flow and the application of the capital budgeting method, i.e. the method of financial decision making: pure current values, internal rates of profitability, period of return and discounted period of return in determining the justification for replacing an old forest machine or acquisition of a new asset.*

Keywords: forestry, replacement of machines, capital budgeting, cash flow

1. Introduction

An essential prerequisite for successful forest management is investments or investment projects. Investments in replacement of existing assets are related to the existing business of the company (entrepreneurs). Deciding to replace the basic asset in use with the new underlying asset is often in the economy, and the cause of these investments is the economic and physical impairment of long-term assets.

Replacement is a specific form of an investment project and it can be considered when a particular asset is diluted or when it can still ensure the achievement of positive cash flows. In the first case, there will often not be an alternative investment solution. In the second case, the decision maker considers the replacement of equipment or other assets that can still generate positive current cash flows but can be replaced by more efficient equipment. Generally speaking, the company is an important factor in decision-making and determining the time of substitution (Orsag and Dedi 2011).

Numerous models of substitution theory have been developed so far (Mathew and Kennedy 2003, Jardine and Tsang 2006, Park 2007, Yatasenko and Hritonenko 2011, Mardin and Arai 2012, Fan et al. 2013, Šebo et al., 2013, Ansaripoor et al., 2013, Sahu et al 2016, Al-Chalabi dr. 2015a, 2015b), while the review of the model for the replacement of machinery and equipment in forestry is detailed explained in Cantu et al. (2017).

The basic approach for replacement is based on the assumption that there is no technological change over an infinite horizon, therefore, there is no technological difference between the old and the new machine and that by using it, the operating costs and maintenance costs will increase. On the other hand, capital cost or ownership cost, which is related to the purchase price, installation cost and residual value, with time will decrease. Thus, the values (functions) of the mentioned costs move in the opposite direction (Figure 1). In fact, the time (year or month) in which the total cost reaches the minimum is defined as the optimal time of replacement i.e. as an economic life of an asset – EL method (Jardine and Tsang 2006, quoted in Ansaripoor et al., 2013, Al - Chalabi et al., 2015a, Al-Chalabi et al., 2015b).

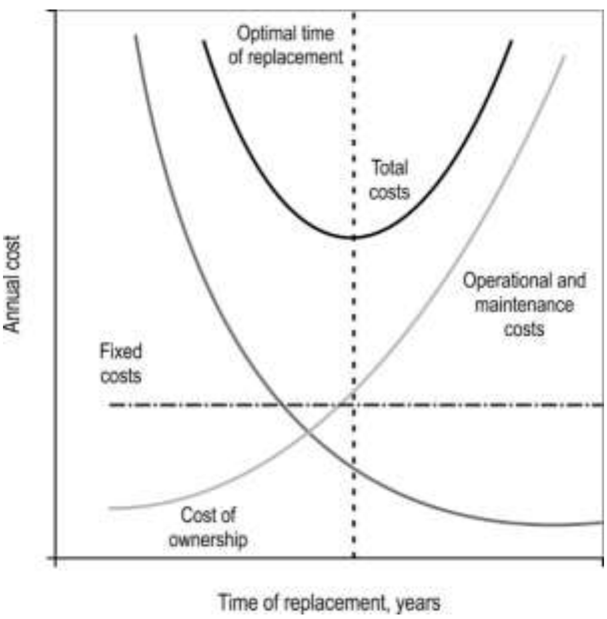

Fig. 1. Optimal time of replacement according to Cantú et al. (2017)

Despite the existence of a relatively large number of approaches, according to available literature in forestry, when replacing machinery, they are not applied to the appropriate extent (Baxter et al. 2010, Spinelli et al., 2011a and 2011b, Elliasson 2016, Cantu et al. 2017). Reasons are multiple, but it should be noted that in the above-mentioned papers, authors use theoretical and/or actual data of vehicles and equipment, often applying complex procedures. Therefore, despite the availability of certain data and information, practitioners in the process of decision making have difficulties with the application of complex methods and models (Al-Chalabi et al. 2015a, Klobučar 2018).

Some authors (Sullivan et al. 2002, Mathew and Kennedy 2003) present the method of applying net present value in the decision-making process of substitution. Mathew and Kennedy (2003), based on cash flow analysis, develop a comprehensive NPV (Net Present Value) model for optimum replacement of equipment. The model encompasses several factors, such as technological changes, rising maintenance costs due to equipment ageing and inflation. Hartman (2005) further analyses and extends of the NPV model. In the selection of the equipment methods of attributive decision making, the analytical hierarchical process (AHP) and PROMETHEE are also in use (Dağdeviren 2008).

It is considered that financial decision-making procedures may be acceptable to the practitioners given the requirement and availability of information and the complexity of the calculation. The aforementioned confirms the research of Eliasson (2016) for Swedish forest companies where 55% of entrepreneurs carry out the assessment of the purchase of a new machine, and evaluate before buying by using different financial methods: payback method 12%, net present value method (NPV) 25%, the annuity method 10% and other methods 53%. This paper aims to present a case for determining the justification for replacing a forestry machine by comparing cash flows and applying the rules for capital budgeting.

2. Materials and Methods

2.1 Cash flow of investment project

Cash flow is a financial category, and the project's cash flow estimate is the most challenging part of the economic analysis process because the cash flow is the basis for the assessment of all financial elements of the project (Orsag and Dedi 2011). For this, it is essential to evaluate for each investment project separately, in particular, the future possibilities of production and sales, future selling prices, as well as all costs associated with earning revenue for each investment project. It is relatively easy to find that some machine is, for example, more productive than the other, but the difficulty is that this statement cannot be expressed simply and reliably in the form of an appropriate sum of revenue and costs, because the revenues and costs depend on from a variety of other circumstances, not just from the technical properties of basic resources (Babić 1973). For the investment decision on replacement two streams of cash flow appear, i.e. cash flows of old and cash flows of new equipment or cash flows of some other asset. In this way, the value of the asset being replaced, its accounting value as well as its potential liquid cash flows are the financial decision-makers and analysis of incremental cash flows. Precisely because of the existence of two characteristic forms of cash flows, this form of investment project comes with a full expression of the possibility of alternative use, tax savings as a factor for increasing the cash flows and the time value of the money. The replacement decision itself must be based on cash flows after tax. For financial quantification of replacement, it is necessary to determine the level of investment costs, the pure cash flows resulting from the replacement and the residual value of the equipment replacing the existing equipment. Only determining cash flow substitutions is the result of confronting the cash flow of existing and new equipment (Orsag and Dedi 2011).

As a result, the cash flow of the investment project can be seen as a sum of three components: the initial cash flow (Int), the cash flow from the regular business operation (RPnt) and the final cash flow (Knt) (Figure 2).

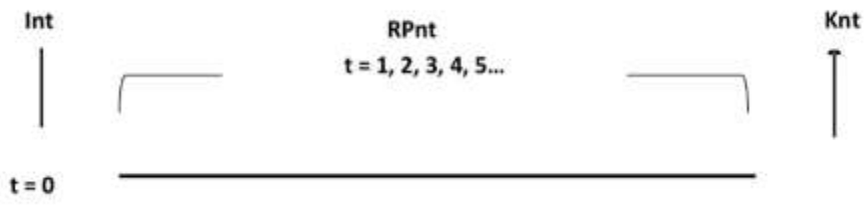

Fig. 2. Cash flow of investment project

Initial Cash Flow (Int) refers to initial investment in machinery and equipment (expression 1), equity investment, a sale of existing equipment and sales tax effect. In this period, the most important are investment costs.

$$Int = Io - So - (-DOK) \quad (1)$$

$$So = TVA - (TVA - KVA) * P(\%) \quad (2)$$

Io - Initial investment, So - Old machine sale (after tax), DOK - additional working capital, TVA - market value of old machine, KVA - book value of an old machine, P - Income tax (18%).

The difference between current cash receipts and current cash inflows during the impact of an investment project is called liquid cash-flow during regular business operation - RPnt (expression 3). Cash flow from a regular business can be calculated according to several methods (Brealey et al., 2007).

$$RPnt = (\Delta PP - \Delta T - \Delta Am) * (1 - P) + Am \quad (3)$$

Δ - Difference in the amounts of economic elements, PP - planned revenues, T - market value, Am – Depreciation, Income tax (18%).

The final cash flow (Knt) refers to the sale of long-term assets (expression 4) i.e. residual value, reimbursement of working capital, sales tax effect and other cash outflows and receipts related to the closure of the project. At the end of the effective period implementation of the investment project, fixed assets with a certain liquidation value or with the possibility of alternative use remains. Also, with the termination of the effects, it results in the release of net working capital or the creation of free cash funds of the company (Orsag and Dedi 2011).

$$Knt = Po + DOK \quad (4)$$

$$Po = \Delta R - (P\% \, (\Delta R - \Delta KV)) \quad (5)$$

Δ - Difference in the amounts of economic elements, Po - sales of post-tax equipment, DOK - additional working capital, R- residual value at the end of the project, KV - accounting value

The total cash flow of an investment project - Ntp is calculated by expression 6:

$$Ntp = \text{Int} + \text{RPnt} + \text{Knt} \quad (6)$$

The analysis of cash flows is carried out by analysing the original cash flows and by analysing discounted cash flows. It is more appropriate to analyse cash flows taking into account the time value of the money. Original cash flows can only be taken as a factor in considering the project's ultimate risk that it will not return the money invested during the course of the operation, i.e. through which time the money will be returned. Due to the time value of money, the best effect is cash flow that is dominated by the beginning and the weakest which is dominated by the end of the effecting period (Orsag and Dedi 2011).

2.2 Capital budgeting

Decisions on long-term (capital) investments, primarily in real-estate business, are made in the capital budgeting process, while the capital budget represents a feasible cash investment. Capital budgeting rules imply criteria based on which projects are accepted or rejected. Criteria are the results obtained through the application of financial decision making methods. The method of net present value and the method of internal rate of return are two basic methods of financial decision making.

Net Present Value is the fundamental criterion for financial decision making. The term "present" refers to the fact that all effects need to be reduced to their present value in order to be comparable in time. This is done by a discount technique where the discount rate represents the cost of the company's capital. The size of the present value is highly sensitive to the discount rate to calculate the present value of the cash flows. The use of more discount rates reduces the size of the present value of the project, while applying a lower discount rate increases the size of the present value of the project. According to the net present value criterion, the investment project is better with a higher net present value (Orsag and Dedi 2011).

Calculation of net present value (expression 7) is carried out in three steps:

1. Calculation of the net present value of expected cash flows throughout the project implementation lifecycle

2. Adding discounted cash flows throughout the entire project implementation period

3. Determining the net present value by subtracting investment costs from the sum of the present value of cash flows throughout the project implementation period.

$$So = \sum_{t=1}^{T} \frac{Vt}{(1+k)^t} - Io \qquad (7)$$

So – net present value, Vt – Discounted Cash Flow Through Years, Io - Investment Costs

The discount rate at which the net present value is equal to zero is called the Internal Rate of Return (IRR) or the return rate to the discounted cash flows (expression 8). This is a discount rate that reduces the net cash flows of the project throughout the entire year to affect the value of its investment costs (Orsag and Dedi 2011).

$$\sum_{t=1}^{T} \frac{Vt}{(1+R)^t} = Io \qquad (8)$$

R - Internal Rate of Profitability, Vt - Discounted Cash Flow by Years, Io - Investment Costs

The payback period is the simplest criterion for financial decision making on real investments. The return period is the number of periods, usually years, in which the money invested in the particular project will be returned. Because of its simplicity, this method is often in practical use. The discounted payback criterion is the method of a recovery period in which the deficiency is eliminated without considering the time value of the money.

2.3 Data

The paper uses the values of the economic elements of the old and the new machine that correspond to the current economic circumstances of decision making in the replacement of a Hittner Ecotrac 120V winch skidder in the state company Croatian forests Ltd. In determining the amount of operating costs (fuel and oil), data from the informational-telecommunication system for remote monitoring of the vehicle were used. The cost of maintenance (internal and external work, spare parts), salaries, as well as income amounts were taken from the accounting records. These data are integrated into the accounting system for monitoring revenues and costs of each vehicle.

Table 1. Comparative data of the old vehicle (defender) - A and the new vehicle (challenger) - B

Economic elements for the calculation of justification of substitution	Old vehicle –	New vehicle –
Market value – TV, €	20,353	115,332
Accounting value – KV, €	0	115,332
Planned revenues – PP, €	37,856	46,676
Costs: operating, maintenance, salary – T, €	31,615	32,700
Depreciation 10% - A = TV × 0.10, €	0	11,533
Residual value at the end of the project – R, €	1,357	20,353
Accounting value at the end of investment period –	0	0
Repair in the fifth year of the investment project, €	40,706	0
Additional working capital – DOK, €	0	
Income tax – P, %	18	
Average cost of capital – WACC, %	4	
Duration of the Investment Project - Effective Period,	10	

3. Results

Based on the difference in cash flows between the old and the new skidder, the amounts for the initial cash flow, the cash flow from the regular business, the final cash flow and the total cash flow were calculated. Table 2 shows the total cash flow of the project used in the calculation of the financial decision-making criteria (Table 3): net present value (NPV), internal rate of return (IRR), discounted return period (DRP) and return period (RP), on the basis of which projects are accepted or rejected and decisions on substitution, are conducted.

Table 2. Total cash flow of the project

Total cash flow of the investment				Discounted cash flows of the			
Year	Ntp	€	Cumulative	Year	Ntp	€	Cumulative
0	Int	-	-98,643	0	Int	-	-98,643
1	RPnt	7,305	-91,338	1	RPnt	7,024	-91,619
2		7,305	-84,033	2		6,754	-84,865
3		7,305	-76,727	3		6,494	-78,370
4		7,305	-69,422	4		6,245	-72,126
5		40,684	-28,738	5		33,439	-38,687
6		7,305	-21,433	6		5,773	-32,913
7		7,305	-14,128	7		5,551	-27,362
8		7,305	-6,822	8		5,338	-22,024
9		7,305	483	9		5,133	-16,891
10	Knt	22,882	23,365	10	Knt	15,458	-1,433

From the financial decision-making criteria (Table 3), according to the mentioned economic elements, it can be concluded that it is not acceptable to replace the old skidder A with the new skidder B. According to the net present value criterion, the investment project is more acceptable with higher value. In this example, the net present value is negative, -4,433 €, suggesting the unacceptability of the investment project. The internal rate of return, the discount rate at which the net present value is equal to zero, is at 3.73%. The assumed cost of capital is 4%. The return period, in this example, is 8.93 years. So, the investment project is at the very limit of eligibility.

Table 3 Criteria for financial decision making

Net present value, €	- 4,433
Internal rate of return, %	3.73
Discounted return period	Out of the duration of the investment project, is
Return period, year	8.93

For the purpose of analysing the financial model, a sensitive analysis was applied in the example of net present value. In the first case, with respect to the basic calculation (Figure 3), the value of the economic elements of a new skidder (B) was increased and decreased by 10%, 25% and 50%. Changeable economic elements of a new skidder such as market value, depreciation of annual income and expenses and discount rate. Thus, the effect of changing the value of an economic element (variables) on the net present value is observed, while the value of other economic elements is constant, equal to the initial values. The increase and decrease of the net present value are expected, depending on the positive or negative percentage changes of the individual economic element of a new skidder. Regardless of the expected results, the model sensitivity analysis is a useful approach as it clearly indicates to what extent (change) it is necessary to influence an individual economic element in order to make the investment project of substitution more positive regarding the net present value and vice versa.

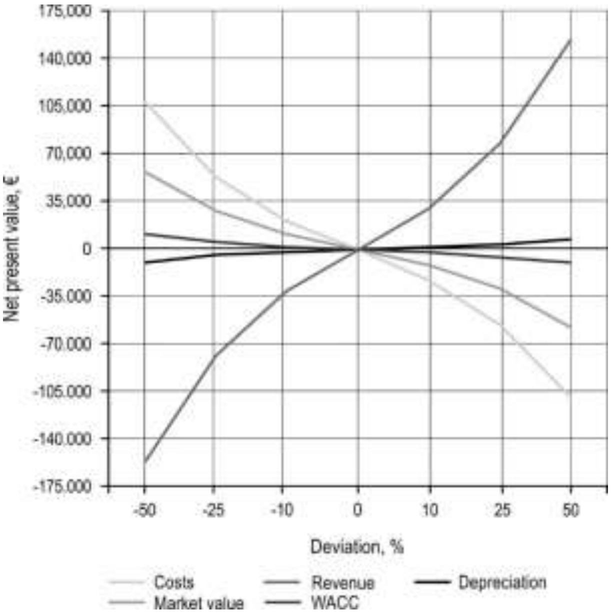

Fig. 3 Sensitivity analysis of the investment project

In the second case, two scenarios were created and the movement of net present value is shown as:

Changing revenue of an old and a new skidder (Table 4)

Changing the cost of an old skidder and changing the revenue of a new skidder (Table 5).

Table 4. Scenario I – Movement of net present value

	The revenue of a new skidder								
			-50%	-25%	-10%	0%	10%	25%	50%
	Deviati	-	23,33	35,00	42,00	46,67	51,34	58,34	70,01
The revenue of	-50%	18,9	-	46,84	93,41	124,4	155,5	202,0	279,6
	-25%	28,3	-	-	30,46	61,51	92,55	139,1	216,7
	-10%	34,0	-	-	-7,299	23,74	54,78	101,3	178,9
	0%	37,8	-	-	-	-1,433	29,61	76,17	153,7
	10%	41,6	-	-	-	-	4,433	50,99	128,6
	25%	47,3	-	-	-	-	-	13,23	90,84
	50%	56,7	-	-	-	-	-	-	27,89

Table 5. Scenario II – Movement of net present value

	The revenue of a new skidder								
			-50%	-25%	-10%	0%	10%	25%	50%
	Deviati	-	23,33	35,00	42,00	46,67	51,34	58,34	70,01
The costof	-50%	15,1	-	-	-	-	-	-	53,16
	-25%	22,6	-	-	-	-	-	25,86	103,4
	-10%	27,2	-	-	-	-	9,487	56,05	133,6
	0%	30,2	-	-	-	-1,433	29,61	76,17	153,7
	10%	33,2	-	-	-	18,69	49,73	96,30	173,9
	25%	37,8	-	-	17,83	48,87	79,92	126,4	204,0
	50%	45,3	-	21,57	68,14	99,18	130,2	176,7	254,4

In the second case for the above mentioned two scenarios, the movement of net present value is expected, but the sensitivity analysis is more complex here, as it suggests that simultaneous positive or negative percentage changes of two economic elements affect the net present value of the investment project.

4. Discussion

The goal of investing in return is to maintain production capacities as well as to be more efficient with fixed assets to increase companies' profitability. The long-term impact of investment decisions or investment projects on the business and development of enterprises (entrepreneurs) as well as the amount of funds spent during the investment and implementation period are reasons that require serious approach and appropriate analysis prior to investing (Klobučar 2018).

Investments in replacement of existing machinery, vehicles and equipment or in replacement of existing real estates are necessary during business operations because they are the cause of economic and physical shortcomings of existing fixed assets. These are necessary interventions to ensure the earning power or profitability of an enterprise that suits the interests of its owners. Investments in exchange may also be the result of companies' attempts to increase their profitability through more efficient fixed assets. Most often, they will typically be characterised by a combination of swapping overpriced property assets and the expected increase in profitability of a company, as well as increasing its market value (Orsag and Dedi 2011).

Furthermore, it should be taken into account that in forestry, many times, replacement of machinery and equipment is done without previous business decision-making or validating economic or other criteria. For example, in seeking optimum decision-making, forest entrepreneurs in Canada rarely use patterns of replacements found in the literature. In this sense, machine owners apply two different philosophies: the acquisition of new resources at shorter intervals to maximise the opportunities and minimise maintenance, versus moderate use with significant maintenance for the purpose of prolonging useful (economic) life of machinery (Cantu et al., 2017). The first has low operating and maintenance costs, but high capital investment, while the possession of older assets increases costs. Premature or late decisions for machinery and equipment replacement can cause financial losses in capital return or increase operating costs (Klobučar 2018).

5. Conclusions

From the available literature, a large number of papers have been identified regarding decision support investments as well as the determination of the optimum time of machinery and equipment replacement. Authors use theoretical and/or actual data to monitor the operation of machines and equipment, often applying complex procedures that practitioners in the decision-making process often find difficult to follow. Therefore, this paper deals with the rules of capital budgeting and methods of financial decision making in the process of machinery and equipment replacement in forestry. These rules can be considered as an easy-to-use tool in the decision-making process. In applying the capital budgeting rules, based on the analysis of the cash flows of the old and the new basic asset (the future potential production unit), these criteria of financial decision making were used: net present value, internal rate of return, discount rate and return rate. The case study shows a complete model for determining the justification of a vehicle in this example a skidder, substitution for practical use in forestry operations.

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A NEW METHOD TO COMPUTE MECHANICAL PROPERTIES OF A CABLE ROAD SKYLINE.

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Extended abtract

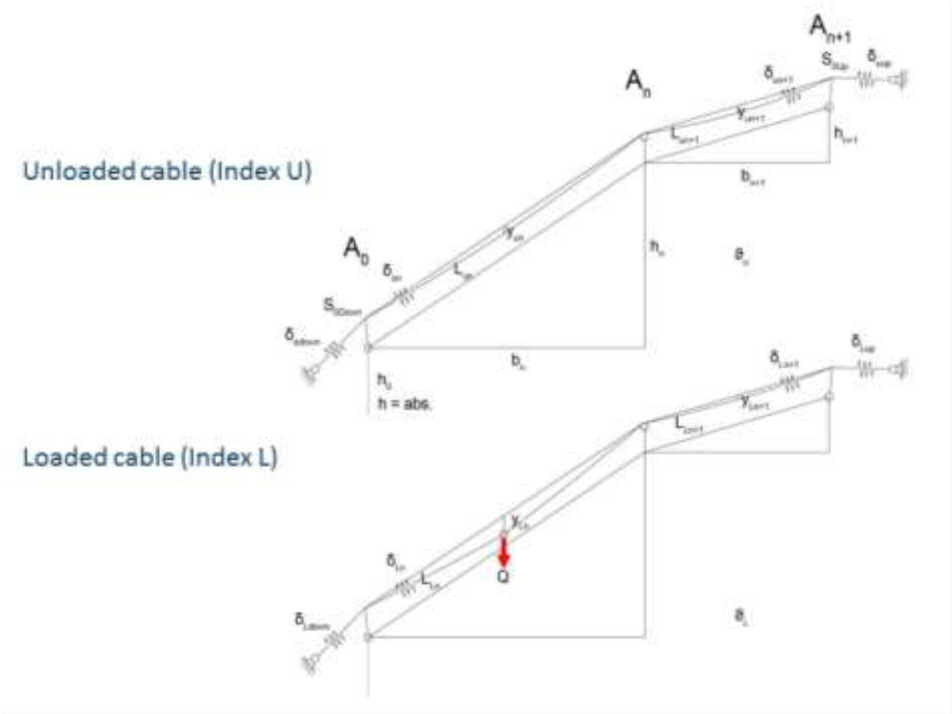
Cable-based technologies is a backbone for harvesting on steep slopes - and more and more on impassable lowlands stands with sensitive forest soil.

The planning process of any single or multi-span cable yarding is essential for a safe, effective and environmentally careful operation. The design of the geometric layout of a skyline has to be adapted to: the terrain profile in that way to get a minimum of intermediate points, an easy and quick set up and to ensure a minimum distance between carriage and ground. For that, the exact detecting and computing of the properties of the skyline, e.g. the load path in reference to the ground profile, the tensile forces of the unloaded and loaded skyline, the maximum load of the carriage and the impact of changes of the surrounding temperature is a challenging task.

Linear assumptions [(Pestal 1961), (Feyrer 1994)] are popular in the field, but qualified not enough to calculate any corresponding variables on both-sided-fixed spans.

The determination of the both-sided-fixed elastic catenary requires dealing with non-linear cable mechanical assumptions, especially with the impact of lateral forces. However, there are several approaches, which are proposing ways to get practical solutions [(Zweifel 1960), (Czitary 1961), (Irvine 1981), (Skyline XL 2018)]. However, all those approaches are still based on simplifications (linearising of non-linear relationships, different approaches for approximations) and mainly designed to solve standard problems with numerical methods. All them are more or less \`near to catenary\`, meanwhile the difference to the exact catenary remains as unknown. Even the stepwise calculation of corresponding variables means a failure of unknown extent.

We present a new approach that is based on catenaries, fulfilled a non-linear equation system specified by several boundary conditions.



Picture 1: Declaration of the used variables: S: tensile forces in kN; Delta: elastic elongation in m; L: Length of the catenaries in m; y: sag of the catenaries in m; Theta: temperature in °C; b: wide of the span n in m; h: altitude of span n in m.

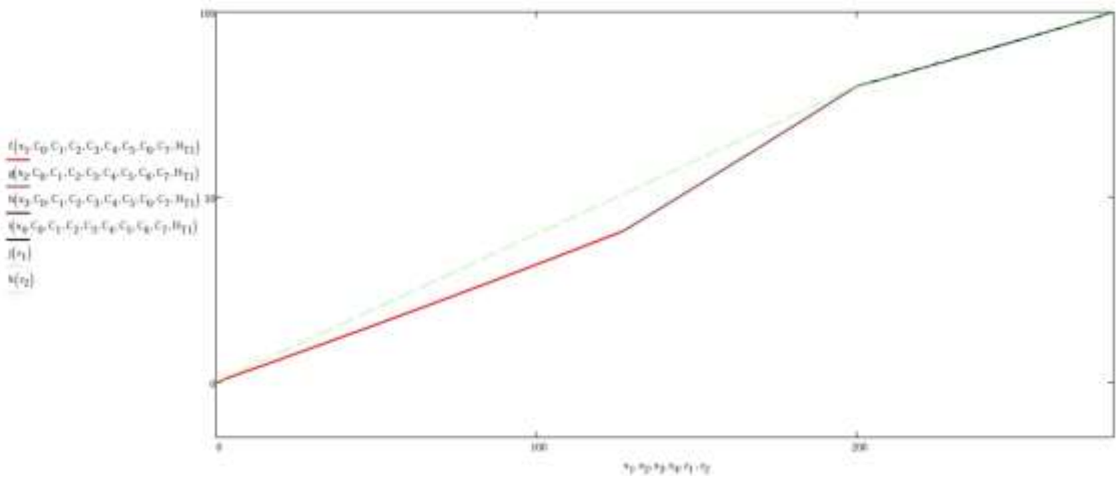
The catenary has the shape of

$$f_n\left(x, C_{n1}, C_{n2}, H_{Tn}\right) = \frac{H_{Tn}}{q_0}\cdot\cosh\left[\frac{q_0}{H_{Tn}}\cdot\left(x + C_{n2}\right)\right] + C_{n1} \quad (1)$$

where x is the horizontal position alongside the span n, C_{n1} and C_{n2} are constants of integration, H_{Tn} is the horizontal part of the tensile force of the skyline in kN and q_0 is the weight per meter in N/m.

By using this new approach, it will be possible to get an exact analytical solution of the shape of any multi-spanned catenaries and their internal forces considering stretch, temperature and elasticity, the elasticity of anchoring cables or glide over intermediate support and to identify any variables as a function of the way alongside the cable. The results were compared with that of several known approaches as with measurements of real cable situations.

The study of the impact of small differences of corresponding variables e.g. of the length of a cable to the sag shows, that it is quiet important to calculate as exact as possible. With our approach, we have a flexible framework to consider individual configurations or particularities by adding additional equations to the equation system.



Picture 2: mathematical solution of an examplary calculation

We aim to extend our approach with dynamical computation caused by typical cable logging situations (Knobloch 2017) and plan to combine it with a spatially explicit optimization tool for cable layout (Bont 2012). Furthermore, we will implement the presented approach in a R or Python Toolbox.

Keywords: cable yarder, cable mechanics, compute exact catenary variables

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MEETING FUEL SPECIFICATIONS OF EN*PLUS* WOOD CHIPS BY SCREENING AND DRYING OF FOREST RESIDUES

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Abstract: *To ensure high fuel qualities, the EN*plus *certification scheme for wood chips was lauchned in October 2016 in Germany. Up to date, 15 enterprises are certified. The following study comprises an overview on fuel processing strategies applied by these companies. Moreover, six field trials on screening (drum, star or jigger screens) and drying (storage piles, rolling bed, walking floor, belt and batch dryer) of forest residue wood chips were performed at German biomass terminals. During the case studies, moisture content before processing was too high for small scale boilers (up to 51 w-%). Raw materials did not meet requirements of EN*plus *wood chips (with respect to ash content, particle size). Technical drying provided moisture contents ≤ 15 w-% whereas after natural drying, values usually exceeded 35 w-%. Screening reduced ash content, fines, oversized particles and chemical elements (N, S, Cl, K, Si). After fuel processing, chips could often be classified as EN*plus *specification A2 or B.*

Keywords: fuel quality, screening, drying, ISO 17225-4, EN*plus* wood chips

1. Introduction

Small scale wood chip boilers require homogeneous and high quality biofuels for failure-free and low emission combustion. Especially with regard to emissions and ash formation, fuel properties should be as suitable and homogeneous as possible considering moisture content, ash content, particle size and specific chemical elements (Kaltschmitt *el at.* 2016, Schön *et al.* 2017).

Many fuel quality parameters affect combustion behavior. For instance, high moisture contents often lead to rather low temperatures within the combustion chamber (Buchmayr *et al*. 2015, Quintero-Marquez *et al.* 2014, Kaltschmitt *et al*. 2016). As a result, emissions of CO or soot increase due to incomplete combustion of the fuels while boiler efficiency decreases. High shares of needles, bark material or impurities such as mineral soil due to inappropriate logging operations increase ash content or the content of combustion critical chemical elements (e. g. N, Cl, K, Si) (Kuptz & Hartmann 2015, Dietz *et al.* 2016) leading to high NO_X or aerosol emissions, bottom ash slagging or high-temperature corrosion (Sommersacher *et al.* 2012, Sommersacher *et al*. 2015, Obernberger *et al*. 2015, Zeng *et al*. 2016, Zeng *et al*. 2018). Oversized particles might cause clogging of screw conveyors (Rackl & Günthner, 2016) or increase bridging tendencies (Hinterreiter *et al*. 2012, Jensen *et al*. 2004) of fuels inside storage rooms while high shares of fine particles might hamper combustion air flow through the fuel bed and, thus, also increase particle emissions.

To address uncertainties on suitable fuel qualities, international standards for solid biofuels were developed to provide specifications for different fuel types. In case of graded wood chips, the ISO standard 17225-4:2014-05 specifies 4 fuel classes (A1, A2, B1 and B2, respectively). Thereby, the standard declares suitable raw materials for production (e. g. forest residues, stem wood) but also gives thresholds for fuel quality parameters such as moisture content, ash content, bulk density or particle sizes. These specifications should help fuel producers, boiler manufacturers and customers to orientate on an optimal fuel quality suitable even for small scale combustion appliances. In case of wood pellets, the respective ISO standard is already applied internationally, e. g. by wood pellet certification schemes such as EN*plus* (EPC 2015). In case of wood chips, a similar EN*plus* certification scheme was launched in Germany in October 2016 by the Deutsches Pelletinstitut GmbH (DEPI 2016). Up to date (June 2018), 15 enterprises have been certified.

Fuel quality of natural wood fuels such as wood chips from recently cut forest residues often do not fulfill the specified thresholds of both the ISO standard and EN*plus*. Thus, these fuels are usually not suitable for direct use in small boilers.

Secondary fuel processing steps such as screening and drying might strongly improve fuel properties and might help to meet the thresholds set by the wood chip standard. To contribute to a better understanding of scope and limitations of different secondary fuel pretreatment techniques, processing strategies applied by certified wood chip producing enterprises have been examined and field trials on fuel processing with screening and drying have been performed. Thus, the present study aims to (I) reveal optimization potential during wood chip production and (II) to indicate the impact of different pretreatment strategies on fuel quality and composition.

2. Specifications of EN*plus* wood chips

Within the EN*plus* certification program for wood chips, three fuel specifications A1, A2 and B were defined (Table 3). These fuel specifications are directly related to specifications for quality classes A1 to B2 of ISO 17225-4:2014-05. However, for individual fuel quality parameters such as moisture content, fine particles or the maximum particle length, thresholds of EN*plus* are more restrictive compared to the ISO standard.

Table 3: Fuel specifications for EN*plus* wood chips (a = value stricter compared to ISO 17225-4:2014-05)

Fuel property	Unit	EN*plus* A1	EN*plus* A2	EN*plus* B
Moisture content	w-%	≥ 8[a] to ≤ 25	≤ 35	To be stated
Ash content	w-% (d. b.)	≤ 1.0	≤ 1.5	≤ 3.0
Net. calorific value	kWh/kg (d. b.)	To be stated		
Particle size class		P31S or P45S		
Coarse fraction	w-%	≤ 6 in P31S (> 45 mm) or ≤ 10 in P45S (> 63 mm)		
Fine fraction (≤ 3.15 mm)	w-%	≤ 5[a]	≤ 8[a]	≤ 10
Maximum particle length	mm	120[a] (P31S) 150[a] (P45S)	150 (P31S) 200 (P45S)	150 (P31S) 200 (P45S)

For EN*plus*, fuel quality is tested regularly by external auditors. Furthermore, the certified companies are requested to implement a fuel quality management system, e. g. by testing and monitoring fuel quality during fuel production. Other aspects of "EN*plus* wood chips" focus on reliable accounting, e. g. by preferring t (dry basis) over m^3, or the application of a complaint management system.

The process chains of all 15 certified enterprises are briefly described in Table 4. Strategies to comply with fuel specifications vary strongly among individual companies. For instance, some companies acquire high quality raw materials (e. g. already dried timber industry residues) while others use screening and drying techniques to improve raw materials with lower qualities such as fresh forest residues. Some entrepreneurs buy already produced wood chips from external sources while others own a chipper themselves. Different methods of screening (drum, star or jigger screens) and drying (natural drying (chipped and unchipped) and technical drying such as batch dryer, rolling bed dryer, belt dryer, etc.) are applied. Finally, process chains differ in the sequence of their process steps, e. g. whether drying is performed before or after screening (Table 4).

Table 4: Process chains used by the 15 EN*plus* certified enterprises (MC = moisture content)

No.	Raw material			Chipper	Fuel processing	EN*plus* class	Particle size class
	Source	Origin	MC				
1	timber industry residues	coniferous wood	dry	no	jigger screen	A1	P31S, P45S
2	stem wood	coniferous wood	fresh	no	star screen - rolling bed dryer with cyclone - jigger screen	A1	P31S, P45S
3	stem wood, forest residues, landscape maintenance	coniferous and deciduous wood	fresh	yes	batch dryer (container) - drum screen	A1	P31S, P45S
4	timber industry residues	coniferous wood	fresh	no	batch dryer (building) with agitator	A1	P31S, P45S

5	stem wood	coniferous wood	fresh	yes	natural drying (unchipped)	A1	P31S, P45S
6	timber industry residues	coniferous wood	fresh	no	batch dryer (container)	A1	P31S, P45S
7	forest residues, landscape maintenance	coniferous and deciduous wood	fresh	yes	jigger screen - batch dryer (container)	A1	P31S, P45S
8	timber industry residues	coniferous wood	fresh	no	jigger screen - feed-and-turn-dryer	A1	P31S, P45S
9	timber industry residues	coniferous wood	dry	no	jigger screen	A1	P31S, P45S
10	forest residues	deciduous wood	fresh	yes	batch dryer (container, only A1), natural drying (chipped, only A2)	A1, A2	P31S, P45S
11	stem wood, forest residues, landscape maintenance	deciduous and coniferous wood	fresh	yes	jigger screen - belt dryer	A1, B	P31S, P45S
12	timber industry residues, forest residues	coniferous wood	fresh	yes	jigger screen - belt dryer	A2	P31S, P45S
13	timber industry residues, stem wood	coniferous and deciduous wood	fresh	no	batch dryer (building)	A2	P31S, P45S
14	stem wood, forest residues	deciduous and coniferous wood	fresh	yes	natural drying (unchipped, only A2), no further processing (only B)	A2, B	P31S, P45S

15	stem wood, forest residues, landscape maintenanc e	deciduous and coniferou s wood	fres h	yes	natural drying (chipped)	B	P31S, P45S

Interestingly, although raw material input and process chains differ strongly, most companies are able to produce high quality wood chips complying with fuel specifications A1 or A2 according to EN*plus* (see Table 4).

3. Materials and Methods

To identify optimization potentials during wood chip production, six case studies on processing forest residue wood chips were performed from December 2015 until May 2016 in Germany (see Table 5). All studies were done at biomass terminals in southern Bavaria with exception of case study 5 which was executed in the east of North Rhine-Westphalia. Raw materials for processing (i. e. samples denoted with an "R") consisted of forest residue wood chips, mainly from coniferous wood (case study 1, 2, 3, 4 and 6) but also from deciduous trees (case study 5). In most cases, raw materials were obtained directly from forest operations taking place shortly before each case study to ensure high fuel moisture contents. In addition, pre-dried wood chips from storage piles were used as raw materials, i. e. in case study 3b, 5b and 5c. Thereby, due to the overall long drying periods of ≥ 5 month, two different raw materials (R1, R2) were investigated in case studies 3 and 5. The actual process chain of case study 5 consisted of two consecutive screening and drying steps of the same raw material (i. e. steps 1 to 4 in case studies 5, see Table 5).

Fuels were processed by screening (i. e. samples denoted with an "S") using a star screen (case study 1, 2a, 2b 5a, 5b), a jigger screen (case study 1, 6a) or a drum screen (case studies 1, 3a, 3b, 6b) (Table 5). Drying (i. e. samples denoted with a "D") was performed using a rolling bed dryer (case study 1), batch drying container (case study 2a, 2b), a walking floor dryer (case study 4) or a belt dryer (case study 6a). Samples of the final products are denoted with an "E" for "end product".

Table 5: Description of process steps in case study 1 to 6 (Samples denoted with an "R" for "raw material" "D" for drying, "S" for "screening" and "E" for "end product". For coupled processes, i.e. in case study 1 or 6a separating lines were omitted).

Case study	Process step	Sample	Screening / Drying	Process description
1	0 - Raw material	1-R	-	Fresh wood chips (coniferous residues)
	1 - Screening	-	Star screen	Backers (> 28 mm)
	2 - Drying	1-D	Rolling bed dryer	Allgaier WB-T (biogas excess heat)
	3 - Screening	1-E	Jigger screen	SF GmbH ASS 100 (< 1.5mm and < 6 mm)
2a/b	0 - Raw material	2-R	-	Fresh wood chips (coniferous residues)
2a	1 - Screening	2-S	Star screen	Komptech Multistar (> 45 mm and < 20 mm)
	2 - Drying	2-E1	Batch container	Self-constructed (biogas excess heat)
2b	1 - Drying	2-D	Batch container	Self-constructed (biogas excess heat)
	2 - Screening	2-E2	Star screen	Komptech Multistar (> 45 mm and < 20 mm)
3a	0 - Raw material	3-R1	-	Fresh wood chips (coniferous residues)
	1 - Screening	3-E1	Drum screen	Terra Select T3 (< 15 mm)
3b	1 - Drying	3-R2	Pile drying	Pre-dried wood chips (coniferous residues, five month, fleece cover)
	2 - Screening	3-E2	Drum screen	Terra Select T3 (< 15 mm)
4	0 - Raw material	4-R	-	Fresh wood chips (coniferous residues)

	1 - Drying	4-E	Walking floor dryer	Self-constructed (biogas excess heat, screening < 2 mm)
5	0 - Raw material	5-R1	-	Fresh wood chips (deciduous residues)
5a	1 - Screening	5-E1	Star screen	Komptech Multistar (> 45 mm and < 20 mm)
5b	2 - Drying	5-R2	Pile drying	Pre-dried wood chips (deciduous residues, five month, fleece cover)
	3 - Screening	5-E2	Star screen	Komptech Multistar (> 45 mm and < 20 mm)
5c	4 - Drying	5-E3	Pile drying	Pre-dried wood chips (deciduous residues, five month, roof cover)
6	0 - Raw material	6-R	-	Fresh wood chips (coniferous residues)
6a	1 - Screening	6-S	Jigger screen	Zeno P90 (> 45 mm and < 15 mm)
	2 - Drying	6-E1	Belt dryer	Stela (wood CHP excess heat)
6b	1 - Screening	6-E2	Drum screen	Doppstadt 620 (< 15 mm)

For each case study, a full container load of approx. 30 m^3 of wood chips was processed. Thereby, the mass of the unprocessed raw material and of the respective dried or screened products (i. e. wood chips, fine particles, oversized particles) were determined onsite by weighing the whole mass of each fraction using a truck scale of the respective biomass terminal or a crane scale (DINI ARGEO MCW1500, AS Wägetechnik GmbH). Mass fractions were compared on dry basis (d. b.) using the individual moisture content of each fraction (see below).

During each case study, wood chip samples were collected for fuel property analysis. Sampling was done for each raw material and after each process step following ISO 18135:2017-04. Sample preparation was done according to ISO 14780:2017-04. Individual fuel samples were analyzed for moisture content (ISO 18134-2:2015-09, n = 10–20), ash content (ISO 18122:2015-10, n = 3), net calorific value (ISO 18125:2017-04, n = 3), bulk density (ISO 17828:2015-12, n = 10), particle size distribution (ISO 17827-1:2016-03, n = 10) and chemical fuel quality (ISO 16948:2015-05, ISO 16994:2016-07 and ISO 16967:2015-04, n = 1, mixed sample). Afterwards, fuel quality was related to the specifications of EN*plus* wood chips (listed in Table 3).

4. Results and Discussion

4.1. Fuel properties of raw materials

Fuel properties of the unprocessed raw materials were within the usual range for wood chips from forest residues as reported in several studies (e. g. Kuptz & Hartmann 2015, Kuptz *et al.* 2016, Pichi *et al.* 2018, Chandrasekaran et al. 2012, Gendek & Nurek 2016, Spinelli *et al.* 2011). Thereby, mean moisture content of the unprocessed biofuels ranged from 38.1 to 51.0 w-% (samples denoted with an "R" for "raw material", see Table 6). Thus, moisture content of raw materials usually exceeded the suitable moisture content for small biomass boilers (Schön *et al.* 2017, Kaltschmitt *et al.* 2016).

Table 6: Mean values for moisture content, ash content, net calorific value, bulk density and chemical elements N, S, Cl, K, and Si of wood chip samples in case studies 1 to 6 (mean ± SD).

Sample	Moisture content	Ash content	Net calorific value	Bulk density	N	S	Cl	K	Si
	w-%	w-% (d.b.)	MJ/kg (d.b.)	kg/m³ (a.r.)	w-% (d.b.)		mg/kg (d.b.)		
1-R	41.7 ± 0.8	3.0 ± 0.6	19.2 ± 0.1	310 ± 10	0.32	0.016	66	1,320	5,250
1-D	12.6 ± 1.0	2.1 ± 0.5	19.0 ± 0.1	260 ± 0	0.25	0.013	< 54	1,090	1,630
1-E	12.8 ± 1.1	1.4 ± 0.2	19.2 ± 0.1	250 ± 0	0.23	0.010	< 58	970	780
2-R	51.0 ± 3.0	7.4 ± 4.2	18.5 ± 0.8	350 ± 30	0.47	0.022	146	1,790	18,750
2-S	52.1 ± 0.7	3.7 ± 1.5	19.0 ± 0.3	360 ± 10	0.35	0.020	126	1,570	8,520
2-E1	3.8 ± 0.2	2.5 ± 0.5	19.3 ± 0.1	220 ± 0	0.33	0.019	94	1,450	5,050
2-R	51.0 ± 3.0	7.4 ± 4.2	18.5 ± 0.8	350 ± 30	0.47	0.022	146	1,790	18,750
2-D	5.5 ± 1.7	2.2 ± 0.7	19.0 ± 0.1	210 ± 0	0.29	0.017	79	1,400	3,720

2-E2	13.1 ± 2.7	1.9 ± 0.7	19.1 ± 0.1	220 ± 10	0.20	0.014	< 59	1,170	2,250
3-R1	41.2 ± 3.8	1.3 ± 0.3	18.9 ± 0.1	280 ± 10	0.24	0.010	< 56	1,330	690
3-E1	42.9 ± 1.3	1.0 ± 0.1	18.9 ± 0.2	270 ± 0	0.20	0.008	58	1,020	220
3-R2	38.1 ± 6.1	2.5 ± 0.6	18.6 ± 0.1	290 ± 40	0.34	0.016	< 56	1,550	5,610
3-E2	38.4 ± 4.2	1.1 ± 0.2	18.8 ± 0.0	260 ± 20	0.25	0.011	< 56	1,340	1,170
4-R	42.0 ± 3.0	1.7 ± 0.1	18.8 ± 0.0	290 ± 10	0.34	0.014	< 66	1,430	1,630
4-E	7.0 ± 1.0	1.4 ± 0.1	18.7 ± 0.0	200 ± 0	0.30	0.012	< 56	1,170	1,020
5-R1	42.5 ± 4.7	3.7 ± 0.2	17.7 ± 0.0	300 ± 10	0.34	0.021	< 63	2,380	4,560
5-E1	39.1 ± 0.4	3.0 ± 0.1	17.8 ± 0.1	290 ± 0	0.33	0.017	< 57	2,090	2,260
5-R2	41.7 ± 3.7	2.5 ± 0.4	18.3 ± 0.1	300 ± 20	0.32	0.015	67	1,980	3,620
5-E2	32.4 ± 1.2	1.7 ± 0.0	18.2 ± 0.0	260 ± 20	0.23	0.014	< 56	1,860	2,080
5-E3	25.2 ± 1.5	2.5 ± 0.4	17.9 ± 0.1	220 ± 0	0.38	0.019	72	2,490	2,560
6-R	48.1 ± 5.2	5.3 ± 1.5	18.5 ± 0.2	330 ± 30	0.36	0.016	< 84	2,040	7,380
6-S	48.4 ± 5.1	1.6 ± 0.2	19.0 ± 0.1	-	0.15	0.008	< 62	1,300	1,880
6-E1	15.2 ± 2.4	1.8 ± 0.2	19.1 ± 0.1	190 ± 20	0.19	0.008	< 87	1,490	1,410
6-R	48.1 ± 5.2	5.3 ± 1.5	18.5 ± 0.2	330 ± 30	0.36	0.016	< 84	2,040	7,380
6-E2	45.0 ± 2.3	1.5 ± 0.2	18.9 ± 0.1	290 ± 10	0.21	0.009	< 74	1,330	1,020

Interestingly, moisture content of many fresh wood chip samples (i. e. except pre-dried material used in case study 3 and 5) was around 42 w-% indicating that at least some natural drying, e. g. by self-heating of the biofuels due to microbial respiration (Hofmann *et al.* 2017, Lenz *et al.* 2015, Barontini *et al.* 2014) or due to drying during unchipped storage (Routa *et al.* 2015), might have occurred prior to the case studies.

Mean ash contents of raw materials ranged from 1.3 w-% to 7.4 w-% (Table 6). Thereby, highest ash contents were measured for case study 2 and 6, exceeding typical ash contents of forest residues of approx. 3 w-% (Kuptz & Hartmann 2015, DIN EN ISO 17225-1:2014-05). Such high ash contents indicate that some contamination of the samples with mineral soil might have occurred prior to the case studies, e. g. during logging, storage on mineral ground, crane loading operations or transport (Kuptz *et al.* 2016, Dietz *et al.* 2016). In contrast, the lowest ash content of 1.3 w-% in case study 3a indicated a high share of stem wood in the fuel.

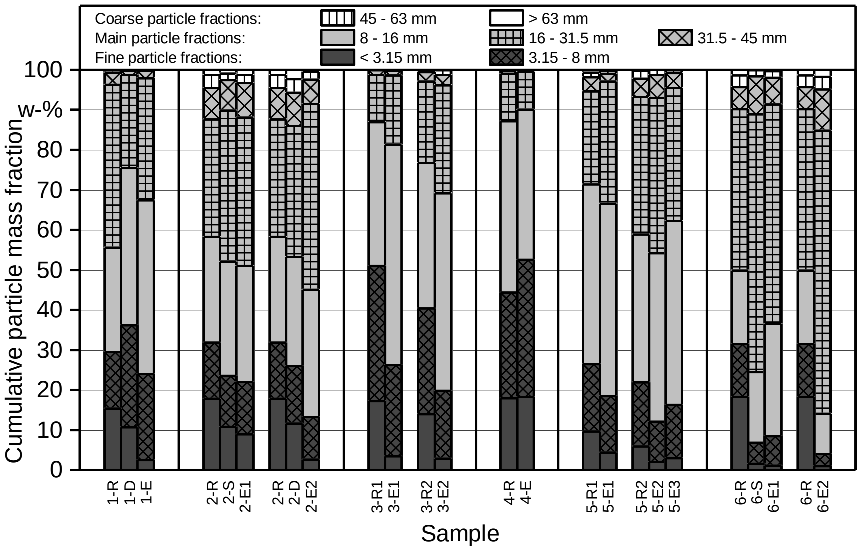

Figure 4: Mean values for particle size distributions of samples in the case studies

None of the untreated raw materials could be classified according to the particle size classes of ISO 17225-4 or EN*plus* wood chips (Table 3) due to high amount of fines (9.6 to 18.2 w-%) or exceeding maximum particle length (153 to 250 mm) (Figure 4). On the other hand, their chemical properties (see Table 6) were within the typical range for forest residues (Kuptz *et al.* 2016). For instance, values for combustion-critical elements such as N, S, Cl or K ranged from 0.24 to 0.47 w-% (d. b.), 0.01 to 0.02 w-% (d. b.), < 56 to 146 mg/kg (d. b.) and 1,130 to 2,380 mg/kg (d. b.), respectively. Moreover, the high concentrations of Si in case studies 2, 5 and 6 (i. e. in samples "2-R", "5-R1" and "6-R", respectively) indicated at least some contamination of samples with mineral soil (Dietz *et al.* 2016).

Overall, the unprocessed raw materials could not be classified according to the EN*plus* specifications A1, A2 or B due to their exceeding ash content or their non-conformity with a specific particle size class.

4.2. Fuel quality after processing

Fuel quality of the raw materials was improved by applying secondary fuel processing (Figure 5, Table 6). Thereby, most fuel qualities of the final products could be classified as either A2 or B quality according to EN*plus* (i. e. in case study 1, 2b, 3a, 3b, 5b, 6a, see Figure 5, Table 3).

Technical drying in case studies 1, 2, 4 and 6 significantly reduced moisture content to levels of 3.8 to 15.2 w-% (Table 6). Thus, after technical drying, most wood chips had a moisture content that is deemed suitable for most small scale boilers (Schön *et al*. 2017, Kaltschmitt *et al.* 2016). To comply with the requirements for the EN*plus* wood chip class A1, however, a moisture content of at least 8 w-% is demanded (Table 3). Too dry fuels below this threshold might lead to an increase in gaseous and particle emission during combustion. Thus, elevated combustion temperatures may lead to a too rapid release of pyrolysis gases which may cause oxygen depletion in the combustion chamber resulting in an incomplete combustion and soot formation. As a consequence, fuels from case study 2a and 4 might be considered "over-dried" and do not comply with moisture content requirements according to EN*plus* class A1. Therefore, to further improve fuel quality, but also the throughput rate of the applied dryer, process chains could be adjusted to moisture contents > 8 w-% (i. e. according to EN*plus* A1, Table 3).

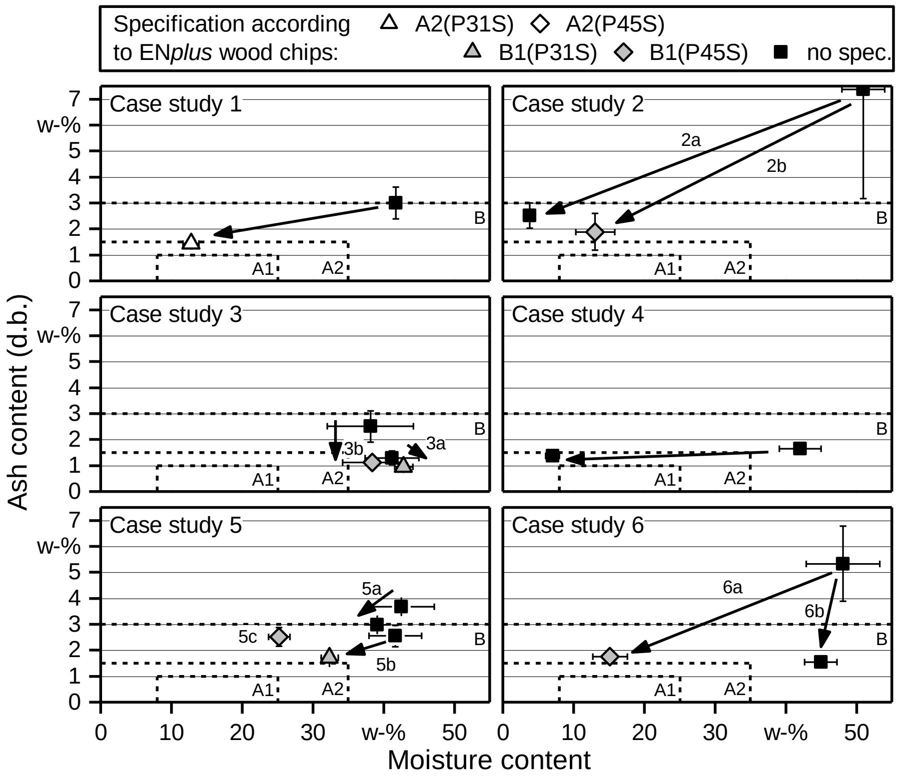

Figure 5: Fuel quality of forest residue wood chips before and after processing in six case studies (mean ± SD, n = 10-20 for moisture content and particle size distribution, n = 3 for ash content). Dashed lines denote thresholds for ash content and moisture content of fuel specifications A1, A2 and B according to EN*plus* wood chips.

In contrast to technical drying, natural drying of wood chips in storage piles did not always lead to a strong reduction in the moisture content during the case studies (see case study 3b, 5b, 5c, Table 6, Figure 5). Drying in storage piles occurs to a large extend due to self-heating of the bulk material during decomposition of organic matter by microbial activity, leading not only to a drying effect but also to dry matter losses between 0.3 and 5.5 w-% per month (Hofmann *et al*. 2017, Lenz *et al*. 2015, Barontini *et al*. 2014, Thörnqvist 1985). Thereby, drying efficiency in piles depends on a variety of factors such as type of the raw material (i. e. tree species, tree compartment, initial moisture content, particle size distribution), the drying season, meteorological conditions during drying, the length of the storage period or the pile covering (Hofmann *et al.* 2018). Unfortunately, no direct conclusion on drying efficiency in storage piles was possible in this study since moisture content could not be determined before and after pile drying due to the long storage periods of approx. 5 months. However, moisture content after 5 month of storage in fleece covered piles still exceeded 35 w-% (case study 3b and 5b). Thus, results from the case studies indicate that natural drying in storage piles for half a year often leads to moisture content levels that are still above the required maximum of 25 w-% (i. e. EN*plus* A1). However, in contrast to the results from the case studies, pile drying is also applied regularly by some of the already certified enterprises (Table 4). Many of these companies produce A1 wood chips. Thus, natural drying in piles as applied in the case studies might be further improved, e. g. by longer storage periods, a change in storage pile design or the use of a different pile covering.

Mechanical screening of raw materials reduced ash contents (case study 1, 2, 3, 5 and 6). Thereby, ash contents decreased to values ≤ 3 w-%, even for raw materials with initially high ash content levels (e. g. case studies 2 and 6). In some case studies, ash content even decreased to values ≤ 1.5 w-% (case studies 1, 3a, 3b, 4, 6b) allowing for wood chips to comply with ash content requirements of specification A2 according to EN*plus* (Table 3, Table 6). Simultaneously, the mass fraction of fines (i. e. particles ≤ 3.15 mm) or of the particle fraction < 8 mm was reduced after screening (Figure 4). As a consequence, particle size distribution of wood chips could be classified as P31S or P45S after the applied screening in many cases due to a decrease of fines and due to a reduction of the maximum particle length (Figure 5).

Ash content and fine particles are interlinked directly as the fine particle fractions usually consist to a large extend of needles, bark particles or impurities such as mineral soil (Dietz *et al.* 2016). These materials have overall higher ash contents compared to stem wood as they contain higher shares of ash forming chemical elements. Moreover, screening not only reduced ash content or fines but also the concentration of chemical elements which are critical for the combustion process such as N, Cl, K, Na or Si. These elements are either relevant for plant metabolism and, thus, elevated levels are typically found in needles and bark, or they are abundant in relevant concentrations within the upper soil layers (e. g. Si) (Table 6). Thus, screening of wood chips can directly improve the combustion behavior and reduce emission of pollutants in flue gas.

The mass fraction of small particles separated from coniferous wood chips by onsite screening was 20.0 to 34.1 w-% (d. b., case study 1, 2 and 6). Lower mass fractions were separated from deciduous wood chips (i. e. 8.8 to 15.0 w-% d. b., case study 5) probably due to the missing share of needles. By using a star or a jigger screen (in case study 1, 2a, 2b, 5a, 5b, 6a), oversized particles could be separated in a range of 1.3 to 14.6 w-% (d. b.). Thus, screening resulted in an overall mass loss in fuels from 23.4 to 35.0 w-% (d. b.) and economically reasonable uses for these by-products should be applied such as bedding for farm animals, composting or combustion in larger CHP plants.

5. Conclusion

Fuel quality in the case studies was typical for wood chips from forest residues. However, untreated raw materials exceeded requirements of EN*plus* wood chips regarding moisture content, ash content or particle size distribution. Moreover, chemical elements implied some contamination of fuels with mineral soil. Thus, the unprocessed wood chips were deemed unsuitable for the use in small scale biomass boilers (< 100 kW).

Similar to the process chains of the 15 certified fuel suppliers, conformity with specifications A2 and B according to EN*plus* could be achieved in many cases during field trials by screening and drying. However, in the case studies the highest specification A1 was never achieved. Further processing of the fuels but also the use of different raw materials (e. g. stem wood) or the use of different machine settings might be necessary to achieve this quality. If wood chips should be combusted in small scale boilers, technical drying seems preferable over natural drying in storage piles. However, "over-drying" (e. g. case study 2a and 4) should be avoided to optimize fuel quality and throughput rate in the drying step.

To increase the overall economic efficiency of the case studies, a high annual capacity for the screening machine and the dryers should be achieved. Furthermore, suitable utilizations for by-products after screening, i. e for the small and oversized particle fractions, are required such as bedding for farm animals, composting or combustion in larger CHP plants as 23.4 to 35.0 w-% (d. b.) of the fuels were removed during processing.

In conclusion, during the performed field trials, secondary fuel processing steps such as screening or drying were a suitable option to improve fuel quality of wood chips. Afterwards, fuel quality complied with fuel specifications according to EN*plus*. Thus, the production of high quality wood chips can be guaranteed by applying these techniques, leading to fuels that should allow for failure free and low emission combustion even in small scale boilers.

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EVALUATION AND COMPARISON OF FOREST MACHINERY OPERATORS' CARDIOVASCULAR WORKLOAD

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Abstract: *Due to fast developing technologies and production process the occupational safety and health in forestry significantly changed through time. From the aspect of energy workload, old ergonomic paradigm "less is better" for traditional forest technologies is now replaced by a new paradigm "more can be better" because reduced physical activity in modern technologies can have harmful impacts on workers' health. Accordingly, in this paper an evaluation and comparison of cardiovascular workload for three forest machinery operators (chainsaw, harvester and forwarder) has been made from an ergonomic point of view by using the heart rate method. In the conducted research Garmin Fenix 3HR device has been used to measure the heart rate frequency of selected machinery operators. Field measurements and data collection were conducted during the summer of 2017 while applying different harvesting technologies in the same forest stand. During the measurement, apart from heart rate frequency, the shares of effective and additional (rest, stoppage, physiological need etc.) worktime were also monitored. The energy workload of workers when operating the mentioned forest machinery was taken as a relevant comparison factor. The results obtained for average heart rate at effective, but also at additional time, show significant difference between motor-manual and machine work in wood harvesting process. Also, the average recorded heart rate during the additional time is noticeably higher in machine work (harvester and forwarder) than in motor-manual operation. For the improvement of ergonomic conditions in forest machinery operating, discussion and conclusion part of the paper provide examples of good practice and guidelines for further research needs.*

Keywords: forestry, workload, heart rate, forest machinery operator, Croatia

1. Introduction

Forestry work, especially harvesting operations, belongs to most dangerous occupations of all human activities (ILO 1981, Bentley et al. 2005, Potočnik et al. 2009, Lindroos and Burström 2010, Potočnik and Poje 2017). This refers to workers workload to which they are exposed in varying terrain and weather conditions. Such work is characterized by high energy consumption, frequent injuries, exposure to vibration, noise, gases, dust and other hazards. In a large number of forestry works, regardless of the significant degree of mechanization, the human body is a basic source of energy because the motor-manual operation is still heavily represented in the production process.

It is known that the working efficiency largely depends on the proactivity of human resources. Their effectiveness in forestry practice, motor-manual and machine work, depends on a number of parameters: work price, work intensity, complexity of working operations, skills and workability for work, workers age and work ability, working competencies and motivation for work (Ronay 1975, Vondra 1995). On the other hand, a large load in the energy and postural aspects significantly limit the operating efficiency and, with the noise and vibration, constitute one of the main causes of premature loss of working ability of forest workers. Accordingly, the ergonomic research is usually conducted with the purpose of evaluation, classification, and, if necessary, the implementation of corrective actions related to the workplace, with the aim of finding the optimal ways to balance the two main components of operating systems - the human ability and working conditions.

Ergonomic research in Croatian forestry are carried out more intensively in the 90s of the 20th century, where for estimating the physical load in a dozen types of forestry work (Tomanić et al. 1990, Vondra et al. 1990, Martinić 1993, Martinić 1994, Vondra 1995), due to its practicality, methods based on pulse measurement were applied. Results of foreign research shows that cardiovascular loads while working with manual saw or chainsaw heavily exceed the permitted values (40%) and increase with the work productivity (Silayo et al. 2010). Also, the loads on fellers are higher during work in younger than in older stands, and higher when working with a processor than with a skidder (Leszczyński and Stańczykiewicz 2015). On the other hand, in mechanized cutting, processing and extracting a continuous ECG recording technique is used for assessing operators' mental workload (Tynkkynen 2001, Berger 2003).

Numerous authors of ergonomic research find that the average pulse rate on a working day provides useful workload information. According to the above, the aim of the paper is the assessment and comparison of the cardiovascular workload for three forest machinery operators (chainsaw, harvester and forwarder) according to the technological structure of working time. An additional benefit of this work is the presentation of examples of good practice of the Western countries in relation to the implementation of measures to reduce overtime and workload with the application of modern technologies (e.g. harvesters, forwarders) in forestry.

2. Materials and methods

2.1 Research area

Field research, i.e. the main experiment of machine felling and processing was carried out in thinning of deciduous forest stands in compartments 14B and 14C of the Management Unit Bjelovar Bilogora managed by the Bjelovar Forest Administration, Bjelovar Branch of the company Hrvatske šume Ltd. Zagreb (Figure 1). As part of the main experiment of measuring the productivity of harvester and forwarder operations, the heart rate monitor Garmin Fenix 3HR was used to measure harvester, forwarder and chainsaw operator's cardiovascular workload, with the aim to evaluate and compare the working risks.

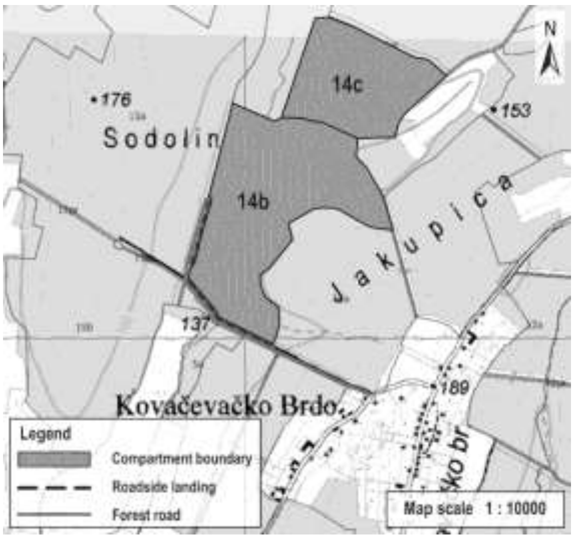

Figure 1 Test sites of the main research in MU »Bjelovarska Bilogora«

Compartment 14 B represents a mixed stand of European hornbeam (84%), common beech, pedunculate oak, black alder and sessile oak, with an area of 18.28 ha and 79 years old. The growing stock is 5.330 m^3, i.e. 291.58 m^3/ha, and the management plan prescribes thinning intensity of 11.67% in the first semi-period. Compartment 14C is a mixture of common beech (50%), European hornbeam (44%), sessil oak and pedunculate oak, with an area of 9.07 ha and 79 years old. The growing stock is

3.681 m^3, or 405.84 m^3/ha, and the management plan prescribes thinning intensity of 11.08% in the first semi-period.

2.2 Research method

Cardiovascular workload for three forest machinery operators (chainsaw, harvester and forwarder) has been conducted from an ergonomic point of view by using the heart rate method. Using the measured heart rate frequency, it is possible to calculate the consumption of oxygen and energy at work (models 1 and 2) (Vondra 1995). It is noted that the physiological unit of work and energy is one liter of oxygen (1 LO_2), and that the consumption of 1 LO_2 in the body releases energy to an average amount of 5 Kcal (calorie equivalent of oxygen).

$$Q_{EC} = 14,42 - (0,4268 \times F_{HR}) + [0,003914 \times (F_{HR})^2] \quad (1)$$

Where: Q_{EC} – Energy consumption, kJ/min; F_{HR} - heart rate, beats/min

$$VO_2 = -1,4533 + (0,027106 \times F_{HR}) \quad (2)$$

Where: VO_2 – Oxygen consumption, L/min; F_{HR} – heart rate, beats/min

The limitation of method and models is that the workload, beside the heart rate, is influenced by age, health, body weight, smoking, internal experiences, mental condition, and so on. However, it is considered that despite these limitations, the average, aggregate level of heart rate on a working day provides a very useful and sufficiently reliable data on the workload of workers.

In this research the Garmin Fenix 3HR (Figure 2) was used to measure the heart rate frequencies. The Garmin Fenix 3HR is a high-speed multisport watch with a heart rate sensor. The watch contains many functions for tracking and evaluating the performance of various open-site activities. It is equipped with barometric altimeter, electronic 3-axis compass and a GPS receiver that automatically calibrates the sensor for more accurate data. With comprehensive navigation and tracking functions the Fenix 3HR records the GPS track log and generates a trace of motion (Garmin 2015).

Figure 2 GPS device and heart rate monitor Garmin Fenix 3HR

Based on the measured heart rate frequency in a particular type of work it is possible, according to the recognized classifications (Ronay 1975, Kaminsky 1971, Grandjean 1980), to classify certain types of work according to the workload categories. The physical workload assessment was based on the methodology proposed by Grandjean (1980) as shown in Table 1. The percentage of heart rate increase was calculated as shown in Equation 3.

$$PHRI = [(WHR - RHR) / RHR] \times 100 \quad (3)$$

Where: PHRI – Percentage of heart rate increase, %; WHR – Work heart rate, beats/min;

RHR – Resting heart rate, beats/min

Table 7 Classification of workload based on the percentage of heart rate increase (Grandjean 1980)

Workload	Percentage of heart rate increase (PHRI)
Very low	0
Low	0 – 36
Moderate	36 – 78
High	78 – 114
Very high	114 – 150
Extremely high	> 150

2.3 Design of research and data analysis

Field measurements and data collection were carried out during the summer of 2017, when different harvesting technologies were applied within the same forest stand. Garmin Fenix 3HR (Figure 1) was used to measure the heart rate frequencies and to evaluate the forest machinery operators' physical workload. Prior to field measurements, the following parameters were determined for each subject: gender, age (in years), height (in cm), body mass (in kg), resting heart rate (in beats/min) and maximum theoretical heart rate. The resting heart rate (RHR) was determined by an individual heart rate count of 1 minute: (a) in the morning after waking or (b) at the measurement site after 20 minutes without activity (pause). The maximum theoretical heart rate was calculated by the formula $HRmax_t = 210 - (0.65 \times \text{age in years})$. Personal parameters made up the so-called input profile of the respondent which, before commencing field measurements, have been entered in the Garmin 3HR memory (Table 2) for each subject.

Table 2 Average values of sampled operators

Means of work	Age, years	Height, cm	Weight, kg	Resting heart rate (RHR)	Maximum theoretical heart rate ($HRmax_t$)
Harvester	26	175	103	68	193
Forwarder	33	180	90	74	189
Chainsaw	40	180	92	62	184

In the field work of the harvester operator a total of 17 hours and 25 minutes of work time was recorded, 11 hours and 33 minutes of effective working time and 5 hours and 52 minutes of additional working time. In the field work of the forwarder operator a total of 16 hours and 33 minutes of work time was recorded (12 hours and 24 minutes of effective working time and 4 hours and 9 minutes of additional working time). In the field work of the chainsaw operator a total of 6 hours and 7 minutes of work time was recorded (3 hours and 52 minutes of effective working time and 2 hours and 15 minutes of additional working time). For further processing and analysis of data, all records recorded using the Garmin Connect IQ application have been uploaded to a special online platform, which provides a more detailed analysis, categorization and statistical comparison of data.

3. Results

Analysis of measured heart rate at the sampled subjects was performed for the effective and additional working time (Table 3). Measured values of the average heart rate at the effective, but also at the additional working time are visibly different (Table 3) between motor-manual and machine operation in harvesting works. In accordance with the average heart rate values obtained, the workload expressed through energy consumption and oxygen consumption also results in a visible difference in the values between motor-manual and machine operations (Table 3). At the effective working time, the chainsaw operator has the highest average recorded heart rate (Table 3). On the other hand, the average recorded heart rate during additional working time is noticeably higher in the machine operations (operator of harvester and forwarder) than at the motor-manual operations (Table 3). The reason for this is that as part of the additional working time in the machine operations, significant proportion have the operating procedures that require intense physical workloads such as chain alignment on the header of the harvester head, cleaning of the harvester coolers during operation, replacement of hydraulic hoses for harvester or forwarder, repair of computer on the harvester head and so on.

Table 3 Descriptive heart rate and workload statistics of forest machine operators at effective and additional working time

Means of work	Effective working time (EWT)			
	Work heart rate (WHR)	Max. work heart rate (WHRmax)	Energy consumption (Q_{EC}), KJ/min	Oxygen consumption (VO_2), l/min
Harvester	87	109	7.12	0.92
Forwarder	91	124	8.03	1.01
Chainsaw	105	127	13.06	1.39
	Additional working time (AWT)			
	Work heart rate (WHR)	Max. work heart rate (WHRmax)	Energy consumption (Q_{EC}), KJ/min	Oxygen consumption (VO_2), l/min
Harvester	98	121	10.39	1.20
Forwarder	97	120	10.02	1.18
Chainsaw	90	123	17.84	0.97

A more detailed insight into workload issues included (a) examining the difference between heart rate, energy consumption and oxygen consumption versus time structure (EWT - AWT) and (b) examining the difference between the average heart rate, at effective and additional working time, versus three modes of operation. Testing of the statistical significance of the arithmetic mean of average heart rate, energy consumption and oxygen consumption between the effective and additional working time was performed using T-test (Table 4). The T-test showed a significant difference between the average heart rate, energy consumption and oxygen consumption between the effective and the additional working time for all three types of work, i.e. three forest workers - the operator of the harvester, the operator of the forwarder and the chainsaw operator (Table 4).

Table 4 Testing the significance of difference in measured values using a T-test

Variable	Means of work	M_{EWT}	M_{AWT}	t-test	df	p
Average work heart rate (WHR), beats/min	Harvester	87.437	98.058	4.883	31	0.000**
	Forwarder	90.888	97.200	2.710	17	0.015*
	Chainsaw	104.846	89.538	-4.197	24	0.000**
Energy consumption (Q_{EC}), KJ/min	Harvester	7.119	10.393	4.812	31	0.000**
	Forwarder	8.032	10.020	2.635	17	0.017*
	Chainsaw	13.064	7.841	-3.948	24	0.000**
Oxygen consumption (VO_2), l/min	Harvester	0.916	1.204	4.883	31	0.000**
	Forwarder	1.010	1.181	2.710	17	0.015*
	Chainsaw	1.388	0.973	-4.197	24	0.000**

* The difference is significant at 0.05; ** the difference is significant at 0.01

In addition, within the formed database, i.e. effective and additional working time, the differences between the mean heart rate values are tested against the descriptive variable that is made up of three types of work (work with harvester, forwarder and chainsaw). The homogeneity of variance between groups of data was tested with *Levene's test* ($p > 0.05$), where on the base of test significance level a further testing difference of defined variables was conducted with parametric and / or nonparametric techniques.

Within the effective working time, the average heart rate in three types of work has been statistically significant $F (2, 35) = 22.82$; $p = 0.01$ (Figure 3). Subsequent testing of the difference using the *Tukey's HSD* test showed that the mean heart rate value of the chainsaw operator (M = 104.85; SD = 10.08) significantly differs from the heart rate value of the harvester operator (M = 87.44; SD = 5.06) and the forwarder operator (M = 90.89; SD = 4.51). The mean heart rate value of the harvester operator during effective working time did not show a statistically significant difference compared to the mean heart rate value of the forwarder operator. Also, within the additional working time, the average heart rate value in three types of work showed statistically significant F (2, 37) = 5.63; p = 0.01 (Figure 4). Subsequent testing of the difference using the Tukey's HSD test showed that the mean heart rate value of the chainsaw operator (M = 89.54; SD = 8.44) significantly differs from the heart rate value of the harvester operator (M = 98.06; SD = 7.18) and the forwarder operator (M = 97.20; SD = 5.51). The mean heart rate value of the harvester operator during additional working time did not show a statistically significant difference compared to the mean heart rate value of the forwarder operator.

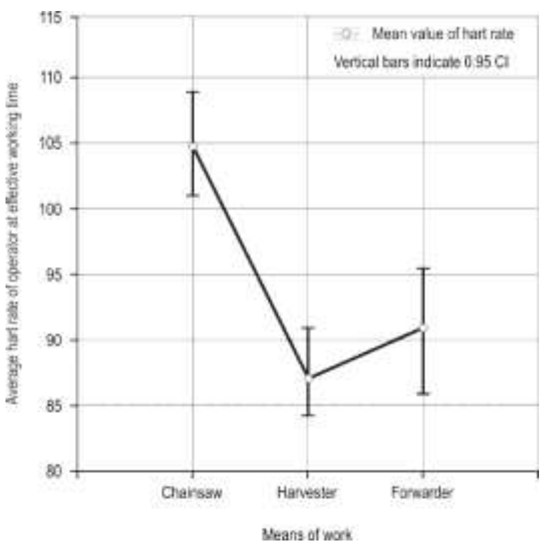

Figure 3 Operators average hart rate et effective working time

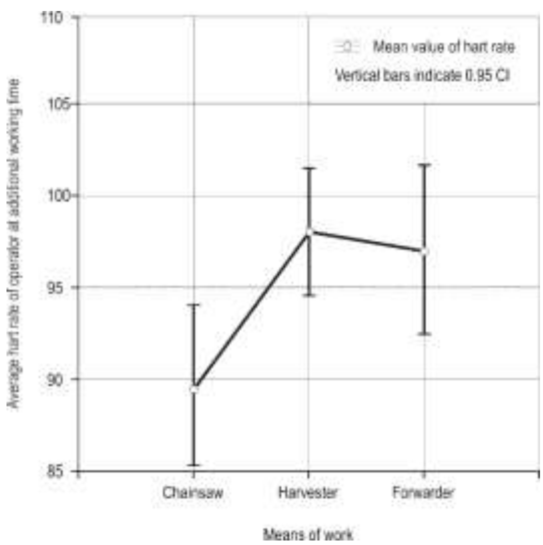

Figure 4 Operators average hart rate et additional working time

Results related to physical workload assessment (Table 5), according to Grandjean (1980), show that for chainsaw operator cardiovascular workload exceed permissible value (40%) at effective and additional working time. For harvester operator cardiovascular workload exceed permissible value only at additional working time (Table 5). Cardiovascular workload for forwarder operator is in within the permissible limits.

Table 5 Operator physical workload assessment by percentage of heart rate increase

Means of work	Percentage of heart rate increase (PHRI)	
	Effective working time (EWT)	Additional working time (AWT)
Chainsaw	69.36%	45.16%
Harvester	27.94%	44.12%
Forwarder	22.97%	31.08%

4. Discussion and conclusion

A great share of manual work in forestry occurring in all phases of wood production, and prevailing in pre-harvesting tasks, traditional harvesting and firewood production, causes a high frequency of studies addressing cardiovascular workloads (Potočnik and Poje 2017). Cardiovascular loads frequently exceed permitted limits. Due to relative simplicity, the measurement of cardiovascular loads is frequently included in broader, complex work studies (Košir et al. 2015).

Results presented in this paper also represents a small part of broader work study related to the productivity measurements of harvester and forwarder operations in Management Unit »Bjelovar Bilogora«. A more detailed analysis of physical workload assessment by percentage of heart rate increase, within three groups of work at EWT, showed that cardiovascular load of chainsaw operator exceeds permissible value (40%) and it statistically significantly differs from the cardiovascular load of harvester and forwarder operator. On the other hand, at machine cutting and processing as well as extracting, the greatest part of the cardiovascular load, and higher heart rate value, is placed within the additional working time, which includes maintenance and repair activities during field work such as hydraulic hose replacement, chain repair on the harvester bar, etc. The comparison of the cardiovascular load at AWT showed a statistically significant difference between motor-manual and machine operation. A visible difference in the assessment of occupational risk based on the cardiovascular load of the forest machine operators, especially those working with the chainsaw, can be explained with great share of manual work and external factors of the working environment on which worker cannot influence.

The new ergonomic paradigm »more can be better« in machine cutting, processing and extracting can have a positive effect on the health of the forest machine operator from the aspect of cardiovascular workload. On the other side, an adverse effect on operators' health is present from the viewpoint of the duration of the working day, reduced physical activity and static working posture. An example of such effect comes from Swedish forestry, where many research results and organizational measures have been implemented in practice with the aim of reducing work safety problems for forest machine operators. Research shows that the average weekly working time in hours of the forest machine operator is 61 hours (Erikson 2000), and the 8-hour daily work load of an operator working in a harvester and/or forwarder for the whole time is considered too high and causes excessive strain and stress (Pontén 1988). The Swedish Authority for Occupational Health and Safety, as an example of a corrective mechanism, has introduced a legal measure where forest machine operators must spend daily at least two hours engaged in some other activities that do not include mechanized work (UNECE/FAO 2011). Another example is related to designing a worker list within a work shift, which includes exchanging jobs and enriching the work with additional tasks. The said example of good work practice uses the method of workload points (WLP) for the identification of the workload and for the substitution of work activities (UNECE/FAO 2011) if more points than allowed are accumulated during the working day, which means excessive fatigue for the machine operator.

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FOREST ROAD NETWORK IN FIRE-PRONE ENVIRONMENT: PLANNING, CONSTRUCTION AND MAINTENANCE FOR AN EFFICIENT ROLE IN FIRE FIGHTING

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Abstract text

The importance of forest roads in forest management is proved by several studies. Forest roads are fundamental for forest operations, surveillance of territory, recreational activities. But these infrastructures play a key-role in fire fighting activities too. In fact, all ground-based operations are strictly related with the presence of forest roads as access to fire edge. In spite of this important role, forest roads are often planned and built without considering their use in fire fighting, and this occurs also in literature, where few studies are dedicated to analyse the importance of forest roads in fire fighting. In fact, wood harvesting is normally the main reason why a forest road is built. This is a very important aspect to be considered especially in Mediterranean areas, where fire events are quite frequent and fire fighters organisation are well structured. Moreover, it is rarely considered that a well-developed and well-maintained forest road network is the answer to different needs in fire management. The objective of this contribution is to show the results of a deep review of the actual state of the art in managing forest roads in fire-prone environments. Many aspects have been faced considering the basic principles to obtain efficient road network for fire fighting activities, taking into account the main roles, the most important aspects and the reported experiences to be considered in forest road network planning and maintenance in fire-prone areas. The most important themes treated are related with: i) the analysis of the functions of forest roads in fire prevention and suppression; ii) the importance of forest road planning and building considering also their importance for protecting forests against fires: iii) the construction and maintenance characteristics to be considered for building and maintaining an efficient forest road network against fires; iv) the importance of fire prevention and the related role of forest roads. Special attention has been dedicated to maintenance activities, because a not well-maintained forest road is a not efficient forest road, and it represents a useless economic and environmental cost. Results and evidences emerged in this study highlighted the possibilities of forest road enhancement under the perspective of forest fire fighters.

Keywords (komaseparated): forest road network, fire fighting, fire prevention, forest management, accessibility

MOUNDING AND MECHANIZED PLANTING IN FOREST REGENERATION IN CHANGING CLIMATE CONDITIONS

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Abstract

Around 30% of forests in Latvia are growing on wet soils where the conventional regeneration methods using disc trenchers cannot provide satisfactory results; therefore specifically adopted soil preparation techniques are needed. During the last decades extreme weather conditions occurs more often and mounding became a common practice in forest regeneration practice in Latvia. Lack of labor willing to do simple forest management operations and increase of labor cost are predictions to introduce mechanized planting on mounds in Latvia. The aim of the presented research is to compare productivity, quality and cost of mechanized and manual planting in Latvia conditions. It was found during the field trials that in case of planting of 2000 trees per ha the productivity of M-planter is 11.9 h per ha, while mounding with following manual planting together takes 11.2 h per ha. Cost of mechanized planting in Latvian conditions depending on the number of seedlings planted and planting conditions varies between 450 and 550 EUR.

Keywords: planting, mounding, silviculture mechanization, productivity

1. Introduction

Mechanized planting is potential solution for 2 problems typical for Latvia – lack of labor during planting season and site preparation in forests on wet soils (Lazdina *et al.* 2014). Widely distributed method – furrowing with disc trenchers is not appropriate for wet forests because furrow are flooded during spring and autumn causing decaying of planted trees. A berm commonly used as a planting place in furrows is not good choice in fertile soils because of weed competition increasing mortality of planted trees and accidental mechanical damages during early tending. It is already well known in Latvia that mounding is the best site preparation method for wet sites, and trees growth in sites where mounding is done is better, as well as the survival rate of planted trees (Kankaanhuhta *et al.* 2010; Uotila *et al.* 2010; Džeriņa *et al.* 2016). Recently it was found that even root system of coniferous tree saplings on mounds grows more evenly around the tree in contrast to furrows were distribution of roots is asymmetric and furrows' oriented, which is important factor determining resistance of trees during wind storms (Celma *et al*. 2018). Manual planting on mounds is more complicated in comparison to planting on furrows. During dry periods there is a risk of drought of top of mound during the period between site preparation and planting in case of manual planting (Heiskanen *et al.* 2016). Planting by machines simultaneously with site preparation gives the same regeneration quality and higher survival rate of planted trees in comparison to manual planting, but this method still is too expensive for Latvian forest owners. However the site preparation by mounding is more and more common forest management practice in wet sites despite of being more expensive in comparison to disc trenching. Limiting factor is not only number and quality of planting sites, but also soil bearing capacity limiting use of heavy forest machines; tracked excavators which are used for mounding on wet sites are less sensitive to soil bearing conditions in comparison to farm tractors or wheeled skidders and excavators can also be used for simultaneous site preparation and improvement of water regime in a stand (LSFRI Silava research report … 2012).

Productivity and costs of mechanized planting using Bracke P11a and M-planter paired bucket devices are tested in Latvia 10 years ago (LSFRI Silava research report … 2008; Liepins *et al*. 2010); during these studies disc trenching and mounding were compared in optimal working conditions for both machines on mineral soils with different clay content. Final conclusions of these studies were that despite high productivity of the M-Planter, reaching 260 seedlings per hour during the trials, it is still too expensive for Latvia (Liepins *et al.* 2011). Swedish and Finish scientists in the latest research review about mechanized tree planting in Sweden and Finland looking on current state and key factors for future growth, concluded that mechanized planting can improve cost-efficiency through education of involved foresters, flexible information systems, efficient seedling logistics, and continued technical development of planting machines (Ersson *et al.* 2018).

As the climate in Latvia enriches with contrasting conditions and extreme events and drought periods or extreme rainfalls became more and more common, and wetter and warmer climate conditions are predicted for our latitudes, planting on mounds will be became more attractive in our region due to better working conditions for operators, smaller labor intensity in field works, more resilient regenerated forest stands and better options for improvement of water regime in forests. If mounding is done water stays in pits during wet period and moves to topsoil layer through the soil micro-capillary during dry period and can be used by seedlings when it's needed. While in furrows water is running down to depressions in a stand, resulting in deceasing of trees due to anaerobic conditions or to nearest water streams causing leaching of nutrients.

During this study productivity and cost of mechanized planting with M-planter single bucket is compared with mounding with MPV-600 bucket in combination with manual planting. Aim of study is to determine costs and time necessary for regeneration of wet forest sites by fully mechanized operations or combination of mechanized mounding and manual planting.

2. Material and methods

Manual and mechanized planting was done in 6 clearcut areas – 2 Myrtilloso–sphagnosa (wet fertile forest on mineral soil), 2 drained forest - peat layer less than 35 cm (*Myrtillosa mel.& Mercurialiosa mel.*) and 2 drained forest - peat layer deeper than35 cm (*Myrtillosa turf.mel. & Oxalidosa turf. mel.*). Area of experimental sites is 3 ha per each forest site type. Each of stands is divided into 4 subplots – 2 for manual planting (1 for spruce containerized seedlings and other for pine containerized seedlings); remaining subplots are divided similarly – 1 is used for mechanized planting of spruce containerized seedlings with single bucket M-planter, while other is used for mechanized planting of pine containerized seedlings.

Single bucket M-planter was selected for mechanized planting in the trials because in the earlier experiments in 2008 in was found the shape of the blade of M-Planter is more suitable for the forest regeneration conditions in Latvia in comparison to narrower Bracke P11.a planting device (Research report ... 2008).

Following operations were recorded during time studies: moving into forest stand, manipulations with boom, cleaning of planting spot, preparation of mound, planting, filling of carousel, other operations, technical issues solved in the field. Operator and machine (engine) working time was used in calculations to determine service cost. Software *SDI 1.2* and *Allegro CX* field computers were used for time records.

Extended version of the cost model elaborated within the COST action FP0902 was used for calculation of the prime costs. Basic principles of the model were adapted in Latvia for calculation of forest regeneration cost already in 2007 and 2008 during the first mechanized planting trials and later in 2012, during research on cost efficiency of the site preparation by mounding. Basic input data used in the model are provided in Table 1.

Table 1 Values used in prime cost model calculations

Category	Value	Unit
Cost of excavator	120 000	EUR (without VAT)
M-Planter planting bucket	38 000	EUR (without VAT)
Total number of days operated by planting bucket	252	Days per year
Number of days when planting done	100	Days per year
Productivity of planting	170	Seedlings per hour
Salary including taxes	9	EUR per hour
Fuel price	0.88	EUR per liter (without VAT)

3. Results and discussion

Results of planting during the trials were affected by poor technical state of the excavator provided by the contracting company – limited hydraulic pressure was the main issue besides regular overheating; which is the main reason for significantly slower moving of boom and other operations requiring higher pressure in the system. However, the same machine was used in all experimental sites – with planting and mounding buckets (Fig. 1), and results are comparable within the experiment but not with the earlier trials. It is also should be considered that insufficient productivity of hydraulic engine affected not only boom movements, but also mounding and planting operations, therefore in normal conditions performance of the M-Planter would increase in comparison to MPV-600 requiring less power to operate.

Productivity of the single tube planting bucket M-Planter in drained sites on mineral and organic soils were similar – in peatland forest site the average time spent per seedling is 18.1 seconds, in drained mineral soil forest sites – 18.9 seconds. Mechanized planting in wet and fertile forest sites with loamy soil (*Myrtilloso–sphagnosa*) took more time; in average 23.4 seconds per seedling was used. Reloading of carousel with seedlings took 4 minutes per 120 seedlings.

Mounding operation with the MPV-600 bucket took 10.5 seconds per planting spot in drained forest on organic soil and 10.7 seconds on mineral soils. No significant difference in mounding productivity was found between the M-Planter and MPV-600 buckets on drained soils. In case of loamy soils mounding with following mechanized planting took more time for site preparation – 12.4 seconds per planting site.

M-Planter MPV-600

Fig. 1 Devices used for soil preparation – single tube M-Planter and mounding bucket MPV-600 elaborated by LSFRI Silava.

According to forest regeneration practice in Latvia at least 2000 seedlings per ha are planted in spruce stands. It means that at least 2000 planting spots should be prepared. With MPV-600 bucket it would take approximately 6 hours per ha in drained forest site type (5.8 hours on organic soil and 5.9 hours on mineral soil). More time (6.9 hours in average) is necessary for mounding of wet loamy soils. Typical area of clear cut in Latvia is 1-1.5 ha. It means that one clear cut area can be mounded per shift. Considering that 2000 trees per ha has to be planted using M-planter, 11.2 h per ha will be spent on drained organic soil, 11.6 h per ha – on drained mineral soils and 14.1 h per ha – on wet loamy soils. Respectively in average conditions it would take more than one shift per site. Planting by a single tube planting bucket is more time consumable in comparison to mounding and manual planting – in average 11.9 hours per ha, but it is just 0.7 hours more in comparison to manual planting following to mounding (11.2 hours) (Fig2).

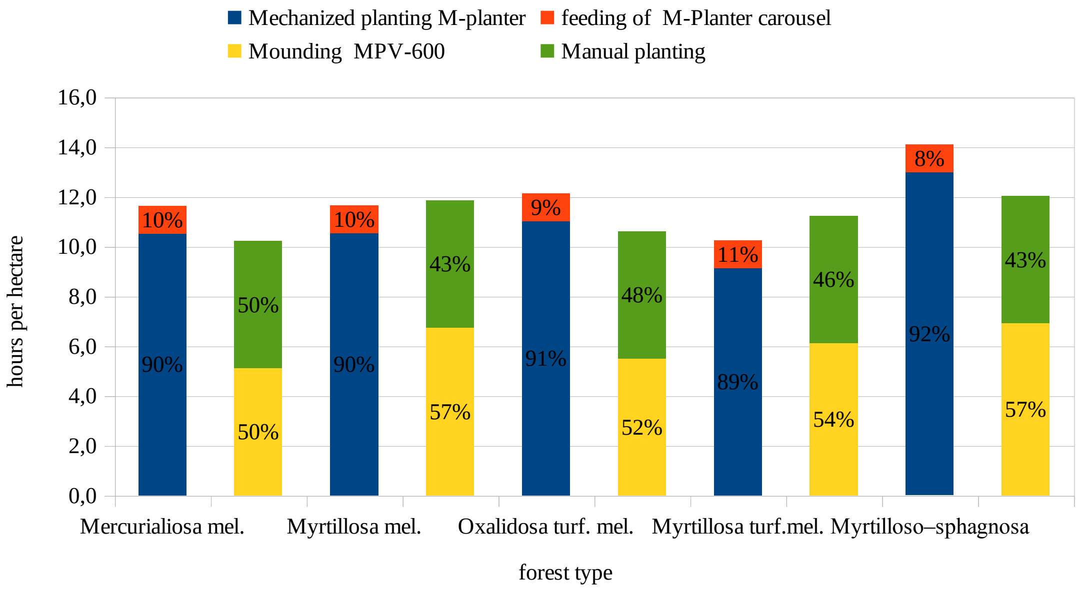

Fig. 2 Distribution of time necessary for regeneration of 1 ha depending of forest type and planting method used.

If planting is done in 2 shifts the prime cost of the service in theory can be significantly reduced due to higher utilization rate of the machine, however night shifts not always can be considered as an option to increase productivity, because in spring it is common that temperature drops below 0°C and seedlings stick to planting tube making the operation nearly impossible.

If average planting productivity is 170 seedlings per hour and planting density is 2000 seedlings per ha, 105 ha can be planted during a planting season with 1 planting device. Decreasing of planting density by 20% to 1600 seedlings per ha, which is common practice in Finland, would decrease prime costs of mechanized planting to 442 EUR ha^{-1} and 131 ha could be planted during one planting season. Planting of 2000 seedlings per hectare and an increasing of planting productivity to 210 seedlings per hour, which is the value observed in earlier studies, would lead to similar result – prime cost reduction to 447 EUR ha^{-1}, which is close to actual price of mounding service (Table 2).

Table 2 Mechanized planting costs using single tube M-Planter depending of productivity and planting density

	Number of seedlings per ha				
Productivity of planting, seedlings per hour	1600	1800	2000	2200	2400
150	501	563	626	689	751
170	442	497	552	608	663
190	395	445	494	544	593
210	356	402	447	492	537
230	327	368	408	449	490
250	301	338	376	413	451
270	278	313	348	383	417

The planting productivity of 210 seedlings per hour reached during mechanized planting trials in Latvia with paired tube M-Planter (Liepins et al. 2011) and decreasing planting density by 20% to 1600 seedlings per ha, would reduce cost of mechanized planting to 356 EUR ha^{-1}, 36% less than in the base scenarios – 552 EUR ha^{-1}.

Cost of mechanized planting can be decreased by increase of planting productivity (experienced operators, better machines and work conditions), reduction of distance between clear cut areas (more effective logistics and often selection of mechanized planting instead of other forest regeneration methods), adaption of hydraulic system of excavator to mechanized planting operations (when maximal pressure is on movement downwards and not upwards, which is constructed by default for digging).

In this study we did not estimated additional time and costs due to use of mechanized planting, such as reduced administrative costs – just 1 contract and 1 contractor for soil scarification and planting instead 2 separate contracts and consequent procedures like visiting forest site only 2 times instead of 4 times to give work order and to check quality. Spatial information of distribution and location of planting spots can be elaborated during mechanized planting therefore quality can be evaluated without visiting forest every site and information can be used in following planning. Regulation of water regime is another considerable benefit of mechanized planting, as well as of mounding using excavators.

Conclusions

Average planting productivity during the trials was 170 seedlings per hour, in best conditions – 195 seedlings per hour.

Planting productivity can be increase by training of operators, adapting excavator to planting bucket and by decreasing the target of number of seedlings per ha.

Mechanized planting cost in Latvia in *Myrtilloso–sphagnosa, Myrtillosa mel., Mercurialiosa mel., Myrtillosa turf.mel., Oxalidosa turf. mel.* forest site types according to study results varies from 440 to 550 EUR ha^{-1}

Time consuming and costs of mechanized planting in comparison to manual planting and mounding are competitive, the only limiting factor for implementation of the mechanized planting practice is short planting season and long payback period of the investments.

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ENVIRONMENTAL IMPACTS OF FOREST HARVESTING OPERATIONS ALONG A GRADIENT OF MECHANIZATION

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Abstract: With forest ecosystems storing more than 80 percent of terrestrial aboveground carbon and more than 70 percent of soil organic carbon, forests can serve as a mitigative agent for increasing carbon dioxide (CO_2) concentrations in the atmosphere, a greenhouse gas contributing to climate change. Climate change affects forest ecosystems, impacting timber production and eco-services. Conversely, sustainable forest management has been identified as a means to help mitigate carbon dioxide emissions, while also maximizing multi-use benefits through close-to-nature silviculture. While benefits of sustainable forest management are recognized, a better understanding of energy-intensive harvest operations presents an opportunity to further mitigate environmental impacts associated with the procurement of timber.

In this study, a life cycle assessment was performed on live harvest operations at three research sites to provide real-world understanding of the environmental impacts associated with harvesting systems typical of Germany: motor-manual (chainsaw and forest tractor), semi-mechanized (single-grip harvester, chainsaw, and forwarder), and fully-mechanized (single-grip harvester and forwarder). Environmental impact categories assessed include greenhouse gas emissions, particulate matter emissions, and non-renewable energy consumption.

Results from the three research sites (two sites in Bavaria and one site in Hessen) were estimated on a machine basis. The semi-mechanized system resulted in the lowest environmental impact, the majority of which was attributed to felling and processing operations. Next, the environmental impacts were estimated for a complete stand rotation period and compared amongst the different harvesting systems. According to results, semi-mechanized harvesting systems had the lowest impact over the full rotation period as well as for thinning treatments when compared

to motor-manual and fully-mechanized systems. However, the fully mechanized system performed the best for final felling treatments where trees normally have a larger volume. With felling and processing receiving so much attention in the recent decades as harvesting methods and systems transition and technology advances, extraction still contributes significantly to the environmental impacts associated with harvesting operations. Even with variability between the research sites, the effects of longer extraction distances (e.g. 800 m vs. 400 m) and shorter log assortments (e.g. 2.0-3.5 m vs. 4.0-5.0 m) on the environmental impacts associated with forwarding were evident when evaluating the SM and FM systems. This places considerable importance on forest infrastructure planning (i.e. truck accessible road and machine operating trail layout) as well as strong operational coordination (e.g. log pile organization). There may also be room for operational or technological development (fuel efficiency improvement aside) to meet changing market demands for wood assortments and reduce environmental impacts. Although there are signs that motor-manual systems are used less frequently than in the past, they still play a significant role in many European countries, specifically in small-scale operations and difficult terrain. The forest tractor used in the motor manual system clearly had the greatest environmental impact, thus steering the direction of future improvements. Improving fuel efficiency, optimizing productive hours, and increasing extraction volume are some examples.

Considering variability between the research sites as well as the system boundary assessed, a diversified approach to harvesting operations may be considered, integrating semi-mechanized and fully-mechanized systems for different treatments throughout the rotation period.

Keywords: close-to-nature, environmental impacts, sustainable forestry, greenhouse gas emissions

IMPACT OF VEHICLE PASSES ON SOIL PHYSICAL AND HYDROLOGICAL PROPERTIES IN SOUTH KOREA

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Abstract:*Soil disturbance has been associated with mechanized timber harvesting operations. Mechanized extraction equipment using a small-shovel and a small-carrier has been primarily used in cut-to-length harvesting, while these technologies could be associated with the environmental impacts in South Korea. The objectives of this study were to compare the soil physical and hydrological properties of three types of soil disturbances: undisturbed area, small-shovel tracks, and skid trails. Soil physical properties were evaluated using a soil corer sampling method at 0-10 and 10-20 cm, and soil hydrological properties were determined with a field saturated hydraulic conductivity by Guelph Permeameter.The result showed that vehicle passes had a significant effect on soil bulk density, porosity, and saturated hydraulic conductivity. Particularly, the largest changes occurred in skid trails, since the trails were temporarily constructed and repeated vehicle passes. This study will provide a comprehensive understanding of the soil impact of mechanized extraction activities.*

Keywords: Mechanized extraction, Soil bulk density, Porosity, Saturated hydraulic conductivity

1. Introduction

Mechanized timber harvesting activities have generated alterations in soil physical and hydrological properties (Curran et al., 2005; Rejšek et al., 2011; Hartmann et al., 2014). Particularly, machine trafficking can cause soil impact such as soil compaction, deformation, and rut formation, since machines are being moved directly in the forest stand (Kolka and Smidt, 2004; Poltorak et al., 2018). In South Korea, mechanized extraction operationusing small shovel (5 metric ton weight crawler excavator with a 1.3m in max jar opening log grapple) with small-carrier (MST-800VD; Morooka Co., Ltd., Ryuugasaki, Ibaraki, Japan) are the traditional common form of extraction method on gentle to steep slope(Figure 1). However, alterations in soil bulk density (SBD), porosity (P), and water infiltration such as saturated hydraulic conductivity (K_{sat})by small-shovel logging system are largely unknown.

Therefore, in this study, we determined (1) changes in soil physical properties (SBD and P) at three locations (undisturbed, small-shovel track, and skid trail by small-carrier) at two soil depth (0-10 and 10-20 cm) and (2) evaluate the K_{sat} of forest soils (20 cm in soil depth) affected by the operations of the small-shovel and small-carrier.

(a)
(b)

Figure 6. Mechanized extraction with two types of machines: (a) steel-tracked small-shovel and (b) rubber-tracked small-carrier

2. Material and Methods

Study site

This study was performed in Joma-myeon, Gimcheon-si, Gyeongsangbuk-do (36°00'03"N, 120°06'36"E).The harvest stand was mixed-conifer stand composed of Korean red pine (*Pinusdensiflora*), Pitch pine (*Pinusrigida*), Mongolian oak (*Quercusmongolica*), and Cork oak (*Quercusvariabilis*). The study area was 15.1 ha, and minimum and maximum ground slope were 40 and 50%, respectively. The averagetree diameter at breast height, height, and stand density were 23 cm, 17 m, 142 m^3/ha, respectively. In addition, soil texture was classified from loamy sand (80% sand, 13% silt, and 8% clay)to sandy loam(66% sand, 23% silt, and 11% clay) by the USDA textural triangle method. The mean soil organic matter content of undisturbed hillslopes was low to medium (ranging from 4 to 11%; ISO 14688-1, 2017).

Harvest operations and machine description

A clear-cutting prescription was performed in the study area. Cut-to-length harvesting occurred between March and April 2017 using a manual felling with chain-saw and mechanized extraction. After felling, the extraction activities followed three steps: 1) throwing, rolling, and sliding logs with a gravity force by small-shovel with one or two passes, 2) constructing skid trail with 3m in width and 30% in trail grade by small-shovel, and 3) transporting logs using a fully loaded small-carrier with more than 10 passes at skid trail to a landing area.

The typical weight and ground contact pressure of small-shovel was 6 metric ton and 40 kPa, respectively. In addition, the small-carrier was designed with rubber crawler type to use on uneven ground condition by MorookaCo., Ltd., having an averagefully loaded weight of 12 metric ton (6 metric ton of empty vehicle weight) and an average ground contact pressure 40 kPa (15 kPa of empty vehicle).

Datacollection and statistical analyses

Soil samples were collected with a soil corer sampling method (Page-Dumroese et al. 1999). Samples were collected at 0-10 and 10-20 cm until 20 samples (total 60 samples) were collected for each soil disturbance type of undisturbed area, small-shovel tracks (one or two passes by a small-shovel), and skid trails (more than 10 passes by a small-carrier).Every sample was placed in ziploc bag and labeled with a sample number. In total, 60 samples were put into paper bags and oven-dried at 105℃ until constant weight. The SBD and P of each soil sample were determined by following the ASTM D854-00 method (ASTM Standard D854-00. 2000).

A Guelph Permeameter 2800K1 (GP; Eijkelkamp Soil & Water, Giesbeek, Netherland) was used to measure the field saturated hydraulic conductivity (K_{sat}; Kanwar et al., 1989).This technology was used to observe water infiltration rate until steady-state infiltration velocity conditions and helped improve accuracy (Elrick and Reynold, 1992). The water infiltration velocity tests were along the similar locations as soil sample and separately conducted by well height (5 and 10 cm) using an air-inlet tip. The water infiltration velocity was measured every 1 or 2 min until the steady-state flow condition at each of well height. The $K_{sat}$of each soil sample was calculated by following the Reynolds and Elrick (1986) equation:

$$K_{sat} = 35.22 \times (-0.0054 \times R_1 + 0.0041 \times R_2)$$

Where: R_1 water infiltration velocity (cm/sec) in well height of 5 cm

R_2 water infiltration velocity (cm/sec) in well height of 10 cm

The data analyses were conducted through IBM SPSS statistics software (IBM Corp, 2013). We tested for normality using the Shapiro-normality test and the Levene's test was used to check the variance homogeneity. Analysis of variance (ANOVA) was used to compare the level of soil physical and hydrological changes among three soil disturbance types: undisturbed area, small-shovel tracks, and skid trails. Post-hoc tests were also carried out according to the Scheffe's test (parametric) at the 5% significance level.

3. Results and discussions

Soil physical properties

Machine passes significantly increased SBD and reduced P by one-way ANOVA and Scheffe's test (Table1). SBD increased by an average 20 and 43 % in small-shovel tracks and skid trails, respectively. P simultaneously decreased by 16 and 34%, respectively. In addition, the largest changes occurred in skid trails which are constructed and repeated (more than 10) machine passes. One of the negative effects of road construction is the soil compaction by earth movement (Weindorf et al., 2013; Caliskan, 2013) and scraping (Laurance et al., 2009). In addition, the degree of compaction was affected by the number of machine passes (Williamson and Neilson, 2000; Solgi et al., 2016).

Table1.Soil bulk density (SBD; g/cm^3) and porosity (P; %) measurement at different locations (undisturbed area, small-shovel track, skid trail)

Measurement	soil depth(cm)	undisturbed	small-shovel track	skid trail	*p-value**
SBD	0-10	1.15^{a}±0.17	1.36^{b}±0.11(▲18%)	1.70^{c}±0.14(▲48%)	0.0021
	10-20	1.19 ^{a}±0.15	1.44^{b}±0.11(▲21%)	1.64^{c}±0.20(▲37%)	0.0001
P	0-10	56.6 ^{a}±6.56	48.4^{b}±3.98(▼14%)	35.7^{c}±5.23(▼37%)	0.0021
	10-20	55.2 ^{a}±5.55	45.8^{b}±4.13(▼17%)	38.3^{c}±7.42(▼31%)	0.0001

Note: *one-way ANOVA test, $p < 0.001$. The different letters in the each depth indicates that SBD and P between sampling locations are significantly different ($p < 0.001$).

Saturated hydraulic conductivity

Regarding the alterations of the field saturated hydraulic conductivity (K_{sat}), the test detected changes caused by machine passes (Table2).In addition, there was significantly differences between undisturbed area and machinery traffic ($p < 0.001$). The largest K_{sat} decrease was in the skid trail (more than 10 passes) and its may be generated impermeable layer.However, the K_{sat} of the small-shovel track and the skid trail were statistically similar ($p > 0.05$). These results may be due to the small sample size and of the great variation in the tests (Pirastru et al., 2013).

Changes in SBD altered the K_{sat}(Pirastru et al., 2013). Resultsfrom this study are similar findings. The K_{sat} was inversely related to SBD, meaning that a decrease in mean saturated hydraulic conductivity comes with an increase in mean SBD after machine passes (Figure 2).

Table2.Saturated hydraulic conductivity (K_{sat}; cm/sec) measurement at different locations (undisturbed area, small-shovel track, skid trail)

Measurement	unditurbed	small-shovel track	skid trail	*p-value**
K_{sat}	0.0085^{a}±0.01	0.0018^{b}±0.00(▼79 %)	0.0001^{b}±0.00(▼99 %)	0.0000

Note: *one-way ANOVA test, $p < 0.001$. The same letters indicates that K_{sat} between sampling locations are not significantly different ($p > 0.05$).

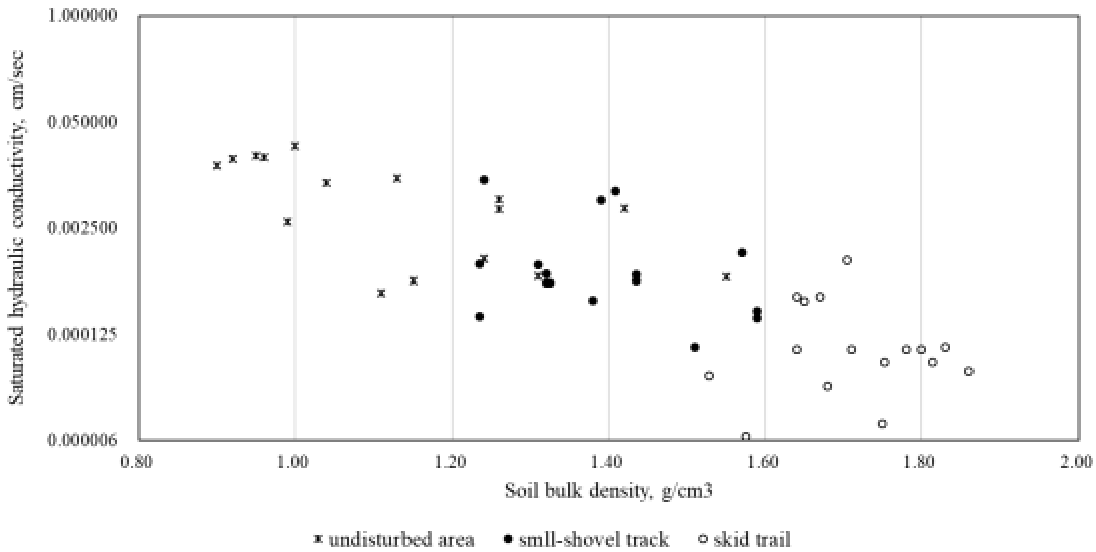

Figure 7. Relationship between saturated hydraulic conductivity and soil bulk density

3. Conclusions

Mechanizedextraction operation on steep slope may directly influence the soil impacts such as soil compaction and water infiltration such as hydraulic conductivity along small-shovel tracks and small-carrier trails. Wefound that changes in soil physical and hydrological properties by first one or two passes. Particularly, skid trails may be seriously associated with soil impacts including soil compaction and soil permeability compared to small-shovel track and undisturbed area. Therefore, a well plannedand controlled mechanized extraction activities should be guided to reduce its soil impact.

Acknowledgement

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ALTERNATIVE PRESERVATION METHODS TO MINIMIZE DRY MATTER LOSSES AND TO MAINTAIN FUEL QUALITY DURING WOOD CHIP STORAGE

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Abstract: *During the outdoor storage of fresh wood chips in large storage piles, high dry matter losses may occur due to fungal and microbial activity. This may also affect fuel quality parameters such as moisture content or ash content. Alternative fuel preservation methods might offer suitable solutions to minimize microbial activity and to avoid dry matter losses or fuel quality changes. In the current study, two methods for the preservation of forest residue wood chips were tested in laboratory trials (approx. 0.6 m^3, each) for 22 weeks: the addition of calcium carbonate ($CaCO_3$) and the storage of wood chips under anaerobic conditions (i.e. silage technology). Before and after storage, moisture content, ash content and the pH value of wood chips were determined for all batches. Furthermore, several batches were combusted in a 30 kW wood chip boiler. The addition of 2.5 w-% calcium carbonate resulted in lower dry matter losses (8.9 w-%) compared to the untreated reference fuel (14.9 w-%). The storage under anaerobic conditions showed almost no dry matter losses at all (≤ 1 w-%). The combustion tests showed an increase in particulate emissions due to the addition of $CaCO_3$. Thus, especially anaerobic storage might be a suitable method for minimizing dry matter losses and fuel quality changes for the storage of fresh wood chips. In addition, the lower emissions during combustion suggest anaerobic storage.*

Keywords: wood chip storage, fuel quality, dry matter losses, $CaCO_3$ additivation, anaerobic storage

1. Introduction

In 2014, approx. 3,400 biomass heating plants (> 150 kW) were in operation in Bavaria. Their annual demand for woody biomass is estimated to be 2.43 million t_{dry} while these plants provide a heat of about 6.4 TWh/a (Weidner *et al.* 2016). In these plants, forest residue wood chips are largely used. They are produced by chipping low quality wood assortments such as crown material that is deemed unsuitable for the timber industry. Compared to wood chips from stem wood, forest residue wood chips are characterized by potentially high ash contents of approx. 2 w-% (d. b.) and a high share of green biomass (e. g. needles), bark and small twigs. If wood chips are not pre-dried, they have a high moisture content of approx. 50 w-% (Kuptz & Hartmann 2015; Hofmann *et al.* 2018).

Due to the often occurring temporal gap between the production of forestry residue wood chips and their use as fuel, they are often stored for several months in wood chip piles. However, during the outdoor storage of fresh wood chips, high dry matter losses may occur due to fungal and microbial activity (Hofmann *et al.* 2018). In order to investigate new ways of avoiding such dry matter losses, this paper examined two alternative fuel preservation options, i. e. (I) anaerobic storage and (II) storage of fuels additivated with $CaCO_3$ (95 w-% $CaCO_3$, Walhalla Kalk GmbH & Co KG). In theory, during storage of wood chips under low-air or anaerobic conditions, the degradation of biomass, i. e. the loss of dry matter, might be reduced as microbes require O_2 for growth (Hartmann 2016; Kofman *et al.* 1999). The addition of $CaCO_3$, on the other hand, should shift the pH value towards a more neutral value, i. e. towards pH 7 as $CaCO_3$ reacts as a buffer. Thereby, degradation might be limited as wood destroying fungal growth is known to be favored by an acidic environment (Hartmann 2016).

2. Material and methods

2.1 Raw material

Fresh wood chips from forest residues (coniferous wood) were used for the preservation experiments. The material consisted mostly of Norway spruce (*Picea abies*) and was procured from the Bavarian State Forestry (BaySF). The wood was chipped with a Jenz A 582R drum chipper. For this purpose, a 30 × 30 mm screen and a conveyor belt discharge system was used. The chipper was operated with sharp knives.

2.2 Preservation methods

The wood chips were stored in open storage containers with a volume of approx. 0.6 m^3. The containers were equipped with an insulation layer on the outer walls to reduce temperature fluctuations. The storage period was 22 weeks from May until

October 2017. Storage was done in a rain and wind protected shelter. Temperature sensors (Datalogger testo 175-H1, Testo AG) were installed in each container and temperature was recorded every 5 minutes. Ambient air temperature and air humidity at the storage location were recorded every 5 minutes (Datalogger testo 175-H1, Testo AG). For all containers, the mass of the fuel was determined after filling with a crane scale (DINI ARGEO MCW1500, AS-Wägetechnik GmbH, accuracy ± 0.2 kg). Each container was weighed at a regular interval of 21 days.

Table 8: List of studied preservation methods

Type of preservation	Variant of preservation
$CaCO_3$ addition (aerobically stored)	0.5 w-% $CaCO_3$ addition
	1 w-% $CaCO_3$ addition
	2.5 w-% $CaCO_3$ addition
Anaerobically stored	Airtight sealed
	N_2 flushed (+airtight sealed)
Reference (aerobically stored)	Stored aerobically without treatment

Table 8 gives a list of the preservation methods and assortments. For anaerobic storage, two containers were sealed airtight (see Table 8). The containers with the addition of $CaCO_3$ and the untreated reference container were stored without sealing. All aerobically stored containers were equipped with a perforated container floor to allow air circulation.

For the storage of wood chips with $CaCO_3$ additivation, the fuels were mixed with three different amounts of $CaCO_3$ resulting in three different additive/wood ratios (Table 8). The three mixing ratios were 0.5 w-%, 1 w-% and 2.5 w-% of $CaCO_3$, based on the wood chips fresh mass. The fuels were thoroughly mixed manually with a shovel. Thereby, adding the respective amount of $CaCO_3$ was done stepwise to obtain a very homogeneous mixing. Fuel homogeneity after mixing of the material with the $CaCO_3$ was tested by measuring the pH (n = 9) and the ash content (n = 3, see section 2.3).

To examine anaerobic storage as a way of preserving wood chip quality, two alternatives were considered. On the one hand, storage was performed in an airtight sealed container. On the other hand, storage was done in an airtight storage container of the same design, but with additional nitrogen (N_2) flushing at the beginning of storage to displace the remaining oxygen (Figure 8). Both containers were closed with a polycarbonate plate, sealed with silicon and equipped with a fermentation bung to allow emerging gas to escape. Thus, the setup avoided overpressure in the containers and at the same time did not allow gases to enter.

Figure 8: Nitrogen flushing of the anaerobically stored container, with oxygen monitoring at the fermentation bung

For flushing the container with nitrogen, the N_2 was injected from below through a perforated double bottom into the container. To determine the end point of the N_2 flushing, the concentration of O_2 in the exhaust gas was measured at the fermentation bung with a Fourier Transform Infrared Spectrometer (FTIR) (Ansyco GmbH). The flushing was stopped as the O_2 concentration remained at a stable and very low level of $c(O_2)=0.05$ vol-% for several seconds.

2.3 Fuel property analysis

Before and after storage, fuel quality parameters of wood chips were determined according to international standards for solid biofuels. The moisture content ($n = 5$) was determined gravimetrically according to DIN EN ISO 18134-2 using a drying cabinet (FED 720, Binder GmbH). The ash content ($n = 3$) was determined according to DIN EN ISO 18122 in a muffle oven (Nabertherm GmbH). The pH value of the wood chips surface area ($n = 9$) was determined on the basis of DIN EN 15933 (Sludge, treated biowaste and soil - Determination of pH), since no standard for the pH determination exists for solid biofuels. According to DIN EN 15933, 150 ml of wood chips were mixed in each fresh state (before and after storage) with 750 ml of demineralized water and stirred for one hour. Stirring was followed by a waiting period of an hour in which the suspension had to remain closed airtight. Afterwards, the pH was determined for each assortment using a pH-electrode

(SenTix 41). The bulk density (*n* = 3) was determined according to DIN EN ISO 17828 prior to the storage. As it was demonstrated in earlier storage experiments, net calorific value does changes only marginally during wood chip storage. Thus, the net calorific value of the fuel was only determined at the beginning of storage with a calorimeter (C 2000 basic, IKA) according to DIN EN ISO 18125.

Dry matter losses were calculated from the mass of fresh fuels before and after storage and from the respective moisture contents. In addition, the energy content of the fuels before and after storage was determined on the basis of net calorific value (measured once before storage), the total fuel dry matter (DM) and the moisture content (i. e. minus the evaporation enthalpy of the water in the fuel) (Hofmann *et al.* 2018).

2.4 Emission measurements during combustion

Some of the fuels were combusted before and after storage. The boiler used for the combustion trials was a moving grate boiler (GUNTAMATIC Heiztechnik GmbH, Powerchip 20/30, constructed in 2010) with a lateral fuel insertion. The ash is removed via the moving grate to a screw conveyor which transports the ashes into the ash box.

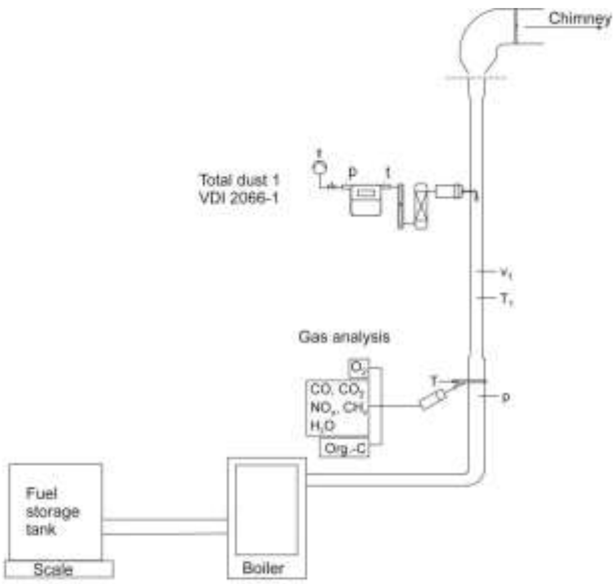

Figure 9: Experimental setup at the TFZ combustion test stand

To determine the fuel consumption during combustion, the storage tank was placed on a platform scale (Mettler-Toledo GmbH, MT KD600) with a resolution of 0.005 kg. The heat consumption was permanently regulated to a nominal load of 30 kW (± 8 %) following DIN EN 303-5. The gaseous components CO, CO_2 and O_2 were determined using a single component analyser (ABB Automation GmbH ABB AO2020), NO_X by a chemiluminescence detector (Eco Physics GmbH CLD 822 Mhr Analysator) and for water vapour content, SO_X, HCI and CH_4 an FTIR-analyser (Ansyco GmbH FTIR DX4000N) was used. The recording interval for the continuous measurement was set to 10 seconds. The total particulate matter (TPM) was measured following VDI 2066-1, applying a heated filter probe and a filter pre- and post-treatment temperature of 180 and 160 °C, respectively. The boiler was operated at a constant flue gas draught of -15±2 Pa as suggested by the boiler manufacturer. The diameter of the flue gas duct and the connecting pipe was 150 mm. The flue gas velocity was continuously measured using a vane anemometer (Höntzsch GmbH, ZS25/25-ZG4) positioned in a narrowed stretch of the measurement section with an effective diameter of 100 mm (Figure 9).

Prior to each trial, the combustion chamber, the heat exchanger and the fuel feeding system were completely cleaned using a vacuum cleaner, a brush and pressurized air. The storage tank was filled with sufficient amount of the tested fuel and the boiler was started and heated up to steady state operation at nominal load (30 kW) within approx. 2 hours. During nominal load operation, 5 particle samplings, each over 30 min, and continuous recording of the gaseous emissions were performed. The gaseous emissions were evaluated as mean values for all periods of PM samplings (30 min, n = 5). All reported emissions refer to dry flue gas at 0 °C and 1,013 hPa and are based on 13 % O_2.

The emission measurements were carried out after storage. The fuels used were the reference material and the material with had been pre-mixed with 1 w-% $CaCO_3$ (based on fresh mass). In addition, 2.05 w-% $CaCO_3$ in dry weight was added to a dry stored sample of the same starting material directly by dosing the additive directly into the screw conveyor of the fuel feeding system. The addition of 2.05 w-% $CaCO_3$ was chosen because 1 w-% additions at moisture content of 49.3 w-% corresponds to 2.05 w-% based on the air dry mass. The addition of the $CaCO_3$ in the screw conveyor was chosen to test (a) how far the storage with $CaCO_3$ influences the emission behavior compared to the exclusive co-combustion of wood chips with $CaCO_3$ and (b) whether additivation of $CaCO_3$ to wood chips fundamentally alters the emission behavior, as shown by parallel research projects for kaolinite at the TFZ. Before the combustion trials, all fuels were technically dried to a moisture content of 15 w-%.

3. Results and discussion

3.1 Fuel quality before storage

The untreated raw material had typical values for forest residues from coniferous wood in terms of moisture content, ash content and bulk density (Kuptz & Hartmann 2015) (Hofmann *et al.* 2018). Thereby, moisture content was suitable for the storage experiment as it was approx. 50 w-%, i. e. it should lead to microbial activity during storage of the untreated biofuels (Table 9). The ash content of the reference material was 0.9 w-%, which is slightly lower than usual for forest residues, indicating a higher proportion of stem wood (Table 9) (Kuptz & Hartmann 2015). As a result of the addition of $CaCO_3$, the ash content increased to levels of > 4 w-% (d. b., see Figure 14b in section 3.3).

Table 9: Selected fuel quality parameters of the raw material (SD= standard deviation, d.b. = dry basis, a.r. = as received)

Parameter	Mean value	SD
Moisture content (w-%)	49.3	0.6
Ash content (w-%, d.b.)	0.9	0.1
Net calorific value (MJ/kg, d.b.)	18.54	
Bulk density (kg/m^3, a.r.)	350.5	1.6

The pH values at the beginning of storage (Table 10) show a shift towards the neutral conditions by the addition of $CaCO_3$. This confirms the effect of $CaCO_3$ as a buffer in this experimental design. In addition, the low standard deviation of the mean values confirms the homogeneity of the mixing.

Table 10: pH values of the aerobically stored fuel before storage (SD = standard deviation)

	Mean value	SD
Reference	5.6	0.26
0.5 % $CaCO_3$	6.5	0.26
1.0 % $CaCO_3$	6.7	0.10
2.5 % $CaCO_3$	6.7	0.21

Figure 10 shows the bulk densities of the respective assortments at the beginning of storage. With increasing $CaCO_3$ addition, bulk density increased, too, while the reference material without additive had the lowest value. Interestingly, experimentally measured bulk density increased to a greater extent than expected compared to theoretical bulk density calculated from the changes in fuel mass due to $CaCO_3$ additivation. It is assumed that due to the mechanical stress during the additivation of $CaCO_3$ and the addition of the fine powder, the surface properties of the chips change which is believed to allow a denser package of the material.

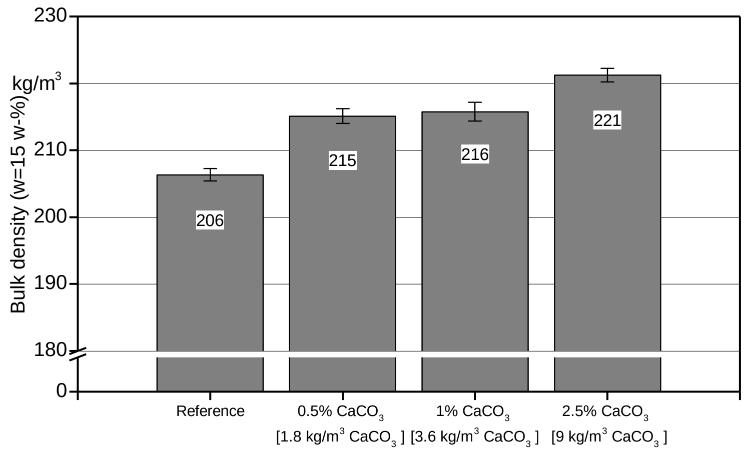

Figure 10: bulk density at the begin of storage in kg/m3 with a moisture content of 15 w-%

3.2 Temperature gradients and container weight during storage

The temperature profiles over the entire storage period showed clear differences between the aerobically and the anaerobically stored fuels (Figure 11, Figure 12). In the case of anaerobically stored wood chips, the temperature increased by about 5 °C above the ambient temperature during the first few days. However, after the first week of storage, the temperatures in the two containers were at the same level of the ambient air temperature and followed the daily variation, respectively (Figure 12). In contrast, for the additivated and the reference material, the temperatures inside the containers were on average well above ambient temperatures over the entire storage period (Figure 11). An increase in temperature is an indicator for microbial activity (Jylhä *et al.* 2017; Whittaker 2017). Thus, in the case of increased temperatures, an increased microbial and fungal activity can be assumed, which indicates a higher dry matter loss in the aerobically stored materials compared to the anaerobically stored materials (Hofmann *et al.* 2018).

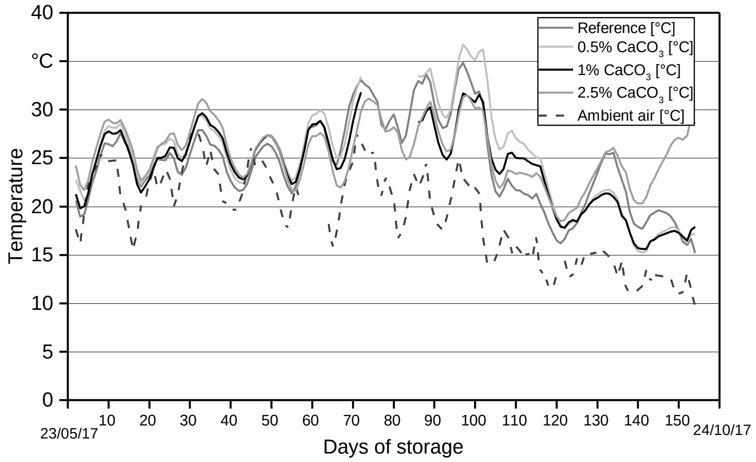

Figure 11: Temperature gradients of the aerobically stored fuels

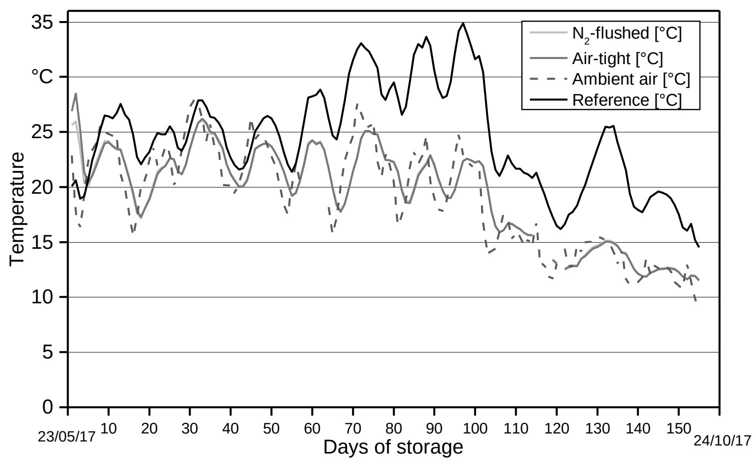

Figure 12: Temperature gradients of the anaerobically stored fuels

During the course of storage, the weight of the anaerobic containers remained at the same level indicating no change of the material while the weight of the aerobically stored containers decreased (Figure 13). Thereby, with increasing $CaCO_3$ addition, the container weight decreased less. Total weight changes are attributed to both, moisture and dry matter losses.

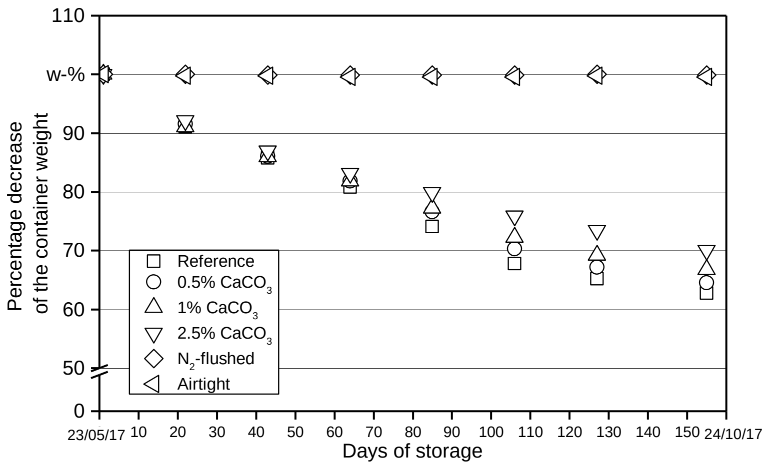

Figure 13: Time course of the container weights

3.3 Fuel quality after storage

After storage, pH values in the reference container were lower compared to pH before storage. This effect could not be observed for the fuels additivated with $CaCO_3$.

Table 11: pH values of the aerobically stored fuel after storage

	Mean value	SD
Reference	4.9	0.18
0.5 % $CaCO_3$	6.3	0.13
1.0 % $CaCO_3$	6.6	0.01
2.5 % $CaCO_3$	7.1	0.05

The moisture content of the anaerobically stored chips was unchanged after the storage period (Figure 14a). In contrast, the moisture content after storage of the reference container and of the wood chips with additivation showed strong drying effects (up to -19.3 w-% in the reference sample compared to the respective moisture content before storage). However, by trend, the moisture content of the material that was additivated with $CaCO_3$ increased with increasing amount of $CaCO_3$ added to the wood chips compared to the reference container. This means that drying was slowed down by the additivation. It may be assumed that this was due to reduced heat build-up as result of an inhibited microbial activity.

For anaerobic storage a similar interpretation is possible. The high moisture content after anaerobic storage and the small temperature increase during storage indicate that drying did not occur, as both, air exchange and microbial activity were largely suppressed.

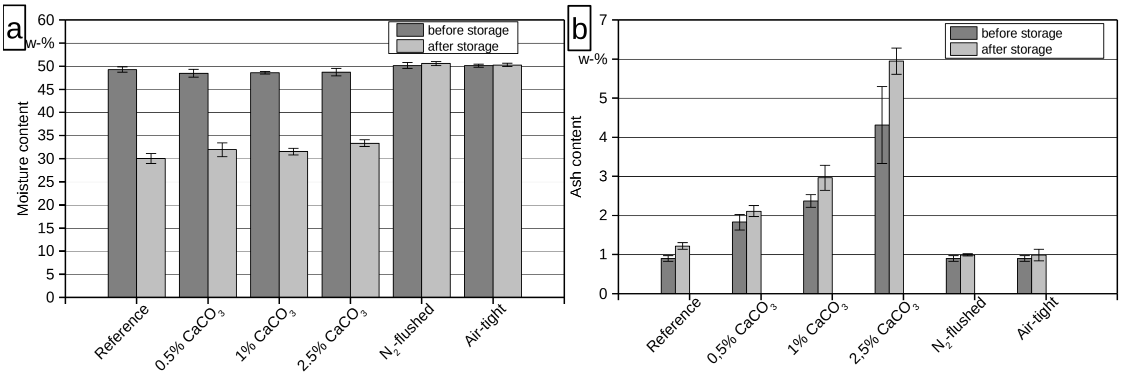

Figure 14: a) Mean moisture content (± SD, n=5) before and after storage b) Ash content (d.b., ± SD, n=3) before and after storage

After the storage period, ash content increased in each fuel compared with the values at the beginning of the storage (Figure 14b). This may be due to changes in dry matter (see also section 3.4) when cellulose or lignin are degraded while inorganic minerals remain (Lenz *et al.* 2017). An increased ash content can lead to mechanical problems during combustion, such as blocking of the ash discharge.

3.7 Dry matter (DM) losses and changes in energy content

Changes in dry matter (DM) showed a big difference between the anaerobically stored and the other variants (Figure 15a). The DM losses of the samples stored under anaerobic conditions were around 1 w-%, and were thus lowest among all stored fuels. Among the aerobically stored fuels, the container with 2.5 w-% $CaCO_3$ addition showed the lowest DM losses (8.9 w-%). DM losses increased up to 14.8 w-% for the material with 0.5 w-% $CaCO_3$ addition, i. e. to values similar to the reference (13.5 w-%). However, the observed slight increase in DM in the 0.5 % $CaCO_3$ variant could be due to outlier values as suggested by the high SD in moisture content of 1.5 w-% at the end of storage. Overall, both conservation methods, i. e. $CaCO_3$ addition and storage under anaerobic conditions, can reduce DM losses.

The results show that for each fuel, the total energy content (in %) decreased after storage compared to the starting material (Figure 15b). The smallest change in energy content was observed for the anaerobically stored fuels with only about 1 % decrease. Similarly, losses in energy content decreased with increasing addition of $CaCO_3$.

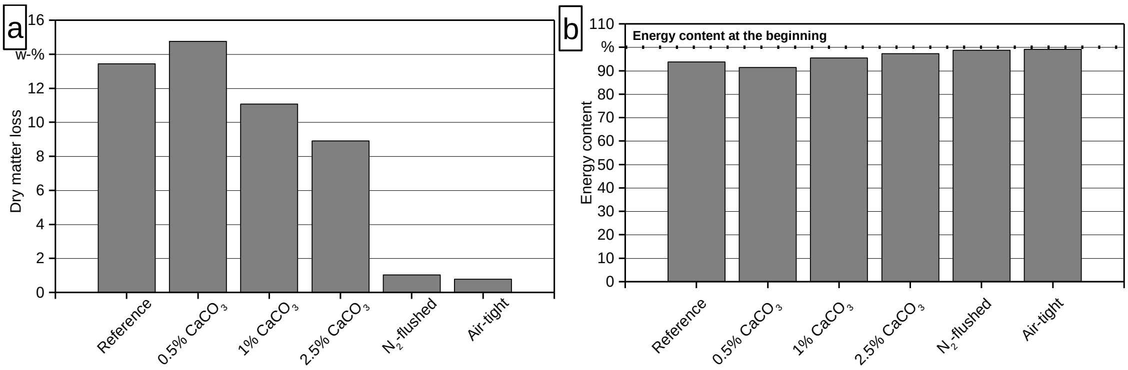

Figure 15:a) dry matter loss after the storage in w-% b) energy content of the wood chips compared to the raw material

3.5 Combustion trials

Combustion trials with the 30 kW boiler showed an increase in PM and CO emissions and a decrease in NO_X emissions due to the additivation of $CaCO_3$, compared to the reference material (Figure 16). None of the measured fuels were able to comply with the national thresholds for particle emissions of the German "First Ordinance of the Federal Immission Control Act" (1. BImSchV) for boilers < 1 MW, i. e. 20 mg/m^3 at 13 % O_2. In contrast, for CO, emissions of the boiler were below the respective limit of 400 mg/m^3 (at 13 % O_2) for all fuels. Thus, none of the fuels were suitable for use in small scale heating systems without additional exhaust gas cleaning systems such as electrostatic precipitators. Moreover, in contrast to additivation with kaolinite, the additivation of $CaCO_3$ increased emissions and, thus, is not advisable in terms of improving air quality (Hülsmann *et al.* 2018; Höfer *et al.* 2017).

For the usual field of application for which such preservation methods are conceivable, i. e. for larger heating (power) plants that can handle moisture contents at 50 w-%, however, other emission limits apply. These limits are set in the European Medium Combustion Plant Directive (MCPD). However, it must be mentioned that primary and secondary technical air pollution control measures are more economically viable in a higher performance range.

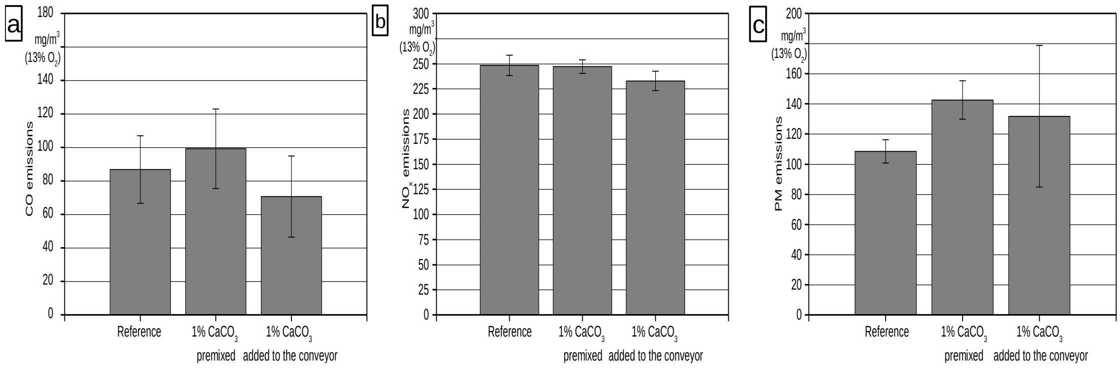

Figure 16: Emissions of combustion a) CO emissions b) NOx emissions c) PM emissions

4. Conclusion

Anaerobic storage might be a suitable method for minimizing dry matter losses, changes in ash content and changes in energy content compared to the reference material for the storage of fresh wood chips. However, due to the suppressed drying, the anaerobic storage of fresh wood chips is not suitable for small scale combustion systems. For large biomass heat (and power) plants that can use fuels with high moisture content, however, anaerobic storage can be a suitable method to organize a steady and efficient fuel provision chain over a heating season. However, due to the possibility that greenhouse gases such as CH_4 might be produced in anaerobically stored biomasses, further research is needed and it is currently ongoing at Technology and Support Center in Straubing.

One possibility for the anaerobic storage to be implemented into regular fuel production could be the use of unused concrete facilities for silage heaps. Another option could be so-called round bale wrappers from agriculture. These devices are used in agriculture to airtight packing of grass silage.

While the addition of $CaCO_3$ might also improve storage conditions due to changing pH, it might lead to elevated PM emissions during combustion. Moreover, the large amount of $CaCO_3$ needed to make distinct improvements in storage in larger piles could mean a high mechanical and financial burden in practice. Thus, the implementation of $CaCO_3$ additivation into usual storage practice is questionable. For a $CaCO_3$ admixture, the homogenization of the material with a wheel loader would be conceivable. Furthermore, an admixture directly in the chipping process should be investigated.

Thus, further investigations should also focus on whether these conservation methods are applicable in practice with regard to technical and economic feasibility.

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ASSESSMENT OF FOREST SOIL HYDRAULIC PARAMETERS BY INFILTRATION EXPERIMENTS TO MEASURE COMPACTION INTENSITY OF HARVESTING TRAILS

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Abstract: In several European countries like Germany and France, forest managers attempt to minimize harvesting machine traffic by setting up specific perennial extraction trails. It is essential to preserve long term trafficability of these trails, as rutting and compaction impair drastically soil drainage capacity. However, efficient and robust tools do not yet exist to predict water flow and water contents in compacted soils, which is a prerequisite for the improvement of harvesting management during rainy weather conditions. This study assesses the ability of BEST method (Beerkan Estimation of Soil Transfer parameters, doi: 10.2136/sssaj2005.0026) to characterize the degradation intensity of forest trails in terms of soil hydraulic properties. The BEST method provides the shape and scale parameters of water retention and hydraulic conductivity functions from particle-size distribution analysis and single ring infiltration experiments at null pressure head. Bulk density and infiltration measurements were carried out on trafficked (T) and undisturbed (C = control) topsoil of 10 plots from North-East of France. For trafficked topsoil, different settling intensities (low, moderate and severe) were defined by visual indicators (rut depth, soil structure and depth of hydromorphic tasks). The comparison of hydraulic parameters between the modalities T and C shows how hydraulic behavior of soil trails were affected by compaction. BEST method appears to provide relevant information regarding the evolution of soil hydraulic properties caused by soil compaction. This tool may be used to establish new classes of trails degradation in terms of hydraulic properties, thus completing visual indicators. Thanks to this dataset, we should be able to develop transfer function to estimate water properties of compacted soils from those of undisturbed one and indicators of settling intensity.

Keywords: forest soil, settling, soil hydraulic parameters, BEST method

ANALYSIS OF FOREST ENTERPRISES IN CATALONIA

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Abstract: The study provides an overview of the present level of mechanization of logging companies in the Autonomous Community (region) of Catalonia (Spain). Data had been collected through two main instruments: 1) survey to the forest companies, using both direct interviews and online survey, and 2) analysis of the subsidies granted by the local government (Generalitat de Catalunya) for the development of forest companies. About 50 companies answered the questionnaire, providing information regarding wood products annual output, available equipment and the number and skills of the workforce. In addition, interviewed persons provided an opinion regarding the more strategic actions to be taken by the public authority for supporting the local forest companies. Subsidies files were analyzed for the time span 2007-2015, providing info regarding the type of machine or service purchased, the total cost, the % covered by the public authority and some company details. Finally, the financial turnover of a subset of companies was considered over a minimum timespan of 8 years, aiming at identifying possible beneficial effects of the subsidies. Preliminary results show that Catalan forest companies are strongly differentiated in a large number of small companies, mostly providing general services (e.g. shrub reduction for forest fire prevention) with variable dedication to forest harvesting, and a reduced number of highly specialized companies, mostly dedicated to the production of timber and biomass. While the former type of companies are generally orientated to the purchase of small equipment (mulchers, winches and adapted agricultural tractors), the latter are rapidly adopting highly specialized equipment (processors, forwarders), further increasing the gap in operative and financial capacity. Regarding the economic trends and effect of the subsidies, larger companies clearly show the negative impact of the international financial crisis, with a peak in 2009, but were capable of slowly recover their pre-crisis turnover. Smaller companies, less related to the industrial timber market, show a more erratic trend: while the crisis did not affect directly their income, the subsequent market shrinkage prevented growth for most of them, probably due to the increased competition with larger and more competitive contractors. In general terms, subsidies do not show a clear beneficial impact for these companies, and this may be related to the fact that due to their limited financial capacity, most of small companies depend on public support for substitution of obsolete equipment, rather than for transition to a more competitive work system.

Keywords: *forest companies, subsidies, mechanization, innovation potential*

EFFECT OF SCREENING ON STORAGE BEHAVIOUR OF WOOD CHIPS

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Abstract: *The removal of fine particles such as needles or small pieces of wood and bark by screening might improve storage behaviour of wood chips due to increased pile ventilation and decreased degradation by microbes. Field trials on storage of screened and unscreened wood chips (forest residues, energy roundwood) in large piles (100 m^3, each) were performed for 5 month during summer of 2017. To monitor storage induced fuel changes, temperature sensors and a total of 36 balance bags were placed into each wood chip pile. Highest pile temperatures were measured in the unscreened forest residue wood chips (63 °C). Screening strongly reduced pile temperature and, thus, might reduce the risk of self ignition. Best drying (-20.9 w-%) was observed for the screened forest residue chips. Overall, wood chip piles of forest residues showed better drying, but wood chip piles of energy roundwood revealed smaller dry matter losses.*

Keywords: wood chip storage, screening, drying, fuel quality, dry matter losses

1. Introduction

Storage of fresh wood chips in large piles is important for biomass supply chains as it is used for drying of the bulk material but also to compensate for temporal and spatial differences in fuel supply and demand (Hofmann *et al.* 2018). Biological degradation processes during storage may cause high dry matter losses and a decline in fuel quality (Hofmann *et al.* 2018, Barontini *et al.* 2014, Lenz *et al.* 2015, Pecenka *et al.* 2014). These degradation processes might be increased by a large amount of fines, such as needles and leaves, due to their relatively large surface area and high amount of easily available nutrients for microbial growth. Furthermore, a large quantity of small particles might decrease pore volume within storage piles and, thus, decrease air exchange rates, leading to longer drying periods (Lenz *et al.* 2015, Pecenka *et al.* 2014, Mendel *et al*. 2016). The aim of this study was to investigate the effect of screening, i. e. the segregation of fines, on the storage behaviour of wood chips.

2. Materials and Methods

A field trial with four piles (100 m^3 each) of fresh wood chips was conducted in 2017 from May until October (22 weeks). The piles were established using two raw materials (coniferous wood chips from forest residues and from energy roundwood, see Figure 1) and two treatments (screened and unscreened). Chipping of fresh wood chips was done using a Jenz A 582 R mobile chipper equipped with a 30 × 30 mm screen and conveyor belt output. Screening was done before storage using a horizontal screening machine with 10 mm round hole sieves to separate fines.

Wood chip piles (10 m length × 6 m width × 3 m height) were build-up at a wood chip storage area near Munich (48.06° N, 11.74° E). The ground was neither graveled nor tarred. Piles were aligned in North-East direction. Each pile was equipped with a temperature sensor and covered with a vapour-permeable fleece (PolyTex, 200 g m^{-2}, Zill GmbH & Co. KG) to prevent remoistening by precipitation (see Figure 2). Pile temperature was measured at three heights within each pile (1.5 m, 2 m and 2.5 m) and on-site meteorological data was continuously monitored using a climate station (iMetos pro, Pessls Instruments).

Figure 1: Unchipped forest residues (left) and unchipped energy roundwood (right)

Figure 2: Fleece-covered storage piles (left) and balance bags for the measurement of dry matter losses and changes in moisture content (right)

During pile build-up, moisture content (M) was determined according to ISO 18134-2:2015-09 (see Table 1) for each of all four wood chip assortments (*n* = 24 per pile). Ash content (A) was determined according to ISO 18122:2015-10 (*n* = 12 per pile), net calorific value according to ISO 18125:2017-04 (*n* = 6 per pile). Particle size distribution of wood chips was measured according to ISO 17827-1:2016-03 (*n* = 3 per pile). Further analyses included bulk density (ISO 17828:2015-12) or content of chemical elements (ISO 16948:2015-05, ISO 16967:2015-04). However, these data are not presented in this text.

Table 1: Analysis methods for fuel quality parameters

Fuel quality parameter	Unit	Standard
Moisture content (M)	w-%	ISO 18134-2:2015-09
Ash content (A)	w-% d.b.	ISO 18122:2015-10
Net. calorific value (Q)	MJ/kg d.b.	ISO 18125:2017-04
Particle size distribution	-	ISO 17827-1:2016-03

To monitor dry matter losses and changes in moisture content, a total of 36 balance bags were placed in each wood chip pile during build-up (see Figure 2 and Figure 3). Thereby, bags were aligned in three cross-sectional areas per pile including three bags within the outer layer, 5 bags within the middle layer and 4 bags within the pile center (see Figure 3). After five months of storage, the bags were removed from the piles using a wheel loader which pulled them out via a rope which had been connected to each balance bag during pile build-up.

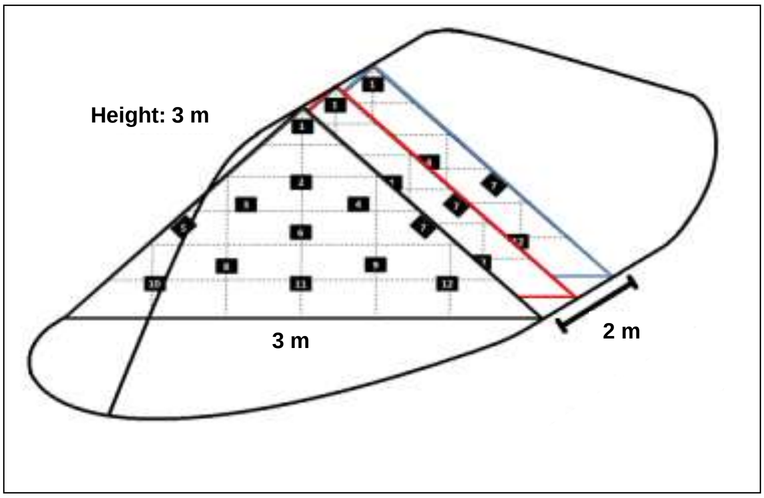

Figure 3: Distribution of balance bags (black squares) within a wood chip pile

Bag contents were analysed for dry matter losses, i. e. for changes in dry weight before and after storage, but also for fuel quality parameters such as moisture content, ash content, net calorific value and particle size distribution.

3. Results and Discussion

3.1 Fuel quality before storage

Before storage, moisture content of the unscreened biofuels was above 50 w-% (see Table 2) as it is typical for fresh wood chips (Kuptz *et al.* 2015). After screening, moisture content of the gained wood chip fraction was somewhat lower while the moisture content of the fine particle fraction was higher. Ash content was typical for energy roundwood while it was rather low for forest residues. This was probably due to low shares of twigs and needles in the forest residues used (Kuptz *et al.* 2015). As expected, screening reduced ash content in wood chips (Kuptz *et al.* 2016). The reduction was in the magnitude of up to 0.3 w-%.

Table 2: Mean fuel quality of screened and unscreened forest residue chips (FRC) and energy roundwood chips (ERC) before storage (d.b. = dry basis)

Wood chip piles	Moisture content	Ash content	Net calorific value
	w-%	w-% d.b.	MJ/kg d.b.
FRC unscreened	50.8	1.0	18.6
FRC screened	47.0	0.7	18.3
FRC fine particles	55.4	2.7	18.7
ERC unscreened	50.3	0.9	18.7
ERC screened	49.6	0.9	18.7
ERC fine particles	54.3	2.4	18.8

All four wood chip assortments could be classified as particle size class P31S according to ISO 17225-4 due to overall low shares of particles with a diameter < 3.15 mm (see Figure 4). Overall, wood chip quality before storage was typical for energy roundwood chips, while for forest residues it was higher compared to typical values (Kuptz *et al.* 2015).

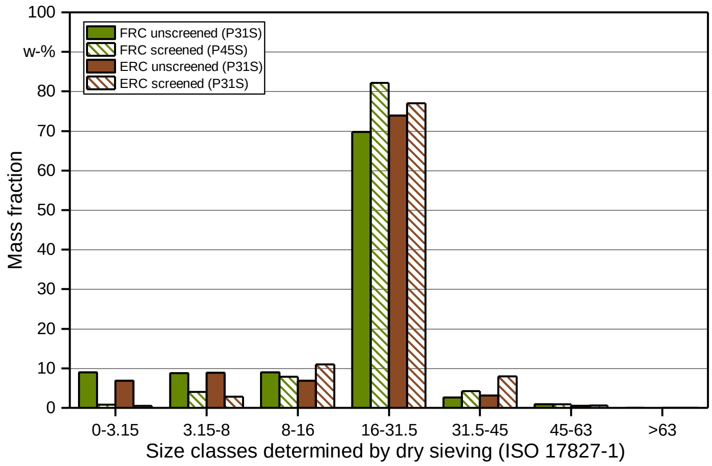

Figure 4: Mass fraction of size classes determined by dry sieving according to ISO 17827-1. (FRC = forest residue chips, ERC = energy roundwood chips)

3.2 Meteorological data and pile temperature

During the 22 weeks of storage, precipitation amounted to a total of 570 mm. Mean air temperature was 15.8 °C, mean relative humidity was 80.3 % (see Figure 5). Maximal air temperature during storage was 35.9 °C. Thereby, mean air temperature was similar compared to long-term mean values (May till October 2004–2016: 15.6 °C, climate station “Ebersberg” of the German Weather Service (DWD)). However, both May and June were warmer and dryer than long-term means of these two months.

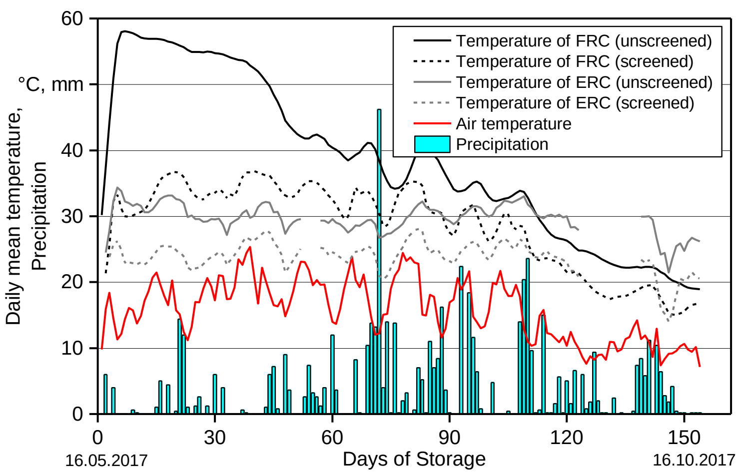

Figure 5: Daily means of air temperature, pile temperature (mean of three sampling points at 1.5 m, 2 m and 2.5 m above ground) and precipitation

during storage (FRC = forest residue chips, ERC = energy roundwood chips)

Within five days after build-up, pile temperatures of forest residue wood chips reached their maximum, followed by unscreened energy roundwood chips at day 16, screened forest residue chips at day 19 and screened energy roundwood chips at day 99 (see Figure 5). Highest absolute temperatures were measured in the unscreened forest residue wood chip pile (63 °C, see Table 3).

Overall, pile temperature was higher for forest residues compared to energy roundwood and for unscreened compared to screened chips (Hofmann *et al.* 2018). High shares of green biomass (e. g. needles) may offer easily available nutrients for microbial growth. Thus, microbial activity should be higher in forest residues compared to energy roundwood, leading to higher temperature due to respiratory processes (Hofmann *et al.* 2018, Mendel *et al.* 2016). Similarly, screening might reduce pile temperatures due to lower shares of green biomass but also due to an increased pile porosity and, thus, due to better ventilation (Lenz *et al.* 2015, Pecenka *et al.* 2014, Mendel *et al*. 2016). Therefore, warm air within piles is obviously removed more easily in screened compared to unscreened piles. As a side effect, pile temperatures of screened wood chips followed daily changes in air temperature more closely than for unscreened wood chips.

3.3 Fuel quality after storage and dry matter losses

During 22 weeks of storage, in all wood chip piles drying caused a decline in moisture content between 14.8 and 20.9 w-% (see Table 3). Best drying was observed for screened forest residues (-20.9 w-%) leading to a moisture content of 26.1 w-%. Thereby, moisture content of screened forest residues was significantly lower after storage compared to the other assortments ($p \leq 0.05$, Student's T-Test). Overall, wood chip piles of forest residues showed better drying than wood chip piles of energy roundwood. This might be due to the overall higher pile temperatures within forest residue piles (see Figure 5 and Table 3).

Dry matter losses ranged from 5.4 to 8.6 w-% during the 22 weeks of storage (see Table 3). Thereby, dry matter losses were higher in forest residues compared to energy roundwood. The higher amount of green biomass in forest residues chips such as needles compared to energy roundwood chips might offer higher shares of easily available nutrients for microbial growth and, thus, might enhance biological degradation.

Table 3: Maximal pile temperature (Tmax) during storage, mean fuel quality after storage (M = moisture content, A = ash content, Q = net. calorific value), change in moisture content (ΔM) and dry matter losses (DM) of screened and unscreened forest residue chips (FRC) and energy roundwood chips (ERC) (d.b. = dry basis)

Wood chip piles	T_{max}	M	ΔM	A	Q	DM
	°C	w-%	w-%	w-% d.b.	MJ/kg d.b.	w-%
FRC unscreened	63	35.4	-15.4	1.0	18.9	7.3
FRC screened	45	26.1	-20.9	0.7	18.6	8.6
ERC unscreened	38	35.0	-15.3	0.9	18.9	7.0
ERC screened	33	34.8	-14.8	0.8	19.0	5.4

Interestingly, for forest residues, dry matter losses were higher in screened compared to unscreened chips while for energy roundwood, the opposite was observed. An explanation may be found in the fact, that with forest residues, screening does not sufficiently remove enough of their high share of crucial green fractions whose microbial activity is at the same time not anymore inhibited by oxygen depletion which is prevented by screening. In contrast, with screened energy roundwood microbial activity and dry matter losses are assumed to be lower, as mean pile temperature is usually below 25 °C and thus below the optimal temperature for fungal growth.

Ash content did not change during storage. In contrast, the net calorific value increased slightly by approx. 0.2–0.4 MJ/kg (see Table 3). This might be due to higher degradation of cellulose compared to lignin due to the abundance of individual species of fungi. However, no correlation could be observed between dry matter losses and net calorific value or between dry matter losses and ash content.

The energy content of the total bulk volume before and after storage was calculated by total pile dry mass, mean moisture content and net calorific value. The choice of the net calorific value instead of the gross calorific value as calculation basis reflects the current practice of most heating plants which do not make use of latent heat facilitation from flue gas condensation. Overall, energy content during the 22 weeks of storage increased for all 4 wood chip piles by 0.5 to 2.7 %. This was due to strong drying and low dry matter losses compared to the energy content at the beginning of the trials. Thus, dry matter losses were more than compensated by reduced moisture content over the warm summer of 2017. No clear trend could be observed between assortments. However, approx. 18 w-% and 16 w-% of dry mass were removed by screening from forest residues and energy roundwood chips, respectively. Thus, if this fine fraction would need to be regarded as a loss, a total of approx. 19.3 % of energy would be lost for screened forest residues and 14.7 % for screened energy roundwood. Consequently, suitable uses for the screened fine particle fractions should be sought, such as combustion in larger biomass heating plants, bedding of farm animals or composting.

4. Conclusion

Screening of wood chips reduced pile temperature due to higher porosity (i. e. better ventilation) and lower microbial activity (i. e. lower shares of nutrients). Thus, screening may reduce the risk of pile self ignition. For dry matter losses and fuel quality, no clear trend could be observed, as microbial activity, pile temperature, porosity, O_2 abundance and ventilation are strongly interlinked leading to better drying and higher dry matter losses in forest residues. However, this was not the case for energy roundwood.

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EFFECTS OF SOIL CLAY CONTENT ON RUT FORMATION

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Abstract: *In Sweden harvesting operations are performed throughout the year to ensure deliveries of fresh high-quality wood to saw mills and pulp and paper industries. It is challenging to operate heavy forest machinery all year round and at the same time minimise ground impacts. Depending on ground bearing capacity and machine configuration, rut formation and soil compaction is more or less likely. To help minimise ground impacts, planning and decision support tools have been developed using information on e.g. topography, soil type and estimated soil wetness to predict terrain trafficability. The current available soil type maps have variable quality and resolution in different parts of the country, and therefore needs development to match the demands on digital data in the forestry sector. SLU and the Geological Survey of Sweden has developed a detailed digital clay content map for agricultural lands. In a part of Sweden where this mapping was done for forest land as well, rutting in four final felled stands had already been surveyed as a part of Skogforsks evaluation of the depth to water maps. In the inventory the number of ruts were counted, and a classification were made of their length (4 classes) and dept (3 classes). This inventory data was combined with the clay content map to investigate the correlations between rutting and clay content. Results shows that the number of ruts per ha tends to increase with increasing clay content in the soil. An increase in clay content also increased the number of long ruts as well as the number of deep ruts. Based on the results clay content maps are likely to improve predictions of terrain trafficability. However, there is a need to analyse their interactions with the currently used digital terrain models and depth to water maps to ascertain that the clay content map provides additional information. New clay content maps have to be produced for forest land before they can be incorporated in planning and decision support tools, and further studies are needed to confirm the results of this small pilot study.*

Keywords: soil compaction, harvesting, forwarding, strip roads, decision support

1. Introduction

In Sweden harvesting operations are performed throughout the year to ensure deliveries of fresh high-quality wood to saw mills and pulp and paper industries. This also enables forest companies and forest owner associations to provide their own harvesting teams as well as their contractors with full time work throughout the year, thus enabling an efficient use of harvesters and forwarders.

Ground-based logging operations can cause rut formation and soil compaction (Wronski and Murphy 1994; Cambi et al. 2015), which can lead to negative impacts of future forest growth. Furthermore, rutting is considered aesthetically negative by both forest owners and the general public. Thus, Swedish forestry faces the challenge of how to operate heavy forest machinery all year round and at the same time minimise ground impacts. Depending on ground bearing capacity and machine configuration, rut formation and soil compaction is more or less likely. Therefore, a combination of planning, adaption of harvesting techniques and technical solutions are used to minimise ground impacts.

Recently planning and decision support tools have been developed to help minimise ground impacts using information on e.g. topography (Mohtashami et al. 2012), soil type and estimated soil wetness (depth to water maps) (Mohtashami et al. 2017) to predict terrain trafficability. An obstacle to use soil type in these applications is that the current available soil type maps have variable quality and resolution in different parts of the country, and especially so for forest lands. The soil type maps need development to match the demands on digital data in the forestry sector. SLU and the Geological Survey of Sweden (SGU) has developed a detailed digital clay content map for agricultural lands. This newly developed "Digital Map of agricultural land" contain estimates of clay and sand content (Söderström et al. 2016 a). In a pilot project, they have made a digital map of the clay content of arable land in Norrland for a 24000 km^2 area (figure 1) between Östersund and the Bothnian coast (Söderström et al. 2016 b). This area contains a lot of forest land and it was therefore interesting to investigate if this map provides an alternative to existing soil type maps. The occurrence of ruts had already been surveyed on four logging sites within this area for a study of the usefulness of depth to water maps (Bergqvist and Friberg 2016).

The aim of the study was to evaluate the correlation between the clay content estimates and rut occurrence and rut severity for the four sites were data already had been collected.

2. Material and methods

Data from four sites that were surveyed within the STIG project were used to evaluate the clay content map. The data had originally been used to evaluate the depth to water (DTW) maps, and as a part of that project operators had access to the DTW-maps when the sites were harvested. The survey data gathered for these sites contain information about all ruts within each site. Position, length, depth and estimated number of passes has been measured or classified for each rut. Rut length were classified in 4 classes (1-5 m, 5-10 m, 10-20 m, >20 m), rut depth was divided in 3 classes (10-20 cm, 20-50 cm, >50 cm), and number of passes were estimated in 3 classes (1-5 passes, 6-10 passes, >10 passes) (Bergqvist and Friberg 2016). GPS-positioned roads and ruts were projected onto the GIS-maps to extract corresponding soil and moisture classes to the field data and to measure the length of road segments in corresponding classes on each map. The new clay content layer was added to this GIS.

The clay content map is based on soil type data from the European LUCAS database, a digital elevation model with 10 m pixel size, soil type maps from SGU, and gamma sensor information (Söderström et al. 2016 b). The resolution of SGU:s soil type maps varies, in some part of the area, i.e. populated areas, the scale is 1:25 000 – 1:100 000; in others there is a medium detailed scale of 1:200 000, but there are forest areas in scale 1:750 000. Unfortunately, the four sites surveyed in the STIG project falls in the last group.

To simplify analyses and handling in the GIS clay contents were classified into four classes:

clay content < 5 %

5 % ≤ clay content < 10 %

10 % ≤ clay content < 15 %

15 % ≤ clay content < 20 %

The sites were dominated by clay content class 1 (Figure 1), and no substantial areas with a clay content over 20 % were noted on any site.

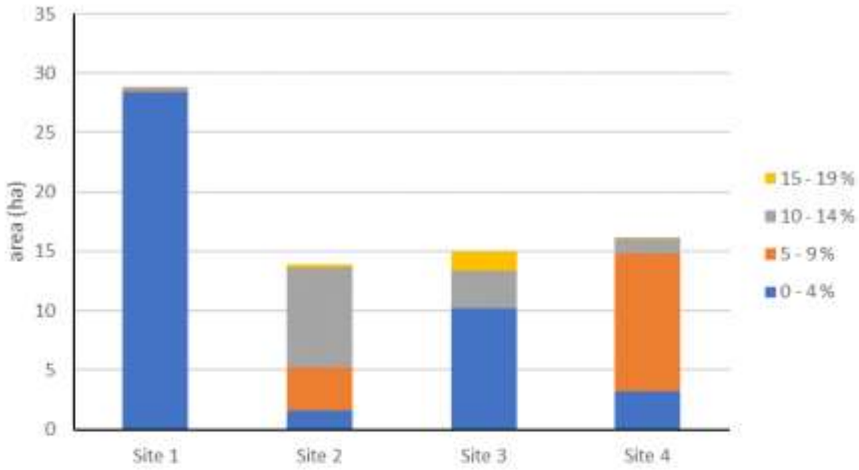

Figure 1. Site area and clay content class distribution.

3. Results

The highest number of ruts occurred on medium trafficked roads, and the least on high trafficked roads (Figure 2). This is not surprising since there are less high trafficked roads per ha and these roads are placed in favourable parts of the terrain. There is a non-significant tendency that the number of ruts increase with increasing soil clay content.

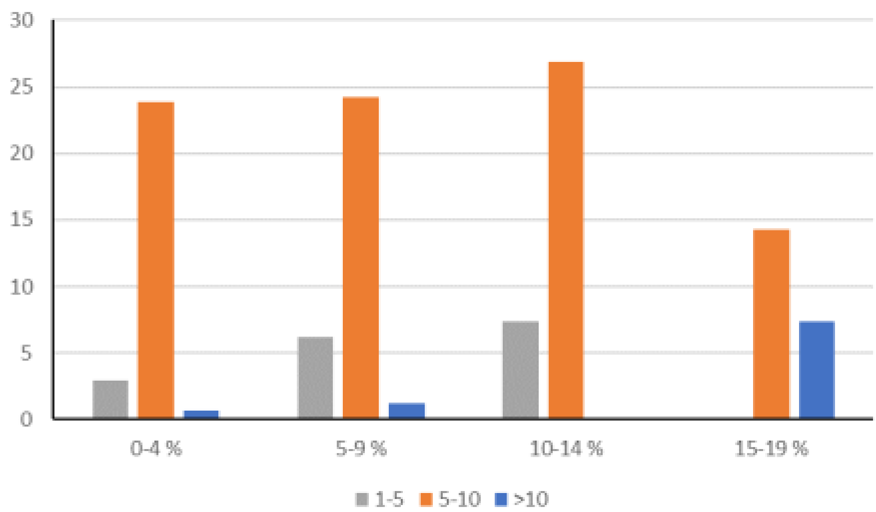

Figure 2. Number of ruts per ha depending on clay content and number of passes.

If site 1 is excluded from the analysis there is a tendency that the frequency of ruts increases with clay content as well as the frequency of deeper or longer ruts (Table

1 and 2), unfortunately this cannot be verified due to the large variability between sites.

Table 1. Number of ruts per ha separated on rut length, clay content class and site.
– means that the clay content class did not occur within the site

		Clay content			
Site	Rut length	0–4 %	5–9 %	10–14 %	15–19 %
1	1-5 m	30,1	714,3	16,5	-
	5-10 m	4,2	53,6	4,7	-
	10-20 m	0,5	0	0	-
	> 20 m	0,3	0	0	-
2	1-5 m	12,2	62,5	27,9	0
	5-10 m	3,2	10,5	5,3	0
	10-20 m	0	1,1	0,5	0
	> 20 m	0	0	0,8	0
3	1-5 m	16,1	-	23,5	21,0
	5-10 m	0,1	-	0,3	3,0
	10-20 m	0	-	0	0
	> 20 m	0	-	0	0,6
4	1-5 m	1,6	11,6	56,4	0
	5-10 m	0	0,6	4,55	0
	10-20 m	0	0	0,8	0
	> 20 m	0	0	0	0

Table 2. Number of ruts per ha separated on rut depth, clay content class and site.
– means that the clay content class did not occur within the site

		Clay content			
Site	Rut depth	0–4 %	5–9 %	10–14 %	15–19 %
1	10-20 cm	14,0	214,3	4,7	-
	20-50	20,4	535,7	16,5	-
	> 50 cm	0,7	17,9	0,0	-
2	10-20 cm	5,1	36,9	13,6	0,0
	20-50	9,6	35,5	19,5	0,0
	> 50 cm	0,6	1,7	1,4	0,0
3	10-20 cm	9,8	-	17,1	16,2
	20-50	5,1	-	6,8	7,8
	> 50 cm	0,0	-	0,0	0,0
4	10-20 cm	1,6	8,1	45,1	0,0
	20-50	0,0	4,1	16,5	0,0
	> 50 cm	0,0	0,0	0,0	0,0

4. Discussion

Due to the limited material used for this pilot study, it is hard to come to any final conclusions on the usability of the clay content maps. Clay content maps were tested on material from only four sites, and one of these sites lacked variation in clay content. The study shows that these maps can be a help to find sensitive areas so that traffic in these areas can be minimised during harvesting operations. However, there is need to further studies on how these maps interact with other information already provided to the operators. There are indications of correlations between the clay content and the DTW index for the studied sites. It may be so that the correlation with information from DTW-maps and digital terrain models are so large that the added value of clay content information is limited.

In the areas where detailed soil type maps are available, they can be used to classify the soil in bearing capacity classes. These classes have a significant influence on the risk for rut formation (Mohtashami et al. 2017). However, in the areas where only low-resolution soil type maps are available, some of the soil types are too general to be classified in a bearing capacity class. The most common group of soils in Swedish forests are till soils (moraines), and they are not separated into soil types in the low-resolution maps. The difference in trafficability and how trafficability is affected by soil water between a sandy, gravely till soil and a clayey silty till soil is large. The clay content maps will provide at least an idea of how fine grained the soil is even in areas with a low-resolution soil type map and should therefore provide some additional information to that already in use.

Before a new study is made there are some factors that influenced the results which should be highlighted and taken into account. The new study should not be made in an area where the lack of high resolution soil type maps is a limiting factor for the clay content maps. This can easily be achieved by performing the study in an area in southern Sweden where the forest land is closer to agricultural land and populated areas. Furthermore, more sites need to be surveyed and sites with little variation in clay content should be avoided if possible.

In a long perspective it would perhaps be more advantageous to have maps on silt content than on clay content, as it is well known that silt soils have lower strength than clay soils. Furthermore, silt causes problem with frost heaving of planted seedlings, increases the costs for road construction, and may limit the use of those roads to dry or frozen conditions. However, at the moment it is unclear if the methods to model clay content can be modified to model silt content.

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WINCH-ASSIST FORWARDERS OPERATING IN BRITISH COLUMBIA: PRODUCTIVITY AND TENSION MONITORING

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Abstract: Winch-assist logging systems, based on integrated or autonomous winch machines, are rapidly spreading to steep slope forest operations around the world. First developed for wheeled CTL machines in Central Europe in the 1990s and subsequently for tracked machines in New Zealand in late 2000s, the implementation of these systems is increasing in all forest industries operating in steep terrain, including the North American west coast. The advantages of this new approach to steep slope forest operations are mainly related to the extension of the operating range of fully mechanized systems with potential benefits related to productivity, cost-effectiveness, and safety of forestry workers. The aim of this study was to analyze the performance of large winch-assist forwarders equipped with integrated winches operating in British Columbia, focusing on the productivity rate and safety level related to the use of the support cables. The study was conducted in three different harvesting sites during the winter of 2017/2018 in the Interior of British Columbia. It comprised three different machines and operators and nine different corridors for a total of 29 work cycles. The data collection was based on a machine-control-unit (based on a camera and an inertial measurement unit integrated with a GNSS sensor) installed on the machines for the time study and the special event detection. A high-frequency tensiometer was used for the rope tension monitoring. The wood volume extracted for each forwarder cycle was estimated through scaling and corrected pictures taken at the landing before the unloading phase. The corridor profiles were measured directly in the field or, wherever not possible, extracted from digital elevation models and using the GPS position of the machine. The data analysis was based on the synchronization of the full set of data and the use of statistical software for the descriptive statistics and the significant variables detection.

Keywords: Winch-assist, Forwarder, Productivity, Cable tension, Tension monitoring

SKYLINE TENSION MONITORING OF CABLE YARDING SYSTEMS IN THE ITALIAN ALPS

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Abstract: The cable yarders represent one of the most common system for steep slope forest operations in the Alps. This system is based on the use of tensioned skylines, which should operate continuously under a specific Safe Working Load (SWL) in order to guarantee a proper safety level for the forest operators.

The aim of this study is to analyse the operative skyline tensions in real harvesting sites, working with different cable systems and rigging configurations, identifying the frequency of the overcoming of the SWL and the main factors influencing the peak tensions and the dynamic amplification.

The analysis was conducted on 12 different cable lines in the North-Eastern Italian Alps, equally distributed between single-span and multiple-span configurations, monitoring totally 502 work cycles. The surveys interested 11 different cable yarders and 10 different logging companies.

The data collection was based on a high-frequency tensiometer, for the skyline tension monitoring, and on a machine-control-unit (based on a camera and an inertial measurement unit integrated with a GNSS sensor), installed on the carriages, for the time study and the special event detection. Each cycle load was measured at the landing. The line and corridor profiles were extracted from a digital elevation model derived from Lidar data and using the GPS position of the support elements. The data analysis was based on the synchronization of the full set of data and the use of statistical software for the descriptive statistics and the development Mixed Effect Models for the significant variables detection.

The results showed that more than 53% of the cycles observed exceed the SWL. The most critical conditions were recorded in the single-span

configurations where more than 73% of the cycles exceeded the SWL and 3% of the cycles overcame the endurance limit of the skylines, generating a potential decrease in the lifespan of the ropes and potentially increasing the risk for the operators.

Keywords:Cable yarder, Cable tension, Alpine region, Safe Working Load, Mixed Effect Models

PERFORMANCE OF GRAVITATIONAL CABLE YARDING OPERATIONS IN STEEP-TERRAIN GROUP SHELTERWOOD SILVICULTURAL SYSTEMS

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Abstract: Cable yarding operations represent the backbone of steep terrain harvesting. Nevertheless, their share in steep terrain harvesting varies widely across the world. In Romania, cable yarding is less used even if it would be more suitable for such operational conditions, especially when dealing with low accessibility or there is a need to operate on sensitive areas. A study was implemented to evaluate the time, fuel consumption and productivity of a gravitational cable yarder operating in group shelterwood extractions deployed in steep terrain beech forests. To this end, relevant operational variables were selected as predictors to model the time consumption based on a number of 558 observations. For the average conditions described by an extraction distance of 326 m, a lateral yarding distance of 43 m, a payload of 1.87 m3 per turn and a terrain slope on the lateral yarding direction of 17°, the yarding cycle time was estimated to about 12.5 minutes. Notable as share in the yarding cycle time were the load attachment (28%), cable pull in and load lift (19%), cable pull out (16%) and load detachment (13%), with the second and the third work elements being significantly affected by very high lateral yarding distances. Productivity was estimated to 8.80 m3 over bark × h-1 and efficiency was estimated to 0.11 h × m-3 over bark. Fuel consumption was estimated to 0.28 l × m-3 over bark, being in line with the kind of technology used, and less compared to that reported for tower yarders. Based on the available figures of steep terrain harvesting in Romania, the study concludes that cable yarding could be more suitable to such conditions and a better fit for environmentally sensitive areas.

Keywords: cable yarding; gravity; performance; fuel consumption; group shelterwood

THE EUROPEAN CHAINSAW CERTIFICATE (ECC) SINCE 2009 TO 2018: DEVELOPMENT AND ACTIVITIES

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Abstract: Mobility of forest operators within the European Union is gradually growing. Some countries have reliable certification systems to test the knowledge and skills of those people, but a shared certificate was still missing. Moreover, it is difficult to assess the validity of foreign certificates. The development of European standards would allow national certificates to add a European recognition to their brand, thus increasing the value for workers who want to work in other member states across the EU. A European standard gives the opportunity to participate in an internationally recognised system to countries that do not have a certificate now. This would increase transparency and workforce mobility within the European trade area and thus strengthen the forestry, arboricultural and green area management sector, with special attention to the use of chainsaw that is still the most common tool in forest operations in many countries. Certification is also often requested by occasional chainsaw users which will enhance the safety and health among non-professional target groups. Since June 2009 in Europe, a new organisation has been active, known as the 'European Forestry and Environmental Skills Council' (EFESC). EFESC has been formed as a result of the Leonard project: "Evaluation and Implementation of Chainsaw Operators Certification". EFESC is an organisation where delegates are represented by various stakeholders throughout Europe. Training centres, EU branch organisations of forest industry, trade unions, manufacturers of tools, machines and equipment for forestry work or environmental work, certification schemes, are examples of stakeholders directly involved in EFESC. The objectives of EFESC are to: - develop minimum qualification standards in professions like forestry, landscaping, tree-work and or horticulture, contributing to the harmonization and improvement of qualification in the above mentioned professions in Europe; - improve safety standardizing common procedures for an efficient and safe work; - improve workforce mobility thanks to the reciprocal recognition of certificates among countries involved in EFESC; - encourage lifelong learning and continuous professional development; - encourage interchangeability of existing national chainsaw certificates. European Chainsaw minimum Standards (ECS) have been developed for different skill levels in chainsaw use. Currently standards are available for the following skill levels:

SMART CHAINSAW
- ICT AND IOT ON MANUAL CHAINSAW OPERATION FOR SAFETY AND PRODUCTIVITY AT FORESTRY OPERATION –

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Abstract:There are no forestry operations without chainsaw operation by manual work. A chainsaw equipped with sensors and a data process system was developed to know the maneuver for felling, delimbing, crosscutting and so on. Machine 3D movements, power, control, saw speed and location were obtained to be interpreted into the productivity and are utilize to grasp how these processed. ICT enabled sensors on the chainsaw to see the posture, movements, vibration and the mechanical movements through process transition probability. This provides operational efficiency and also enables worker operation assist, such as adequate cutting for not well/enough trained workers for safety and such as for experienced workers for efficient sequence of operation for productivity. Also a set of the utilization and the further utility for regional/national/grovel management and control on the handheld machinery were discussed.

Keywords: chainsaw, manual work, safety, productivity, ICT, IOT

Introduction

There are no countrieswhich have been suffering from frequent accidents at manual chain saw operations in forestry business. Even in the countries where have vehicle based sophisticated forestry operation much consideration waspayed for manual works.

The smart chainsaw is one of these machineries in the field but which is close to human activity. By sensors multi data are obtained on the condition of the human operation. The data can be utilized for productivity management and safety management.

Definition, function and utilization of Smart Chainsaw

Motion and maneuver sensor equipped chainsaw together with data process, evaluation, understand and communication function/system is named Smart Chainsaw, as on figure 1, Patent pending, P2016-78265A. Extensionally, operation advice, alert and report functions are included.

Mechanism and acquiring data

We put smart chainsaw following seven sensors to know the manual chainsaw work state,

1) 3D acceleration sensor

2) 3D rotation speed sensor

3) 3D magnetic direction sensor

4) throttle trigger reader

5) engine revolution sensor

6) saw chain running speed sensor

7) GPS

They are transmitted through Bluetooth communication protocol to an information device.

An illustration on understanding sensor data for tree felling operation can be on figure 2. A data of 3D acceleration sensor can indicate chainsaw vertical posture and show felling process movement. At the beginning chainsaw is upright position, and come to horizontal to horizontal cut, then slant cut, and move to backside then come to back cut.

A combined analysis on chainsaw operation is under field evaluation trials.

Figure 1. Smart chainsaw and 3D coordinates.

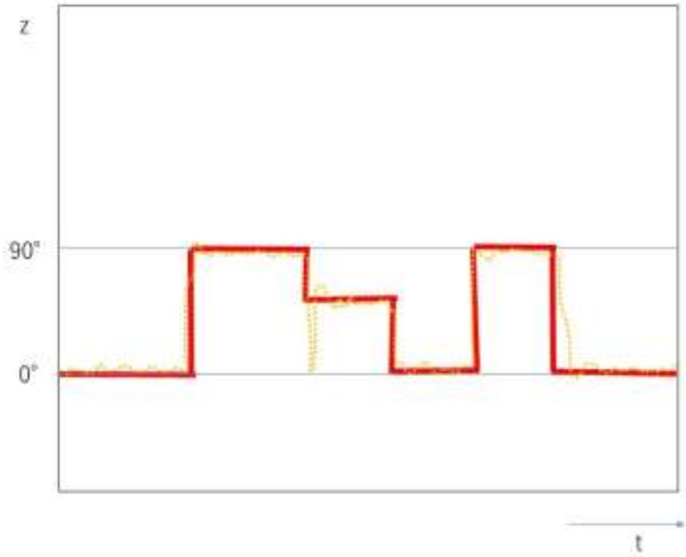

Figure 2. Chainsaw movement and felling operation process.

Data analysis and work process understanding

A series of dataset obtained by chainsaw operation can be analyzed by detecting change of operation process in a certain duration time section,data wind. It is based on the model of transition probability, and AI method is also useful.

Discussion

We needed special sensors for throttle trigger reader and saw chain speed sensor. A solenoid based special mechanism was developed and utilized to know maneuver on throttle trigger and a special sensor with high speed independent metal movement recognition was developed and installed.

The smart chainsaw provided sufficient performance to know the manual chainsaw work on its state, process and results.

Conclusion

Smart chainsaw teaches us number of trees felled/processed by the worker in the day. It shows also his operation skill and manner for the work. It promotes not only operational productivity but also work safety.

Usually, chainsaw operations are conducted in rural area deep in forests, and the data of chain saw through operation is transmitted to smart phone of the worker at first. Which stores the data and communicates with regional office to check his status at that time. The daily work data is uploaded to the office PC for the daily report. It can be involved at the regional forest supply chain management system as on figure 3.

He can inform office managing system his daily achievement and have evaluation for daily work evaluation form erogomonical aspects, such as to know when and how he did not catch the safety criteria.

This digital daily report system enables regional wide and country wide forest manual operation management.

A guidance system on smart phone of the worker can indicate process accuracy and guide their favorable sequence.

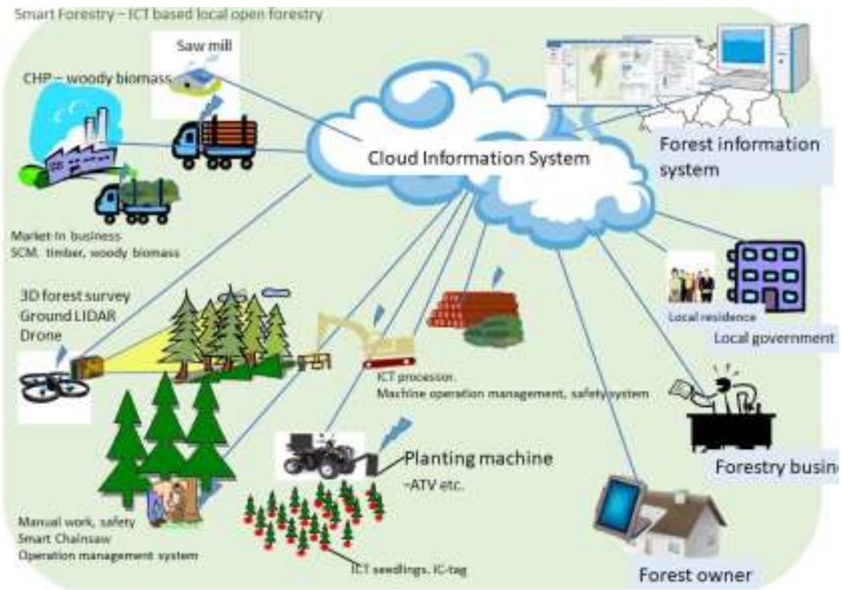

Figure 3. Image illustration on a local forestry supply management system.

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THE EFFECT OF A STAND'S TREE VOLUME VARIATION ON HARVESTER PRODUCTIVITY

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Abstract: It is a well-known fact that the work productivity of a harvester is positively correlated with the mean volume of harvested trees. This is valid up to tree-volumes close to the technical limitation for the given harvester. However, two stands with the same arithmetic mean stem-volume (MSV) can have substantial differences in tree volume distributions. Hence, the actual productivity might also differ substantially between the stands. Thus, the aim of the study was to evaluate the possible effect of the tree volume distribution on harvester productivity. Analyses were based on data from 383 final fellings, with information on the mean productivity per stand and on volumes of all trees harvested per stand. Based on regression analysis, the mean productivity was found to be highly dependent on MSV ($p<0.001$). When also adding the coefficient of variation (CV) for the tree diameters, as an indicator of volume distributions within stands, it also significantly ($p<0.001$) contributed to predict the productivity, and R2 increased. At a given MSV, a small CV resulted in higher productivity than a large CV. Hence, tree-volume distributions should be considered to be included in future productivity models for harvesters, especially since such data starts to be readily available with current technological development.

Keywords: Productivity models, regression analysis, mean tree size

SUSTAINABLE FOREST OPERATIONS (SFO): A NEW PARADIGM

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Abstract: Wood has played a major role throughout human history. With increasing climate change, resource shortages and the need for environmental protection, wood products have been receiving increased attention as key resources for the development of a sustainable bio-economy. A sustainable forest management depends largely on carrying out forest operations in a sustainable manner. In this context, it is important to understand the major driving factors for the future development of forest operations that promote economic, environmental and social well-being. The main objective of this paper is to identify several important issues of forest operations in the light of a new sustainability framework, while offering a new forest operations paradigm. Previously developed concepts of forest operations are reviewed, and a newly developed concept – Sustainable Forest Operations (SFO), is presented. Five key performance areas to ensure the sustainability of forest operations include: (i) Environment; (ii) ergonomics; (iii) economics; (iv) quality optimization of products and production; and (v) people and society. Practical field examples are presented to demonstrate how these five interconnected principles are relevant to achieving sustainability, namely profit and wood quality maximization, ecological benefits, climate change mitigation, carbon sequestration, and forest workers' health and safety. The new concept of SFO provides integrated perspectives and approaches address ongoing and foreseeable challenges the global forest communities face, while balancing forest operations performance across economic, environmental and social sustainability. In this new concept, we emphasize the role of wood as a renewable and environmentally friendly material, and forest workers' safety and utilization efficiency and waste management as additional key elements of the sustainability. For the practicality of SFO, it is essential to: (i) promote operationally safe, environmentally responsible, locally acceptable and economically viable forest mechanization; (ii) invest on workforce training that improve not only operational skills but also awareness of health and safety issues and quality operations that are sensitive to changing work conditions; (iii) develop certification programs to meet and enforce new standards; (iv) encourage forest professionals to improve their management skills and sustainable business strategies; (v) improve forest workers' health and safety without compromising the profitability, viability and economic competitiveness of forest business and practices; and (vi) encourage renovation and innovation of forest machinery in order to improve the efficiency and greenness of forest operations. It is crucial for local, regional and global markets to recognize the important role of wood products and their sustainability in the bio-economy, and therefore provide their fair values in order to fulfill or further expand the sustainability of forest operations.

Keywords: Sustainability, equipment, logging, ecosystem services, forest workers

Introduction

Wood, as a renewable and environmentally-friendly raw material, has played a major role throughout human history. With the unprecedented rate and scale of climate change, resource shortages and the critical need for environmental protection, wood products have been receiving attention from scientists, policymakers and the public as key resources for the development of a sustainable bio-economy and the future. In fact, sequestering carbon itself is an important role of wood that helps mitigate and abate greenhouse gas emissions. A sustainable forest management depends largely on carrying out forest operations in a sustainable manner. In this context, it is important to understand the major driving factors for the future development of forest operations that promote economic, environmental and social well-being. The main objective of this paper is to identify several important issues of forest operations in the light of a new sustainability framework, while offering a new forest operations paradigm.

Material and methods

Previously developed concepts of forest operations are reviewed, and a newly developed concept – Sustainable Forest Operations (SFO), is presented (cf. Marchi et al. 2018). Five key performance areas to ensure the sustainability of forest operations include: (i) Environment; (ii) ergonomics; (iii) economics; (iv) quality optimization of products and production; and (v) people and society. Practical field examples are presented to demonstrate how these five interconnected principles are relevant to achieving sustainability, namely profit and wood quality maximization, ecological benefits, climate change mitigation, carbon sequestration, and forest workers' health and safety.

Results, discussion and conclusions

The new concept of SFO provides integrated perspectives and approaches address ongoing and foreseeable challenges the global forest communities face, while balancing forest operations performance across economic, environmental and social sustainability. In this new concept, we emphasize the role of wood as a renewable and environmentally friendly material, and forest workers' safety and utilization efficiency and waste management as additional key elements of the sustainability. The balanced view of SFO should be continuously reflected on the best forest practices developed to meet local, regional and global needs of forests and people. The concept of SFO is not intended to provide any specific performance standards, but rather it provides an overarching framework in which individual performance and evaluation criteria can be developed for appropriate scales and purposes. Development of region-specific, practically relevant performance criteria are highly desirable that meet local needs and maintain flexibility to evolve and be capable of incorporating ever-changing work environment and challenge.

For the practicality of SFO, it is essential to: (i) promote operationally safe, environmentally responsible, locally acceptable and economically viable forest mechanization; (ii) invest on workforce training that improve not only operational skills but also awareness of health and safety issues and quality operations that are sensitive to changing work conditions; (iii) develop certification programs to meet and enforce new standards; (iv) encourage forest professionals to improve their management skills and sustainable business strategies; (v) improve forest workers' health and safety without compromising the profitability, viability and economic competitiveness of forest business and practices; and (vi) encourage renovation and innovation of forest machinery in order to improve the efficiency and greenness of forest operations. It is crucial for local, regional and global markets to recognize the important role of wood products and their sustainability in the bio-economy, and therefore provide their fair values in order to fulfill or further expand the sustainability of forest operations (cf. Marchi et al. 2018).

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MANIPULATING WORK SETTING TO REDUCE FUEL CONSUMPTION IN CTL TIMBER HARVESTING MACHINES

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Anstract: The objectives of this study were to examine the possibility to reduce the fuel consumption of harvesters during cut-to-length operation by applying various technical settings to the machine through the machine´s own software package. Adjustment of machine settings had an effect on the fuel consumption per unit product (l m-3) and can reduce the fuel consumption and CO_2 emissions in CTL harvesting operations. The main factor significantly affecting both fuel consumption and productivity was the stem size. The study involved three CTL machines with one operation each operating in thinning with comparable stand environment and silvicultural prescriptions. Successfully tested for CTL harvesters, similar measures could be considered for other machine types, such as forwarders, used in timber extraction.

Keywords: harvesting, fuel consumption, productivity, settings, emissions, CTL

FINAL CUSTOMER EXPERIENCE LINKED TO SUPPLY EXPERIENCE. GESTAMP BIOMASS' EXPERIENCE, RECOMMENDATIONS AND REQUESTS TO THE COMMUNITY

Lucía Roca Fernández-Vizarra, Eng. GESTAMP BIOMASS, Spain.

EXTENDED ABSTRACT

Gestamp Biomass owns and operates a 15 MWe Biomass Power Plant in Garray, Soria, Spain and a 75 MWe power plant in Berlin, New Hampshire, USA. In addition Gestamp Biomasshas supplied through his own subsidiary (Gestion de Biomasas) up to 200,000 t of biomass per year to other customers in Spain. The company gathers the experience as supplier and as consumer of biomass in different formats (dried olive cake, chips, bundles, logs, green pruning).

Gestamp Biomass is always trying to optimize processes in order to face the challenges the regulation imposed once Garray plant was already in construction with a biomass supply scheme that no longer could be used once commissioned.

The aim of this communication is to outline the problems and needs detected on the final consumption to request the suppliers and the academic community research on this topics in order to improve the mechanization of those works. There are several blocks of items we have selected to outline our experience:

The need to provide flexible solutions: changes in the regulation in Spain have impliedthe need to diversify supply sources and to adapt to market, versus the old system/ and the paper & pulp system, where design fuel was/is the fuel fixed for all the lifetime of the project.Due to the changes in the regulation we have faced an evolution in time of our supply mix with many operational challenges involved. Lessons learnt.

BIOMASS IN THE PLANT

There is a need of research on blade materials resistance to wear that can secure plant consumption for diverse supply inputs (bark, bundles, pruning) allowing flexibility of supply. Experience, recommendations and requests

Experience and recommendations regarding attack angle in chipper depending on biomass. Our experience in changing blade angle attack with eucalyptus bundles. The importance of sharing knowledge within the community.

Rope problems regarding bundles: experience, recommendations and requests for suppliers/research regarding materials and amount of rope in the bundles

Need to reduce inerts in the supply (especially in some formats such as bundles). Problems derived in the Plant and boiler due to inert presence.

Need to obtain ahomogeneous mix, associated logistic. What do we measure in biomass and why do we do it

Solutions for bridges in the dosing bin derived from size/type of biomass mix (example mixing dried olive cake with chips or green pruning). The effect on O&M and in the boiler and importance of these mechanical problems. The need for research on screw design. The solutions adopted.

BIOMASS IN ORIGIN

Regarding Logistic optimization: experience with an automated weighbridge connected to supplier trucks via app. Cost reduction in plant and benefits in the supply management. In addition the system allows knowing the place of loading, forestry species and product, type of truck and fuel consumption allowing us to calculate the Carbon footprint of our supply.

Innovative Financing solutions: Financingsupplier's machinery (bundles)

Keywords: biomass logistics, regulation, consumer needs, biofuels requirements

AUV-SUPPORTED DELINEATION OF FOREST AFFECTED BY MIXED-SEVERITY FIRES: CREATION OF HOMOGENEOUS MANAGEMENT UNITS WITH THE TOOL HOT SPOT ANALYSIS (GI-ORD).

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Abstract: Fire-caused economical degradation of forests is important to be precisely assessed in order to forest managers be able to plan the rehabilitation of those forest areas, which present heterogeneous vertical and horizontal stand structure. Many studies of AUV imagery have already demonstrated that this technology allows the acquisition of remotely sensed precise data, which gives a precise picture of the spatial distribution of stand stocks. However, this information can be paradoxically too detailed, and therefore the creation of, on one hand size-meaningful and on the other hand homogenous, management unit need to be done in order to propose rehabilitation strategies. This contribution presents a case study conducted in a fire-cause economically degraded forest land of 3,940 ha in the Argentinian cloud forest of Yungas Pedemontana, for which spatial delineation of fire severity and aggregation of homogenously stocked stands was conducted. For the assessment of stocks, a plot-based field inventory and aerial survey with a UAV were conducted. Adjusted Canopy Coverage Index (ACCI) as a metric for stand structure was formulated to predict basal area from canopy height models. A SPOT6 image of the area was object-segmented and classified into four level of degradation by training it with the ACCI values. Cluster of close and similar stands in terms of their structure (ACCI) were identified through the use of the tool *Hot Spot Analysis (Getis-Ord Gi*)* from the environment Arc-GIS using four threshold distance: 178, 252, 309 and 357 meters (as radii from the neighbouring 10, 20, 30 and 40 ha). The is a trade-off for bigger and homogeneous areas: one hand the average area of the resulting clusters ranges from 33.9 ha to 138.5 ha; on the other hand, the ratio between correctly and incorrectly clustered areas ranges from 3.3 to 2.2 across the distance threshold gradient. In a scenario of rehabilitation by enrichment planting, at the first threshold distance of analysis the rehabilitation of highly lowered stocked forest, would be done in 608 ha compromising 28 and 100 ha of the least affected stands; at the fourth threshold distance scenario, it would be done in 1,036 ha compromising 68 and 226 ha of the least affected stands.

Keywords: Fire damage assessment, UAV, hot spot analysis, forest management units.

PRODUCTIVITY AND COST-EFFICIENCY OF MECHANIZING TENDING WITH CUTLINK DEVICE IN SPRUCE SEEDLING STANDS

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Abstract: According to forest inventory data, there is urgent need for tending of seedling stands in at least 700 000 ha and need for 1 million ha in Finland. The motivation of forest owners to conduct pre commercial silvicultural operations is low due to associated high costs. Especially the costs of tending and clearing operations after the regeneration of the stand have been increasing. In addition, the availability of labor can be restricting factor due to high seasonality of silvicultural works. In 2000's several solutions for the mechanization of tending have been presented. They are based on the use of a harvester or a forwarder as a base machine. Typically light weight base machines are favored to reduce the hourly cost of operations and also impacts on remaining seedlings. Challenge has been the high speed of the cutting device which increases the risk of damages when the circular saw or chain hits e.g. stones. In addition, the chain can dislocate due to bending forces caused by stumps. Cutlink has presented a low RPM solution based on rotating cone-shaped shears that cut 50-100 cm wide corridors between and around seedlings. In this study productivity and cost efficiency of mechanized tending with Cutlink device compared to manual tending was evaluated in spruce seedling stands in central Finland. The productivity, fuel consumption and quality of seedling stand after the operation was measured. It was found out that a crucial factor for the competitiveness of mechanized alternative is the annual working hours and finding suitable work areas for the machine. Additional work for the device and base machine can be found also in the clearing of forest road sides.

Keywords: Seedling stands, mechanized tending, productivity, cost-efficiency

DEVELOPMENT OF A SENSORIZED TIMBER PROCESSOR HEAD

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Abstract: Forest operations and dedicated machinery are in constant development in the urge to provide always higher standards of economic and environmental sustainability. The latest innovation trends are concentrated in the generation, storage and management of data related to the harvesting process, timber products and logistics operations. Current technologies may easily provide parameters such as productivity and position of the machines, but when quality of timber products is considered, just physical parameters are made available (e.g. taper, dimensions). The possibility to provide a comprehensive quality evaluation of roundwood early in the supply chain (at forest landing or roadside) and link the information to the single items (log) provides a new tool for optimization of the whole forest-timber supply chain. Current in-field methods for grading logs are based on visual rating scales, which are subjective, operator-dependent and time-consuming. As an alternative, in the frame of the EU project SLOPE, a sensorized processor head was developed. The prototype here presented features the following sensors: near infrared (NIR) spectrometer and VIS-NIR hyperspectral cameras for the identification of surface defects (e.g. resin pockets, rotten areas, etc.), stress wave and time of flight sensors for estimation of timber density, hydraulic flow sensor for estimation of cross-cutting resistance and delimbing sensors (on stroke piston and below delimbing knives) for estimation of branches number and their approximate position on the log. The prototype also deploys a RFID UHF auto-ID system (reader and tagger), which allows to identify the incoming tree and individually mark each log, relating the quality parameters recorded to the physical item and tracing it along the supply chain. Finally, a Wi-Fi communication system enables the machine to exchange data in real-time with logistic operators and end-users for online purchase. The tested sensors are installed and designed in order to be independent, thus leaving the option to install just one or more of them, according to the specific requirements of the market, owner and end-users. Nevertheless, the whole set of sensors was designed for providing a comprehensive evaluation of timber quality, returning a "Quality Index" for each log. Results here presented were collected both in laboratory and real forest conditions, proving the potential of the concept.

Keywords: Timber quality, processor head, sensors, NIR, cutting forces

DIGITISING COMMUNICATION FROM HARVESTERS TO SAWMILLS IN THE GERMAN FOREST AND WOOD INDUSTRY SECTOR

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Abstract: *By improving the former German ElDat Standard for data transfer between forest companies and wood utilising companies, the overall data communication of the sector was ought to be simplified. This was done by narrowing down the standard's content and communicating clear boundaries in which the standard is used via "use cases". The result is a modular data standard with five pre-built information containers, each of these being developed to fit for a specific step in the German wood procurement chain. The information contained is brought to a minimum to enable small file sizes and on- the-point status messages. Another result of the project is a public website for low-tech SMEs, with a basic front-end to fill in data and create a valid ELDATsmart-file. This aims to simplify data entry and also to avoid false entries from inexperienced users.*

Keywords: wood supply chain, digitalisation, standardisation

Introduction

With an explicit recommendation from the German Forestry Council (DFWR) and the German Timber Industry Council (DHWR), the electronic data Standard "ElDat" (Electronic data standard for wood data) was introduced in the year 2002 in the market and has since been supervised by the German Centre for Forestry Operations and Technology (KWF).

This ElDat standard (ELDATclassic) was based on the idea of a shopping cart. The user was given a variety of different standardized documents which he could use and combine individually. This opened up a wide range of variants to describe raw wood. However, it proved to be detrimental that the exchange of data between the respective logistics partners always required a bilateral coordination of the information structure. The business partners who used the standard had to create individual software solutions. The necessary high investments could only be made by the economically strong forestry and timber companies. This adaptation process was too high a hurdle for small and medium-sized enterprises without efficient information technology capacities. Consequently, ElDat found hardly any use there. Thus the sectors call for a more practical ElDat solution increased.

As part of the project "ELDATsmart" a solution was developed which standardized the wood data transmission better in order to prevent individual interpretations of the standard. To this end, an approach has been chosen that focuses on the timber logistics process and thus the different steps at which information is exchanged between market partners. This method of electronic monitoring of the wood logistics process is also used in the international standard PapiNet, and in the Austrian standard FHP DAT. With the increased standardization, the technical solutions by the software developers should be provided faster and more cheaply, thereby promoting the penetration of the market. This is seen as an indispensable success criterion for a data standard.

In addition, a website has been created for small and medium-sized enterprises that allows anyone to create or view .eldat-files free of charge. The aim is to resolve a first hurdle to participation in the digital wood logistics chain. At the same time, the additional effort for large companies is to be incurred, when processing non-standardised data from small and medium-sized market partners.

Material and Methods

Evaluating the needs

The ELDATsmart standard has been fundamentally built on the experience of the previous users of the ElDat standard. For this purpose, the "ELDAT user group" already existing as a panel of the KWF was used. The primary members are the expert employees of the state forest companies and big woodworking companies, as well as employees of German-speaking forest software developers. Established as an open body, however, it was up to all interested parties to participate freely in these meetings and to actively contribute, or merely passively to pursue the discussions. The focus of these panel meetings was to improve the exchange of information between these parties, as both the supplier and the receiving party were represented. To this end, basic agreements had to be made, such as the level of view on logistics objects (single logs or log piles) and the extent of the data considered.

In addition to these meetings, separate meetings were also convened for the respective actors, forestry, timber industry and software developers, in order to discuss and record their specific requirements for a data standard. Since the messages created in ELDATsmart are usually created only by one party and must be read from the other, more detailed requirements for the structure of the messages could be worked out via separate sessions.

The authors gained a plus of experience in the process of the data dispatch and the size of the files by visits to selected representatives of the forestry and wood industry, as well as to software developers. The content of these meetings was to evaluate the current state and to develop ideas for improvement on the ground. In addition, software developers helped design various visions for the future of wood data transmission in the German-speaking countries or beyond.

The website was created as a result of the first finished concept of the standard. This included the user's requirements gathered in the sessions which were combined into a usable ELDATsmart standard for the first time. The finished website could then be tested by all interested users for over three months. The constant feedback of the users during this time was implemented in the page and the standard after direct examination in an immediate revision.

At the end of the standard’s development, the parties, both the forestry and the timber industry, were once again given the opportunity to take a stand on the standard in its entirety and its feasibility. Minor comments were recorded directly and, if necessary, incorporated into the structure.

The data standard was officially published in April 2018 by the signature of the framework agreement for ELDAT, a rulebook for the use of the standard, by the umbrella associations of the forestry and timber industry. However, feedback on the standard is still possible and welcome, so that the standard can be continuously improved.

Basic requirements from the users

During the development of the ELDATsmart standard, the demand for a clear logistics object was especially voiced. Mostly companies with little interest in individual stems, but rather on wood mass, needed only little descriptive information, but much more clear logistical information. Nevertheless, detailed information on individual stems needed also to be communicated, if wood purchasers were dependent on it. The log pile was therefore chosen as the central object. This must be specified in each ELDAT-message, and should be enriched with as much detailed information as possible. In addition, a pile can be extended with single log information. If possible, each individual log, including its number and metric data, can be described as part of a pile.

The obligatory integration of GPS coordinates to the respective piles was also an important demand of the timber buyers, which was realized in the standard. Therefore it is forbidden to send the data without the GPS coordinates.

Due to the highly diversified technical equipment of the users, it should in principle be possible to send the data as an e-mail attachment. However, it is still possible for further developed users to send or receive ELDAT files via automated protocols. This is especially important for logistics apps that are increasingly present on the market.

Results

The Standard

The result of the project "ELDATsmart" is a standard of the same name in version 1.0.2, published on April 23, 2018. The standard takes into consideration an optimal wood logistics chain. In this optimal wood logistics chain, five situations require the exchange of data between the market partners. This is why five modules were created. These are wood allocation, transport order, delivery note, measurement journal, clearing. Each of the modules contains the information necessary for the respective process step. This means that a sequence is specified in which information placeholders, so-called tags, are listed below each other. Each tag has rules regarding its allowed characters and number of characters, or whether it must be filled with information (required). Some tags refer to so-called value tables from which a valid value must be chosen. Different tags can also be grouped thematically in containers. This makes it easier to reuse the same container with the same content elsewhere in the standard’s structure, which simplifies the programming of an interface.

Table 1 - Module names and principle standard structure

Module Name ＼ Container Name	Wood Allocation	Transport Order	Delivery Note	Measurement Journal	Clearing
Address	Address At least the Supplier must be defined.	Transport Address Supplying, receiving, transporting party must be defined.	Transport Address Supplying, receiving, transporting party must be defined.	Address Sending party should be defined.	Address Supplying and receiving party must be defined.
Process Step Information	Delivery Information Contracual delivery info, e.g. terms of delivery	Transfer Information Transport info, e.g. range of delivery numbers	Transfer Delivery info, e.g. delivery number, loaded mass	Measurement Data Measuring info, e.g. calibration duration, measuring method	Invoice Header Invoice info, e.g. net price, gross price, discount, vat
Wood Data	Wood Data Single log or aggregated wood data and mandatory pile data	Pile Data Pile data of the to be transported pile	Origin Pile data of the loaded pile	Measurement Detailed single log or pile data	Invoice Item Single log or pile data
Status (optional)	Status Gives time, location of sender and status update to the message	Status Gives time, location of sender and status update to the message	Status Gives time, location of sender and status update to the message	Status Gives time, location of sender and status update to the message	Status Gives time, location of sender and status update to the message

The modules can be roughly divided into four thematic areas. In addresses, process step information, wood data, status message (table 1). Each module specifies the structure and content of a generated message (.eldat file).

Address

The addresses involved must be specified for each message. At least the sender and receiver of the message must be named with the usual address information, but also contact details of contact persons and, if necessary, bank account information. In addition, other stakeholders, such as transporters or surveyors, can also be added. You can also specify loading or unloading locations with address, or GPS coordinates.

Process Step Information

This component is the most variable between the different modules. It contains the information necessary for the respective process step. In the case of wood supply, this is delivery information with delivery conditions, transport period, etc. For the transfer order, it is the transport information with validity information for the order, permissible delivery note numbers, or information about transport distance and freight price determination. The delivery note contains the delivery information with, among other things, information on the carriers and the quantity of loaded goods. The measuring protocol carries out extensively the basic conditions of the measurement and then outputs the wood data for the respective measuring method. The billing focuses on the information relevant to the invoice.

Wood Data

The wood data is always given according to the same scheme. As the pile goes through the entire wood logistics chain as a central logistics unit, this data can be transferred from one message to the next, so that manual copy becomes obsolete and error sources are prevented. In addition, in the wood allocation message the associated lot, or detailed wood data can be sent out, which are not relevant for the logistics process, and thus the other reports. The measurement protocol also gives the possibility to describe the wood in much more detail. This is necessary because the price calculation of the wood is based on this information.

Status

The status that is attached to each message indicates the creation time and location of the message. Similarly, certain statuses can be added to the message, such as "accepted", "rejected", "completed", etc., so that a constant feedback on the course of the logistics process is possible.

Technical Specifications

The ELDATsmart standard is programmed in JSON format. This makes it possible to create smaller files than could be done with the XML format, for example. In addition, it is easy to write applications for this file type which can then be installed on mobile devices.

In principle, everyone can set up a standard interface as long as the product is a file that corresponds to the framework agreement for ELDAT (RVE). No specifications are made for the procedure to enter the data, whether automatic or manual, immediately or over a longer period of time.

An .eldat file can be sent as an e-mail attachment, PDF attachment, or within a web service.

The Website

The website is accessible via any standard browser and is available for free, without registration. The layout of the site is very simple so that it does not distract from the intention of the site. First, the module to be created can be selected, which is then filled in on the following page by means of an input mask. If at least all required fields are filled in, the message can first be viewed again in the viewer, and then downloaded as a JSON file. The finished file must be sent via an external e-mail account.

It is also possible to upload and view a finished .eldat file via the page. Changes in such files are possible, as well as the printing of the browser view.

In a separate section of the page you will find information that is specific to software developers. Here the documentation, the structure of the standard, the rules for individual tags, and the value tables can be retrieved (Fig. 1).

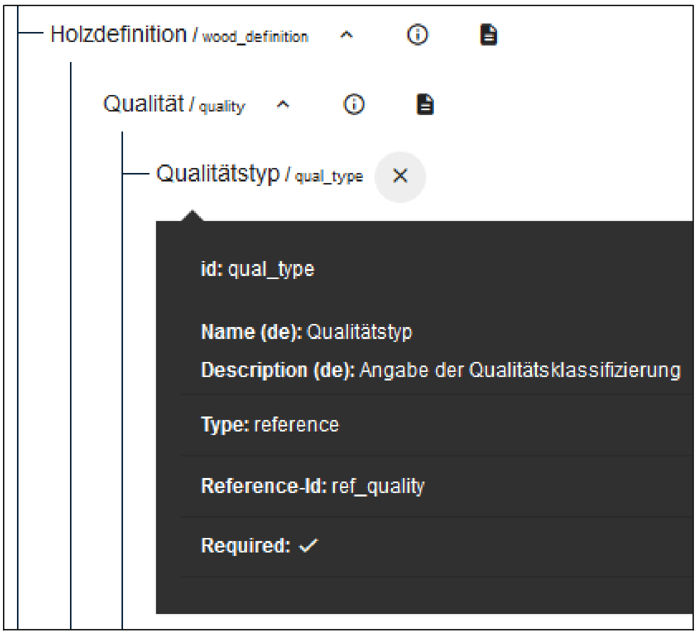

Figure 1 - Tag with specifications: tag name, german name, german description, type of tag (linked to reference table), name of linked reference table, required information

Discussion

The ELDATsmart standard was deliberately developed with the state forest companies, large timber companies and IT service providers. As a result, the actors affected by the standard were directly involved in the conception and were able to incorporate their requirements from the practice for data transmission. The ELDAT user group as an open body offered the platform to anyone interested. In particular, unorganized actors, such as transport companies or private forest owners, were seldom able to attend these meetings. In addition, individuals from these actors could not speak for the entire group, but only for their own company. Thus it was not possible to obtain solutions from the private forest or the forwarding industry for their needs. Accordingly, other interested parties had to keep an eye on these actors and speak on behalf of them. However, the well-established and organised representatives of the large forestry and timber companies did not always have a uniform idea of what was needed in the standard, though. The wood logistics chains can be different between two companies. Accordingly, the processes and technology in these companies are also adapted to it. The effort to switch to a uniform wood logistics chain is therefore sometimes very high and is thus spared. The resistance to such solutions is correspondingly strong. Additionally, the technical equipment and the necessary know-how differ between companies. While some companies have SAP systems, others rely on Microsoft Office applications, although faxes are not a rarity.

The objections and suggestions in the ELDAT user group were accordingly qualified. The aim of the project was therefore to create a solution that can be sent and processed with cloud and Web services, as well as with small applications and with little effort to operate and send. Users were therefore provided with the basic functions of the website, in order to at least enable the creation and reading of such standardized files. At the same time, few specifications were made to create and send the files, in order not to slow down well-developed companies and not deter low-developed companies. The stipulation that each pile must be equipped with GPS coordinates already posed problems, even for large forestry companies. On the one hand, the technical equipment of these companies was not sufficient to meet this requirement. On the other hand, the reception of GPS data, especially in the forest, is a physical challenge. The status updates of the messages have been added due to the exchange with the Austrian FHP dat standard. There, the constant feedback from the process chain to the organizing system helps to make the logistics process run smoothly and in a controlled manner. The entrances to the plant can be coordinated, for example, so that waiting times in the factory for the transporters are no more. However, this solution relies on the sender to be appropriately equipped to send such messages, for example by a customized application on its mobile device, and that the receiver can adequately process this information. However, there are virtually no solutions for both sides in Germany. Forestry companies, in particular, have not yet exhausted the technical possibilities of the time and therefore have to take some major development steps. But the freight forwarding companies, as the weakest link in the timber logistics chain, also need stronger support in order to adapt to new processes.

A difficulty in the final developments of the standard was the relatively low participation in the practice trial of the website. This allowed the users to test the standard online. The trial aimed to check the usability of character limitation of tags, but also the lack of tags in the modules in general. However, since the entry of the data on the website was time consuming and at the time no interfaces were set up to read and process the files in the companies, the interest in taking part in the trial was low. For this reason, a realistic data flow could not be tested with this. Nevertheless, minor errors were found and fixed in the standard. Further development and troubleshooting will now shift to the time during the establishment of the standard, which is why intensive monitoring of this process is necessary.

Almost all state forest companies have already agreed to use the standard at the latest 2020. At the same time, over 40 wood customers in Germany will also be able to implement the standard in their own systems. Only with this far-reaching implementation of the standard it will be able to see where the weaknesses of the standard are and whether a modernisation of the timber logistics chain can be achieved.

FOREST OPERATIONS IN CLIMATE CHANGE AFFECTED FORESTS

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Abstract: The climate change causes various impacts on forests and forest management. The forest on the one hand is affected due to forest ecosystem shifts, timberline shifts, prolongations of growing seasons, changes in biomass growth rates, increasing drought and decreasing frost periods and more frequent weather extremes. The forest management on the other hand is reacting, for example when converting from monocultures to more both vertically and horizontally structured forests, reducing rotation periods or changing the intensity and frequency of thinning and final felling operations. As a consequence, forest harvesting and extraction operations are affected as well. It is likely for example that the higher proportion of broadleaved trees in future forests will lead to an increased use of fully mechanized hardwood harvesting operations and also of forestry tractors, the latter because of both the mandatory manual felling with optional cable support and the limited trafficability of these sites. Further, cable-assist systems, winch-supported felling processes and lowland cable yarding systems will possibly get more popular. Forest operations during growing seasons might be an option to compensate the shorter harvesting periods. Moreover, future harvesting and extraction operations should be preferably low-emission, environmentally and societally friendly. Further reduction of soil traffic with regard to forest certification criteria's and to increase carbon stock in both forest soils and woody biomass might be necessary. Selected forest wood supply chains will be presented based on the most relevant predicted forest development types in Germany including important forest operation parameters such as slope gradient and soil sensitivity based on ground conditions.

Keywords: forest development types, forest wood supply chains, future harvesting and extraction operations, low-emission

TIMBER HAULING WITH A REMOTE-CONTROLLED MINI FORESTRY CRAWLER

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Abstract: The changes in tree species composition towards more broadleaved forests may lead to major technical challenges for harvesting and extraction machines. The use of modern technologies such as lowland-cable yarders, six- and eight wheeled forestry tractors, tire width and inflation pressure, as well as cable-assist-systems (or tethering winches) might be feasible techniques which also support the growing awareness of reducing negative impacts on soils. However, restrictions might limit the number of possible options, as for example the 40 meter distances of skid trails in the state forests of Baden-Württemberg, Germany, where harvesting and extraction operations basing on the combination of harvesters and forwarders could be applied only when supported by chainsaw-felling and pre-hauling. Remote-controlled mini forestry crawlers might be a suitable option to support forest operations in challenging terrain or under difficult working conditions. Expected benefits from this compact dimensioned and low weighted tracked mini-skidder preceding a harvester-forwarder combination are an enhanced productivity in the extraction process, reduced occupational health and safety risks, lessened stand damage as well as reduced soil compaction and displacement. Nevertheless, the economic feasibility, the environmental advantages and also the effects on human labour need to be demonstrated. Goal of the study was to determine the performance of the mini forestry crawlers by carrying out field studies under representative work conditions as offered by commercial operations. The trials were carried out in different stands in south-west Germany in the winter 2017/18. Thereby, data concerning reliability and productivity were collected. As a result, advantages and disadvantages of the machine were identified, the productivity and the related processing costs were evaluated.

Keywords: pre-hauling, trend towards broadleaved forests, technical challenges, machine productivity, working time study, safety risks, processing costs

USE OF LARGE CAPACITY SITE PREPARATION MACHINES FOR FIRE LINE ESTABLISHMENT IN THE SOUTHERN US

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Abstract: Mastication of biomass using a variety of equipment types has been studied as a method to decrease fuel loading and reduce ladder fuels to control the spread of wildfires and as pre-treatment for the re-introduction of prescribed fire. In the US south carefully planned prescribed burns are used to manage southern pine forests, as wildfires are a significant financial risk. Fire lines to manage prescribed burning have traditionally been established with small crawler dozers (10 t, 80 kW). Large wheeled mulchers may provide an alternative with equivalent costs, but offer increased flexibility with faster travel speeds between sites and reduced soil disturbance. We used a 261 kW Caterpillar 586C site prep tractor with a Cat HM825 mulcher head (2.54 m cutting path) to apply 3 treatments: a slow treatment (0.8 km/h), fast treatment (1.2 km/h), and a 2 pass treatment at a fast speed (1.2 km/h or 1.6 km/h). Treatments were applied on a level site with clay soils, a gently sloping site with loamy soils, and a gently sloping site with sandy loam soils and a high incidence of surface sandstone. The disturbed area from single pass treatments was about 3 meters wide, and the width of double pass treatments averaged 3.6 meters. Most of the fire line surface for all three treatments had mineral soil exposure across the full width. Skips in the lines were typically due to sudden changes in terrain or obstacles, such as dips, rises, rocks, or stumps. Retreatment of skips caused delay time and lowered treatment speeds. In general we were able to maintain the target speeds with less than 10 percent delay, but were unable to maintain the 1.6 km/h speed on the gently sloping sites. Mulched fire line costs ($/km) for the slow and double pass treatments are likely greater than the cost for dozed fire line. However, mulcher productivity (km/hr) could be 2 to 3 times greater than the dozer in open woodlands or young stands where the mulcher can easily navigate.

Keywords: fire line, site prep tractor, mulcher, productivity

THE VARIABILITY IN VISUAL PERCEPTION OF A WORKING SPACE OF A HARVESTER'S OPERATOR

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Abstract:

The variability of visual scene perceived by a harvester's operator was determined using the method of analysing eyeball movements (eye-tracking). The studies presented here aimed to identify the visual perception of a working space of harvester's operators, more or less experienced, working in mature and thinned pine stands. The research was performed with the use of the Tobii Pro Glasses 2 analyser and covered analyses of eye scanpath (gaze plots), areas of interest (heat maps), variability in duration of eye focusing (fixation points), and eye shifting between the successive points (saccades). The visual scene reflected different levels of work experience of harvester's operators. During cutting operations a more experienced operator put greater attention to the material being processed. Less trained operator focused his sight also on the higher parts of trunks and crowns, as well as on the harvester's head. Varied behaviour of operators, determined by the level of their work experience, difficulty of tasks, and readiness to work within a single working shift, was readable in the variability in duration of fixations and saccades. As the work experience increased, the mean duration of fixations grew by ca. 20%, while the duration of saccades decreased by ca. 50%. Behaviour of the investigated operators changed within a single working shift, and this variability turned out to be proportional to the duration of the shift – the duration of saccades grew, while the duration of fixations decreased. Eye-tracking studies may significantly complement standard methods of physiological analyses used in investigations of worksites, since they document not only the work outcome but also the manner of its performance.

Keywords: ergonomics, eye-tracking, timber harvesting, harvester

SUSTAINABILITY IMPACT ASSESSMENT OF ALTERNATIVE THINNING OPERATIONS IN MEDITERRANEAN UMBRELLA PINE PLANTATIONS.

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Abstract: Mediterranean pines account for almost 14,000 ha in Tuscany (IT) alone, where it forms large and homogeneous stands along the coastal region and represents an important resource for the forest economy. The total surface occupied by these pines is estimated at 13 million ha, or 25% of the total forest area of the Mediterranean basin. In regions like North Africa and Anatolia, it may account for up to 75% of the total forest area. Among the many harvesting systems applied to thinning operations, the most popular are whole-tree (WT) and cut-to-length (CTL) harvesting. The first consists of felling trees and extracting them whole to the landing, which might offer the advantage of simplified in-forest handling. The latter, CTL, requires laborious in-stand tree processing but results in lower organic matter removals which is especially desirable on poorer sites, where organic fertility may be a serious issue. Both WT and CTL harvesting can be deployed with different levels of mechanization. The decision which system might be the best option in a specific case often leads to conflicts as different management goals favor different aspects of system performance. Thus, an accurate determination of economic, environmental and social indicators is crucial to take balanced decisions reflecting specific management goals. The objectives of this study were to apply a Sustainability Impact Assessment to typical forest supply chain alternatives that can be adopted for the thinning of pine plantations and to make comprehensive evaluations of the alternatives using the method of Multi Criteria Decision Analyses (MCDA). Therefore, trials were carried out in umbrella pine plantations in Tuscany, Italy. The analyzed energy wood chips supply chains considered four alternative thinning operations and included the processes harvesting, extraction and chipping. In the analysis, 11 sustainability indicators were considered (e.g., Global Warming Potential, production costs, fatal accidents). The results of the investigation allow quantifying possible sustainability impacts and thus, supporting management decisions.

Keywords: Motor-manual and mechanized harvesting, WT- and CTL-harvesting, energy chips, Life Cycle Assessment, social indicators, sustainable forest management, decision support

PRODUCTION OF MICROCHIPS AS A SURROGATE OF PELLETS: TECHNIQUES AND COST.

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The term "Microchip" describes a very small (7 mm target length) homogeneous wood chip product that can be used to feed conventional pellet stoves and boilers, usually after minor modifications of the feeding system and a resetting of the combustion controls. Microchip production matches the need for replacing industrial pellets with a new product that can be manufactured by small enterprises, using locally available raw materials and low-investment technology. The presentations describes the techniques used to produce microchips by small-scale logging operators, and the additional cost incurred when shifting to microchip production, from conventional fuel chip manufacturing. Furthermore, the Authors indicate the profitability of the two main options left to local producers for seizing the growing pellet market, and namely: pellet production with small-scale pelletizing plants and microchip production. Based on eight case studies, production cost averaged 228 € t-1 for pellets (9% m.c.) and 134 € t-1 for microchips (m.c. between 11 and 18%). Profits were estimated at 10% and 6% for pellets and microchips, respectively - with no statistically significant differences. Raw material cost accounted for 30% and 50% of total cost respectively for pellets and microchips. Product drying is normally achieved with renewable energy sources, such as reject wood or solar radiation, which allows reducing manufacturing cost. The most important success factor is always direct sale to final users, without intermediation, which is only viable when targeting local markets. Additional success factors are: self-construction of plant components, use of unutilized resources at marginal cost, control of raw material supply and capture of opportunity wood.

PROBABILITY OF DAMAGE TO REGENERATION DUE TO TIMBER HARVESTING IN THINNED STANDS

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Abstract: This paper aimed to analyse the probability of occurrence of damage to regeneration depending on the form of timber assortments dragged from the felling site to the skidding routes, and timber harvesting technology employed in logging works. The scope of these studies enclosed a comparison between two motor-manual methods of timber harvesting in thinned stands, with dragging of timber in the first stage of skidding from the stands to landings. The research was conducted in stands within the age classes II-IV mostly, located in the territories of Regional Directorates of State Forests in Krakow and Katowice, and in the Forest Experimental Unit in Krynica-Zdrój. In the course of a preliminary stage of investigations 102 trial plots were established in stands within early and late tinning treatments. Based on the results of investigations and analyses it was revealed that regardless of the category of thinning treatment, the highest probability of occurrence of destroying P(des) to regeneration (0.24-0.44) should be expected when the first stage of timber skidding is performed using cable winches. Slightly lower values of probability (0.17-0.33) should be expected in stands where timber is skidded by horses, while in respect to processor-based skidding technology the probability of destroying occurrence oscillates between 0.12 and 0.27, depending on the particular layer of regeneration. P(des) values, very close to those of skidding technology engaging processors, were recorded for skidding performed using the light-duty cable winch driven by the chainsaw's engine (0.16-0.27). The highest probability of damage P(dam) to regeneration (0.16-0.31) can be expected when processors are used in the first stage of timber skidding. Slightly lower values of probability (0.14-0.23) were obtained when skidding was performed with the use of cable winches, whereas engaging horses for hauling of trunks results in probability of damage occurrence oscillating between 0.05-0.20, depending on the particular layer of regeneration. With regard to the probability of occurrence of both, destroying and damage P(desdam) to regeneration (0.33-0.54), the highest values can be expected when cable winches are engaged in the first stage of skidding. Little lower (0.30-0.43) was the probability of their occurrence if processor-based technology of skidding was employed, while in respect to horse skidding these values oscillated between 0.27-0.41, depending on the layer of regeneration. The lowest values of probability of occurrence of damage P(dam), and destroying and damage treated collectively P(desdam), within all layers of regeneration, were recorded in stands where thinning treatments were performed using the light-duty cable winch driven by the chainsaw's engine.

Keywords: destroying and damage, natural young regeneration, advance growth, motor-manual technologies, early and late thinning

DEVELOPMENTS IN POST-HARVEST SITE ASSESSMENT AND THEIR POTENTIAL FOR IMPROVING OPERATIONAL AND ENVIRONMENTAL PERFORMANCE

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Abstract: The application of sensors such as machine, cable-carriage, and person based LiDAR & cameras, the introduction of unmanned aerial vehicles (UAVs), and improved procedures for coupling these with machine tracking and terrain trafficability maps, is opening new possibilities for improving the planning and management of forest operations, and for assessing their impact on the site. This paper will summarize findings from a number of recent case studies where these technologies have been applied, then goes on to discuss the main challenges faced and further opportunities for development as seen from the perspective of the authors. Higher resolution information on the actual machine pathway, correlated with the number of passages and the crane scale information on individual load size, provides a critical data source that can be used in improving predictions on the bearing capacity of forest soils. Especially the performance of cartographic Depth-to-Water (DTW) and Terrain Wetness Indices (TWI) calculations can be correlated with greater accuracy. Traffic intensity data can also be used for in-service evaluation of how forwarder operators interpreted the situation on the ground during the operations. Data on the scanned trails can further be used in identifying any severe wheel rutting that might require amelioration, reducing the need to traverse the entire site for this purpose. Finally, the trails can be stored in a repository for later use in e.g. evaluating vegetation growth in highly trafficked areas.

Keywords: forest operations, environmental impact, sustainability, certification

1. Introduction

Soil disturbance is an unavoidable outcome of forest operations, although knowledge of the physical, the physiological and the pathogenic impacts on forest ecosystems is much improved. The causes of compaction, rutting and surface erosion have been well documented over the past decades and considerable technical developments have been made in mitigating them. Wider tyres, more axles, longer bogies, high-flotation steel belts, or even the development of tracked machines have all made substantial contributions in reducing the impact of heavy forest machines on the soil. There have also been marked improvements in the availability of data and the development of algorithms for improving the prediction of soil bearing capacity. These have been brought about by e.g. LiDAR based terrain (and moisture) modelling, and the possibilities around real-time web-based interpolation of weather data and the possibilities given by the internet of things (IoT) in combining onboard sensors with this data (Talbot, et al. 2017). Forecasting bearing capacity in connection with production planning has been significantly improved through the development of new methods that can capitalize on this data (Jönsson and Lagergren 2017).

Recently, there has been a resurgence in research activity dealing with site impact. For some ongoing Horizon 2020 projects such as TECH4EFFECT, EFFORTE, Forwarder2020 and OnTrack, research on issues around site impact are either central or of considerable importance to the project.

2. Contents and focus areas

This presentation provides a summary of the latest reported activities and developments related to the measurement of site impact as well as some of the more recent technical developments on machinery. These include the use of new tools, predominantly laser and photogrammetry based, as well as methods and technologies for improved planning, mapping, and decision support. For each of these, the challenges faced in development and implementation are elaborated on, and an indication of potential for a more widespread application is provided.

Figure 1 A prototype machine based scanner (left) and resulting point cloud (right)

3. Discussion

Low cost sensors being applied in new settings allow for monitoring of site impact at a considerably higher spatial and temporal resolution than before. Quite a number of challenges remain in developing systems that are robust and stable enough to be offered as optional extras on conventional machines. This is related more to the need to use low costs sensors in keeping total costs below the sector's ability to pay than it is about the tough operating conditions or algorithm development. Location accuracy remains one of the biggest challenges. Systems for research applications on the other hand, that can tolerate higher costs, a number of useful tools already exist. Perhaps the most important issue to be dealt with while moving ahead with these developments, is how the tools are applied in a way that does not constitute policing of forest contractors, but that they are used constructively in contributing to a reduced environmental impact overall. Some of these uses include provision of map indicating areas needing amelioration, or a reference for later follow up studies on the longer term influence of machine trails on vegetation growth.

4. Acknowledgements

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MODELING THE REALISTICALLY SUSTAINABLE POTENTIAL OF FOREST WOOD SUPPLIES FOR ENERGETIC USE

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Abstract: In Europe, transition from fossil fuels to renewable energy sources like bioenergy has become an important strategy to meet EU objectives of reduced greenhouse gas emissions, diversified energy supply, and increased energy independence/self-sufficiency. To meet these ambitious goals, recent assessments of biomass potentials for energetic use have indicated that the use of forest-sourced woody biomass for bioenergy ("ForEnWood") will play no small part. EU-wide demand of ForEnWood is projected to increase by 65 % between 2010 and 2020. Meeting this steep demand has appeared feasible because only 76 % of the purported sustainable supply of woody biomass is currently extracted from European forests. However, the actual sustainable woody biomass supply is determined by biophysical constraints (e.g., climate, soils) as well as by forest management (e.g., intensity and timing of entries) that affects annual increment, forest age structure, growing stock and mortality. Economic aspects play an important role when it comes to the exploitation of potential respetively harvesting operations. Unfortunately, current estimates of ForEnWood availability vary widely, are highly uncertain, and largely depend on possibly questionable assumptions about constraints and their effects on mobilization rates. Specifically, existing availability studies at EU or national scales would best be supplemented by identifying regional hotspots for economic and sustainable bioenergy production to locally match technology to resources and scale of use: i.e., what ForEnWood potentials are actually sustainably available, to what extent, and at what cost. To quantify these ForEnWood availability potentials, we worked within a conceptual framework to explicitly incorporate ecological and economic constraints in a detailed, hierarchical, spatially explicit analysis using the example of Switzerland and its five ecological regions. Our specific objectives were to (1) quantify the reduction in available ForEnWood potential with the application of realistic ecological and economic constraints (harvesting costs), (2) evaluate the degree to which management can mitigate this reduction by simulating ForEnWood potentials that reflect increasing use intensity drawing on 3 production scenarios over a 40-year simulation period, (3) evaluate the degree to which subsidies in protection forests can mitigate these reductions, and (4) investigate the regional distribution of ForEnWood potentials in order to identify where strategic investments might be most advantageous. For each simulation, two market situations were evaluated—one favorable and

one less favorable for ForEnWood—which determine the proportion of total wood production allocated to ForEnWood given market prices for energy, with or without subsidies for protection forests.

Keywords: energy wood potential, szenario modeling, harvesting costs, subsidies

PRODUCTIVITY, EFFICIENCY AND ENVIRONMENTAL EFFECTS OF WHOLE-TREE HARVESTING IN SPANISH COPPICE STANDS USING A DRIVE-TO-TREE DISC SAW FELLER-BUNCHER

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Abstract: Whole tree harvesting was conducted on two coppice stands, different for their tree species composition (*Q. ilex* and *Q.pyrenaica*, respectively, the two more abundant coppice species in Spain). Felling and bunching were performed by a drive-to-tree heavy feller buncher, consisting of John Deere 130 kW wheeled carrier with JD FD45 disc saw head.

Both operations were analysed in order to develop productivity models based on significant explanatory factors and to assess operational costs. The study also aimed at determining biomass collection efficiency, and evaluating the impact of the new harvesting method on the soil, the remaining trees and the stumps, which represent the main regenerative element of coppice stands.

The treatment consisted in a very heavy thinning that reduced tree density from 5000 and 4000 trees•ha^{-1} respectively for *Q.pyrenaica* and *Q.ilex*, to 606 and 433 residual trees•ha-1. Both coppice stands grew on gentle terrain conditions. DBH-to-height and DBH-to-weight curves were fitted for both *Quercus* species, as height was not found to be a significant predictor of tree weight. The curves showed that, although *Q. ilex* trees are shorter than *Q. pyrenaica* ones for the same DBH, they have more crown biomass and higher total weight.

Time and motion studies were conducted on 17 plots 25x25 m^2 that were inventoried before and after the harvesting operations. Productivity ranged from 2.8 to 4.6 odt•pmh^{-1} in the *Q. ilex* coppice, and from 0.9 to 2.6 odt•pmh^{-1} in the *Q. pyrenaica* stand. The productivity models showed significant differences between the two species. Besides tree species, average dry weight per tree and thinning intensity (expressed as the percent of removed basal area) were identified as the main independent variables with an effect on productivity.

Regarding residual tree damage, 44% of the *Q.ilex* remaining trees showed some kind of damage, but most of the wounds affected the branches and were light (only an average of 5% affected the wood or were greater than 200 cm^2). In the case of *Q. pyrenaica*, the frequency of residual tree damage was 25%, and was lower than for *Q. ilex* likely because of the smaller crowns. Stand damage was caused by the peculiar work pattern of the drive-to-tree feller-buncher, as demonstrated through GPS tracking. Soil damage was also light; in no plots, deep disturbances were found. However, most of the stumps were damaged. The effect of stump damage on sprouting must be followed up in further studies.

The productivity and cost of forwarding and chipping were also evaluated, and the limits of profitability under the present market conditions were assessed. In the average observed conditions, operational costs exceeded revenues. Treatment cost was 220 €•$hectare^{-1}$ for *Q. ilex*.

Regarding collection efficiency, actual harvest (chips dry weight) was -8% and -30% than the predicted harvest estimated using the weight table for *Q.ilex* and *Q.pyrenaica*, respectively. That may be connected with an excessively large estimation error, rather than with poor mass recovery. The slash left on the terrain averaged 3.0 odt•ha^{-1} in $^{Q.ilex}$ and 1.5 odt•ha^{-1} in *Q.pyrenaica*, including scrub debris.

As a conclusion, while the heavy feller-buncher can be useful in heavy thinnings when the trees are larger, it would be a good option to try lighter sawdisc felling heads mounted on the harvester boom tip, which would probably reach better productivity and reduce the frequency of stand damages.

Keywords: whole tree harvesting system, Quercus ilex, Quercus pyrenaica, harvesting damages, operational cost, work study.

POST-FIRE REGENERATED MIXED STAND THINNING AND BIOMASS HARVESTING WITH A FIXTERI FELLER-BUNDLER IN SPAIN: ENVIRONMENTAL, PRODUCTIVITY AND COST ANALYSIS

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Abstrac

Whole tree mechanized felling and bundling were performed on a mixed stand grown by natural regeneration – by seedlings and resprouting - after a severe forest fire occurred in 1994 in Girona province (Catalonia, Spain).

The treated stand was heterogeneous in small patches, from very dense forest copses to scrubland plots with spotted trees. The main tree species were *Pinus pinaster* (from very small to 25-30 cm dbh trees), cork oaks (*Quercus suber*, some of them large and medium-sized surviving trees and most of them small cork oaks regenerated after the wildfire), other oaks (*Quercus* spp.), *Arbutus unedo* small trees and planted eucalypts in some adjacent plots, being the average DBH around 9 cm. The understorey was dense and high in most of the surface.

The treatment goal was reducing the density and favoring the cork oak growth in front of pines and eucalypts competition, besides reducing the forest fire risk and improving the forest health. The thinning consisted on a mechanized selective felling using an accumulating shears head that afterwards fed a rear Fixteri bundling unit that compressed, crosscut and automatically produced round bales formed by tree sections. The feller acted on a 28% of the forest surface, with an average slope of 16% and an average basal area from planted pines of 23 $m^2 \cdot ha^{-1}$, in front of significantly different values of 32% (slope) and 7.6 $m^2 \cdot ha^{-1}$ (pine basal area) in the not thinned area.

The bundling unit and the felling head were mounted on a Logman 811 FC base machine with a Logman C140-11 telescopic boom allowing the swing-to-tree selective felling. The productivity was high – the machine produced a 300 to 550 (average 387) fresh kg cylindrical bundle every 4.35 minutes of work time E15, as an average -. The productivity averaged 4.40 green tonnes/SMH or 5.33 green tonnes/Work hour E15, although the adoption of a more systematic work

pattern – defining parallel strip roads where possible – and the definition of more clear felling criteria since the beginning, would have allowed reaching higher values for productivity and thus reducing the operational costs.

The moisture content was sampled in order to provide the results in terms of dry matter, being the average moisture close to 45%, on humid basis. The machine was tracked using an onboard GPS and the productivity was followed up using its own weighing device, checked to verify its weighing accuracy.

A previous forest inventory, aerial photography and GIS analysis permitted to characterize the daily treated areas regarding initial and extracted trees density and percentage, tree size, initial and extracted basal area and percentage, extracted biomass weight (odt·ha^{-1}) and slope. The influence of such factors on the productivity was analyzed and the main influential factors were the weight of the extracted tree (odt·tree^{-1}) and the percentage of extracted basal area, allowing a fitted nonlinear regression with R^2= 73% (adjusted R^2=52%).

Also the thinning intensity was analyzed after a post-harvest inventory on the same plots: as an average, the extracted dry weigh was estimated as 45.4 odt·ha^{-1}, corresponding to a 69% of trees density reduction (from more than 6,000 per ha to close to 1,900) and an average basal area reduction of 66%, from 30.8 m^2·ha^{-1} to 10.4 m^2·ha^{-1}. The study also permitted to assess the biomass collection efficiency (very high, almost no slash was left on the ground) and the environmental immediate effects on the soil and remaining trees, slight to moderate (an 8.3% of the remaining trees were damaged, while soil damages were isolated in few road sections).

The operating hourly and unit cost of the machine was also estimated. The consideration of the average forwarding, chipping and transport unit costs shows that, in the present studied case, despite the poor work conditions, the operation would be profitable if a consumer located at 35 km of the forest would have paid 66 €/chip tonne (at 30% of moisture on humid basis), provided that no stumpage price were paid to the forest owner. The productivity equation allows discussing the profitability conditions for this kind of post-fire treatments or the subsidizing needs where the treatments were not self-financing.

The Fixteri technology was evaluated as a cost-efficient and environmentally smooth alternative for this kind of post-fire stands treatment.

Keywords: Post-wildfire restoration, whole tree felling-bundling, mixed Mediterranean stands, cork oak, forest machinery, work study.

WEB-BASED SERVICEFORASSESSMENTOF FORESTRY CONTRACTORS – THE CASE OF SLOVENIA

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Abstract: This article presents web-based information system, designed to assess the quality of forestry work performance. The web-based information system, calledMojGozdar, represents and innovative approach to a more transparent service market. MojGozdar offers support in the search for forestry services. At the moment, the system incorporates over a thousand forestry contractors, offering diverse forestry services. The MojGozdar system covers a three-level sustainability assessment of the forestry contractors in a simple, clear, and objective way. On the first level, all involvedforestry contractorsget a formal suitability assessment following the traffic lights principle. The assessment made by a professional qualified assessor represents the second assessment level. The main principle of an independent professional assessment will be sustainable forest management and achievement of a higher standard in social, economic, and environmental aspects of work execution. Forestry contractors, who legally and formally meet the basic conditions, i.e. who were assessed as adequate at the first assessment level, can join the second level. The third sustainability assessment level is intended for the customers to present their experiences or opinions about the quality of the provided services. The comprehensive assessment system should increase motivation among the forestry contractors in competition and quality performance of works in forests. At the same time, this is a comprehensive system for the providers' quality objective assessment, also of the additional possibility for evaluating offers for work in the state-owned forests, where offered price is the only criterion at the moment.

Keywords: work quality, adequacy of service providers, services, forestry, sustainable management, information system,

INTRODUCTION

In Slovenia, the forestry services market is highly dynamic. Owing to the rapid changes and the emergence of increasingly new forestry contractors, abuses and frauds are possible. Problems arise (particularly) during increased demand for services upon major surface disturbances (e.g. ice storms, bark beetle attacks, windbreaks), when individual forest owners (e.g. owners who do not practice active forest management) have no information on service providers in terms of their quality and reliability. Particularly small forest owners who require forest services only rarely and have no experience in forest management, opt for a certain forestry contractoron the grounds of their intuition and through personal acquaintances (recommendations by a district forester, neighbour or friend). It can be expected that the service market in the sphere of forestry work will be additionally restructures after the changes taking place in state-owned forest management arrangement. In Sweden (Sääf&Norin, 2013), the structure (number and characteristics) was altering in the period from the 1960s to 1990s from independent providers with horses to larger forest companies that had their own machinery and employed workers, to workers who worked for forest companies but had their own machines, while in the last phase the workers became totally independent. With this kind of changes, productivity distinctly increased as well.

Qualified, motivated and well-informed forestry contractors are crucial basis for cost-effective and environmentally-friendly forest management. On the one hand, forestry contractors are liable to pay regard to the legislation and environmental aspects of forestry work, while on the other hand the greater part of responsibility lies on forest owners. One of the basics in certification schemes, for example, is that the forest owner is responsible for providing utter compliance with forest management standard demands (e.g. PRFC and FSC). From the aspect of assessing the companies that carry out forestry work, their assessment is very complicated owing to the extensive impact on the economics of production as well as on social and environmental aspects of forest management. The aspects of work implementation and, in turn, the environmental suitability is assessed only indirectly with tools that can be defined as a method of assessing the products' life cycle. This method is a process with which the environmental burdens, which are related to the production of a product or service, are evaluated, in order to ascertain how much energy and materials relative to the type and quantity is needed, what are the types and quantities of waste and emissions into the environment, and what are the potential consequences for the environment (Košir, 1999: 92–93).

On the basis of annual reports by the Slovenian forestry inspection and annual reports by the Slovenia Forest Service (ZGS) there is no sign that the quantity of forestry work in Slovenian forest management would be in any way problematic or that there are major deviations from the stipulations of the forestry legislation, especially if the estimation that about 100,000 forest owners are felling trees in the forests each year is taken into consideration (with 41,589 Agricultural holdings harvesting forest timber assortments according to the Statistical Office of the Republic of Slovenia, 2016).

2. AN OVERVIEW OF PAST EXPERIENCES AND RESEARCH

In Germany (as in the case of Bavaria)(Borchert &Benker, 2015a), small-sized enterprises prevail on the forest service market, most often self-employed forestry contractors. On average, they carry out services in the areas smaller than 1,000 ha and implement them in the local environment (at a distance of up to 20 kilometres from the company's seat). Apart from often utilizing old and worn out mechanization, they are subjected to intense competition in work acquisition. The recent analysis of this economy segment in Bavaria (the questionnaire embraced 10% of the companies) has shown (Borchert &Benker, 2015b) that owing to the fact that the main role in the acquisition of work on the market is played by the price of services, the quality of the implemented work is falling rapidly, even though the very state of the forest upon the carried-out work is one of the key issues of sustainable forest management. The researchers in Slovenia (Košir et al., 1996) have been devoting their attention to assessing the quality of forestry contractors and possible assessment criteria for concessions in the state-owned forests.

The practical assessment of the quality of the carried-out work abroad either focuses on the evaluation of damages in trees and soil during the production phases of skidding to the forest road or, recently, on inspecting the contractors' performance and the quality of the carried-out work relative to the selected indicators within the framework of FSC and PEFC certification schemes (Seizinger, 2013; DFSZ, 2016). The latter controls embrace only the contractors who implement their services in certified forests. On the basis of FSC and PEFC standards, ISO 9000 quality standards (quality management), ISO 9001 (quality work with the customers), ISO 19011 (methods of verification) and ISO 17021 (evaluation of quality system) in Germany, the certificate of forest service quality has been introduced in Germany. In the past, a few attempts at evaluating the contractors' performance on the basis of surveying the working site upon the carried-out service according to the 'Bonus-Malus' principle (Ofner, 2005) have been made, but this kind of approach has not established itself to a large extent.

Theoretically, wood is a sustainable renewable natural resource, with its production and processing burdened, in practice, by numerous negative influences. These are most comprehensively encompassed by the life cycle assessment (LCA) of wood products that also include the quality aspects of the execution of works. Although the LCA methods are well known in forestry, they have failed to reach a prominent position in assessing the quality of forestry work in practice (Heinimann, 2012; Cosola in sod., 2016). Owing to the great significance of the quality of the carried-out work from the aspect of providing for compliance with the requirements of certification schemes for forest management, both certification schemes (FSC and PEFC) are also developed for independent certification of forestry contractors. An emphasis in these schemes lies on social aspects and on utter compliance with the legislation. Apart from it, forestry contractors are liable to carry out, in certified forests, their work in compliance with the provisions of certification schemes, i.e. to provide for compliance with the provisions related to social, environmental as well as economic aspects. From the environmental aspects, the greatest emphasis lies on the protection and conservation of water sources.

In the European Commission's document "Corporate Social Responsibility: A business contribution to Sustainable Development (2002)", designed for the promotion of European orientation for social responsibility of businesses or organizations, the latter is defined as a concept with the aid of which companies incorporate, on voluntary basis, social and environmental issues into their business as well as into their relationships with stakeholders. According to ISO26000:2010 standard, the definition of social responsibility reads as follows: Social responsibility is responsibility of a business or organisation for the influences of its decisions and activities on the society and the environment, which through transparent and ethical conduct contributes to sustainable development, including the society's health and well-being; takes into consideration the stakeholders expectations; is in accordance with valid legislation and international norms of conduct; is incorporated into the entire organisation and implemented in all of its relations (CEC, 2010).

The quality of forestry contractors is relevant not only for part of private forests, but also in state-owned forest management, where the main criterion is currently the offered price due to the rules of public service contracts. This aspect is also drawn attention to, for example, in the Latvian state-owned company Latvijasvalstsmeži (Gercans, 2013). One of forestry companies in Slovenia that assess the quality of the carried-out work is the GozdnogospodarstvoBled, d.o.o. The company collects the users' opinions about the quality of its services (GG Bled, 2018) and methodically correlates the quality of work with remuneration of its production workers (Soklič, 2015). Recently, we have been given good conduct instructions in Slovenia for individual environmentally demanding technologies (Krč et al., 2014; Košir, 2007). In Slovenian forests, the contractors are introducing new machines and technologies, which are marketed as environmentally friendly abroad (Visser & Stampfer, 2015), but in practice the service commissioners have no chance of checking their adequacy in our specific conditions.

WEB-BASED INFORMATION SYSTEM MOJGGOZDAR

Through the research project entitled "The system of assessing the quality of forestry contractors" project groupstrive for the development of tools that would contribute to a greater competitiveness of the forestry sector in terms of social responsibility, economic effectiveness and environmentally friendly forest management. The web-based information system for assessing the quality of forestry contractors, which will be utilized during the project's implementation, is an innovative approach to a more transparent service market. It should be simple to use and should enable an effective transfer of information's to end users. Furthermore, the system is to contribute to the correlation of supply and demand

and to provide the users with a possibility of selecting the most suitable contractor, as well as to promote forestry contractordsand services carried out by them. The system users, as the commissioners of forestry services, will actively contribute, with their ratings, to a greater motivation among forestry contractors for a more sustainableoriented actingon the market.

At the end of 2017, an important milestone was reached by the project through the introduction of web-based information system named MojGozdar (in translation: MyForester). It is publicly accessible at www.mojgozdar.si (Figure 2). During the project, it will function as a pilot system.

MojGozdar is intended for all internet visitors. By registering with the MojGozdar web system, they become members, who may access all functionalities of the MojGozdar system and also become commissioners of forestry services. MojGozdar offers support to the users in their search for forestry services, such as chainsaw felling, tractor harvesting, silvicultural works, cable harvesting, machine felling, wood chip production (chipper), and forest road construction. The membershave the right of accessing the contractors' profiles and data correlated with them. They can also send inquiries about individual forestry services to various forestry contractors, who had already joined the MojGozdar system. The users are forest owners or managers of forests and other wooded areas, who wish to get, via the MojGozdar web-based system, offers for selected services.

MojGozdar incorporates forestry contractors who are registered for performing forestry servicesand have been legally checked prior to the beginning of their activities by the competent forestry inspection (The Inspectorate of the Republic of Slovenia for Agriculture, Forestry, Food and the Environment - IKGLR). According to Slovenian legislation each contractor is responsible to assure professional competence of their workers and certifications needed for performing various works that regulate safety and health at work, working equipment and personal protective equipment. On the basis of certifications submitted by forestry contractors, forest inspections regularly supplement the list of contractors who fulfil the minimal conditions, as well as the list of contractors that had been issued a written order prohibiting them to carry out their work (IKGLR, 2018). The forestry contractors not registered by forestry inspection (e.g. transport of wood and wood chips production) have been incorporated on the basis of the service market research.

Figure 1: Entry page of the web-based system MojGozdar.si

3.1 Sustainability assessment of the quality of forestry contractors

Most suitable for the sustainability assessment of forestry contractors is the combined evaluation, which embraces economic (as the most important ones in the selection), social (following the example of the concept of companies' social responsibility) and environmental aspects. The MojGozdar system will embrace a three-level sustainability assessment of contractors in a simple, transparent and objective manner. Hereinafter, the evaluation mode based on different data sources is presented.

3.1.1 Level 1 – Formalsuitabilityofforestrycontractorsbasedonavailabledatasourcesonbusinessentities

During the first partof the project, the automatic evaluation of forestrycontractors was created according to the traffic lights principle using databases of the Agency of the Republic of Slovenia for Public Legal Records and Related Services (AJPES), Financial Administration of the Republic of Slovenia (FURS) and the *Inspectorate* of the Republic of Slovenia for Agriculture, Forestry, Hunting and Fishing (IKGLR). At the moment (June 2018) more than 1300 forest contractors are included in this first level of evaluation. Figure 2 denotes information flow of the first level assessment of the MojGozdar system. The evaluation is daily updatedon the basis of changes occurring in any of related databases.

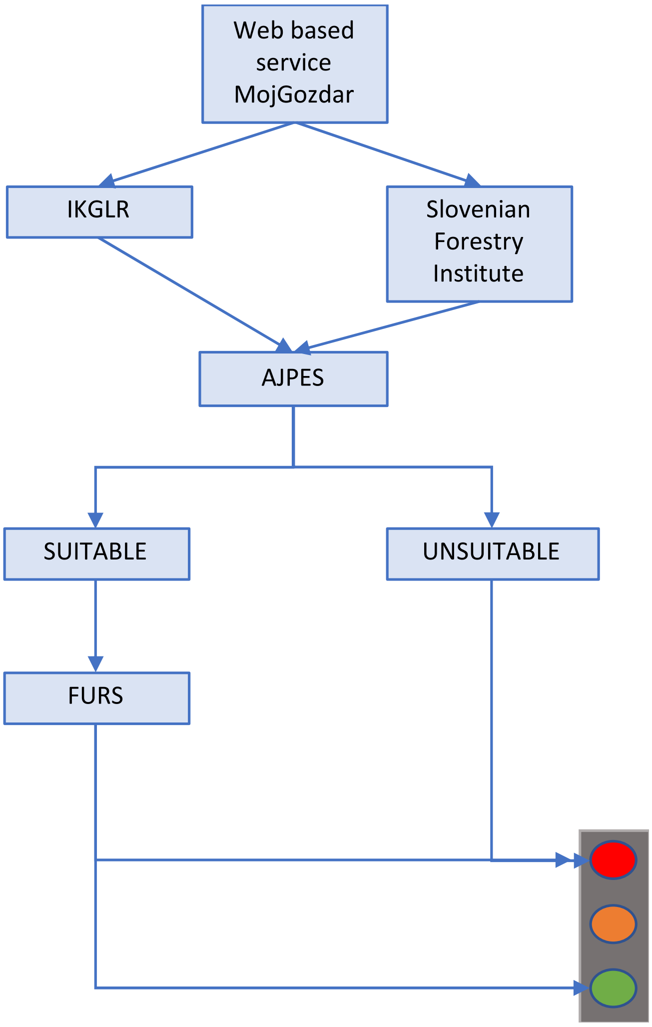

Figure 2: Schematic display of formal classification of forestry service providers relative to the publicly accessible data (Level 1).

The assessment according to the traffic lights principle is regularly updated and is accessible by all users (from December 2017 on). The basic conditions that are to be fulfilled for each individual rating are defined in Table 1 and graphically presented in Figure 3.

Table 1: Evaluation of forestry contractors' suitability according to the traffic lights principle

	Green light denotes forestry contractors that fulfilled all requirements during inspection, are not on the list of tax debtors, and are legal entities according to the Business Register of Slovenia.
	Yellow light denotes forestry service providers that are not on the list of tax debtors, are legal entities according to the Business Register of Slovenia, and are registered for relevant activities per standard classification of activities. One should note, that yellow light denotes the companies of which no official record is kept by forestry inspection. These are, for example, the companies offering the service of producing wood chips, wood transport entrepreneurs.
	Red light is a warning sign that the contractor has been prohibited, by order, from carrying out at least one of the registered forestry activities (the activity thatis prohibited is marked separately),or is tax debtor, or is non-active legal entity according to the Business Register of Slovenia, or has not registered relevantactivities per standard classification of activities.

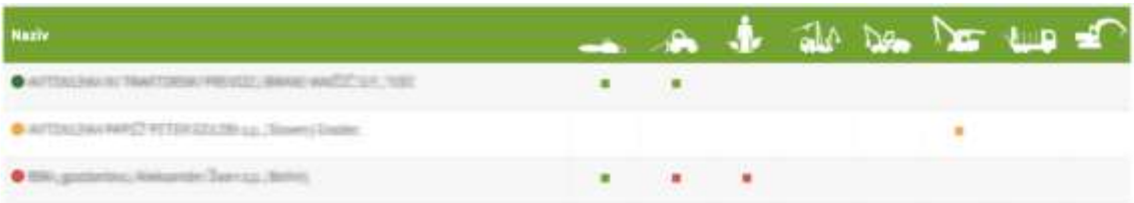

Figure 3: An example of evaluation display according to the traffic lights principle in the MojGozdar system

3.1.2 Level 2 - Professional assessment of the suitability of forestry contractor

The second partcomprises the methodology of conferring independent professional rating. In the second level of assessment, all contractors who were rated as suitableduring the first level can take part, i.e. those that received green or yellow light. The main principle of independent professional assessment will be fulfilment of measures of sustainable forest management by achieving higher standard in social, economic and environmental aspects (Figure 4). The guidance in the method will be independence of ratings, the principle of equality and compliance with criteria that are crucial for quality implementation of forest work and can help the users in their final selection of forestry contractor.

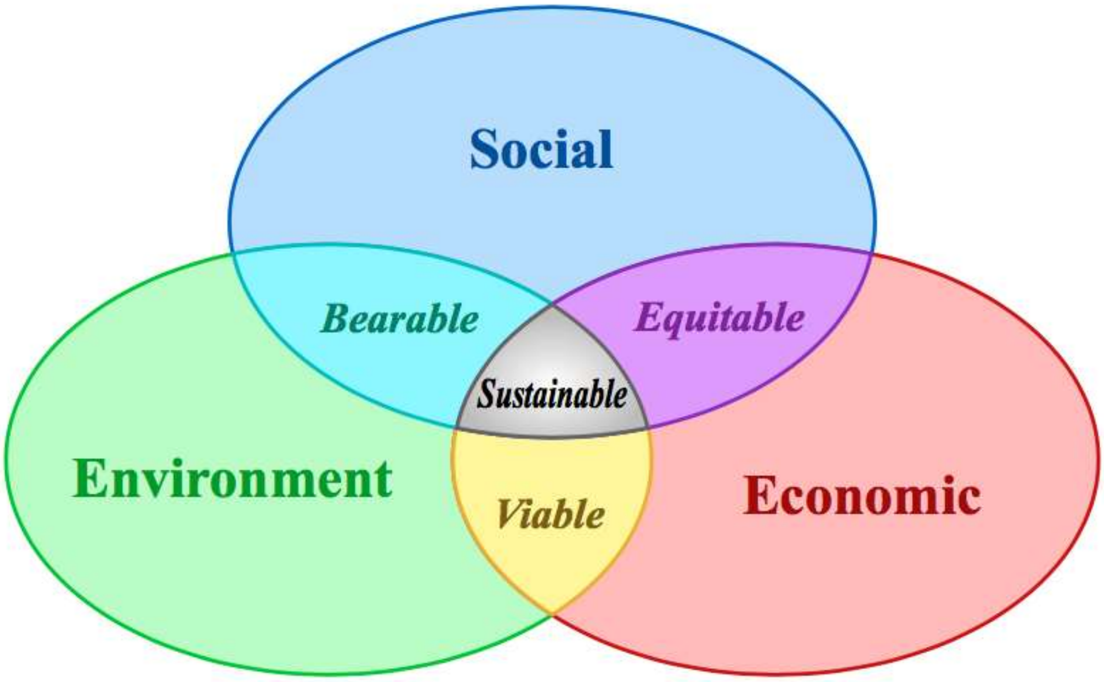

Figure 4: The principles of sustainability are the main guidance in the development of independent professional rating methodology (Source: Wikipedia).

On the basis of the survey of hitherto research and coordination workshops with the stakeholders' representatives, a proposal of principles, criteriasand indicators was made. The participators in its preparation were experts from the Faculty of forestry (a partner in the project) and other institutions such as IKGLR, Chamber of Agriculture and Forestry of Slovenia, Institute for Nature Conservation, Slovenia Forest Service, representatives of major contractors, and representatives of the company Slovenskidržavnigozdovi (Slovenian State-owned Forests). Final result of coordination with the stakeholders is the hierarchic list, which embraces three principles, eight criteria and twenty-nine indicators (Figure 5). In the second round, an extended group of the stakeholders' representatives will set measures for the selected principles, criteria and indicators on the basis of methods for multi-criteria decision making. Result of the second round will be the participative set criteria for the sustainability assessment of forestry contractors. In the final round, the project group will prepare guidelines for a professional sustainability assessment of forestry contractors. These guidelines will be intended, on the one hand, for experts for them to objectively assess whether the evidences submitted by contractors correspond, partially correspond or do not correspond with individual indicators. On the other hand, the guidelines will serve forestry contractors as a document on the basis of which they will be able to improve their business practice in terms of social responsibility, economic justification and environmental suitability.

The sum of measures (points) will denote a composite assessment, which is conferred according to the principle of categorization of the accommodation facilities (with categories/stars) (Rules on categorization of…, 2008). The composite assessment will be presented along with other publicly accessible data on legal entities. Let us underline, however, that the independent professional assessment is withdrawn and not conferred to legal entities for which it is established that they do not meet the conditions for any reason to be given green or yellow light (first level of assessment).

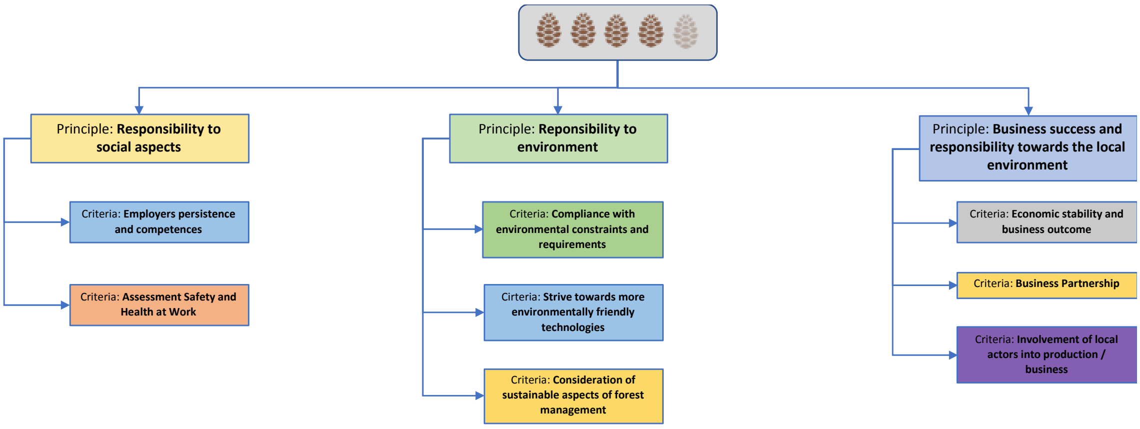

Figure 5: Schematic display of independent professional assessment of business entities relative to the indicators and criteria collected with entry into »mojgozdar.si« system

3.1.3 Level 3 – Assessment of the customer's satisfaction with the carried-out service

On the MojGozdar system, experiences and opinions concerning the quality of the carried-out service can also be conveyed by the MojGozdar system users. The average rating obtained from the users (third level) will be published together with the acquired measures (third level assessment) of the forestry contractor. It is envisaged that the users assess the contractors who have preliminarily registered with the MojGozdar system. Assessment is possible with the use of online questionnaire.

The project group believes that assessment of the user's satisfaction (third level) is, together with the independent professional assessment(second level), crucial for a solid selection of forestry contractor as well as is a key information that can tell the contractor seeker most about an individual legal entity.

CONCLUSIONS

Idea is to make the MojGozdar information system a central information portal of the forestry contractors in Slovenia and that it shall not be intended for the service users only, but also for education and information purposes as well as for networking of a wider public.

Through checking the suitability of forestry contractors, the project will contribute to better services on the market. Furthermore, it will contribute to a greater recognisability of Slovenia, given that in future the project group will strive to extend the system also over the border to the neighbouring countries. Control over forestry contractors and their ratings would benefit not only private forest owners but also the companies managing the state-owned forests. With return information of a state-owned company on the service quality, private forest would hugely gain as well. With its ratings, the MojGozdar system would also benefit the contractors of forestry services as promotion of their quality and reliability.

The research project entitled »The system of assessing the quality of forestry contractors« enables active participation in the system's development through incorporation of stakeholders and consideration of their knowledge and experience in the system's structuring. The MojGozdar web-based system will enable its users to exert influence on the assessment of forestry contractors by assessing their services. Great importance is given to the credibility of assessments and, in turn, prevention of abuses in the inclusion of the system's users in the pricing of the contractors' services.. Last but not least, the MojGozdar system will also be a promotion of forestry contractors.

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Implementation of medium-sized harvesters in coppice stands: Performance and potential environmental risks

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Abstract: Coppice forests are an example of the pronounced intervention of humans in forest ecosystems. This intervention has served human purposes for thousands of years by providing a large variety of wood and non-wood products, thus serving as an important factor in the survival of rural communities. In recent decades, in some parts of Europe, the management of coppice forests has been abandoned due to socioeconomic changes. This has resulted in aged coppice stands, whose potential to provide wood products remains unutilized just as the demand for wood and wood-based products is rising. A possible solution to this problem could be the introduction of small- and medium- sized harvesters in coppice stands. However, thus far, there has been limited research on the topic. The study was carried out in one oak and two alder coppice stands in Northeast Poland, harvested using a TBM PREUSS 84V.II 6WD harvester. Time consumption was investigated by means of time studies. The results show a wide range of productivity rates: 10.43m3/PMH0 (9.30m3/PMH15) for site 1 (oak), 4.99m3/PMH0 (4.29m3/PMH15) for site 2 (alder) and 3.76m3/PMH0 (3.13m3/PMH15) for site 3 (alder). Furthermore, the environmental impact of the harvesting operations was recorded. Tree dimensions and form were found to affect the performance of the harvester. The skills of the harvester operator influenced the environmental impact on the harvesting site. Excessive rutting was observed when there was a higher soil moisture content, raising the central issue of the human factor in forest work. Limited work experience or work technique can lead to the increased frequency of machine breakdowns and lower work performance. Analysis of the results suggests that the introduction of mechanized harvesting in coppice stands should be the result of careful consideration by the forest enterprise, otherwise poor financial outcomes and a negative environmental impact might be expected.

Keywords: Medium-sized harvester, oak, alder, production rates, rutting, Poland

LESSONS LEARNT FROM CAPACITY BUILDING RESEARCH-ACTION WITH PROFESSIONAL WOOD MOBILISERS: TACKLING THE KNOWLEDGE-TRANSFER CHALLENGE

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1. Extended Abstract

EU member States' Forest Policies call for increased wood mobilisation to maintain a resilient and competitive forest-based industry. Although a policy imperative set against a strong market, there are a range of technical and economic constraints acting as barriers against mobilisation. But willingness to reconsider business-as-usual actions of organisations, can provide a relevant context to investigate new practices and strategies with forest companies and their professional skills and competences. We describe the methodology used in 14 EU regions, and 20 pilot projects with the forest sector community to steer knowledge transfer, facilitate capacity building, and change through the implementation of research action. Each pilot project linked theory of change to the mobilisation of people. As part of the process, stakeholders' commitment and mutual understanding (social learning) was facilitated within Regional Learning Labs (RLL). Two were operated in France from 2014 to 2017. They co-produced new knowledge with participating practitioners. Impacts were evaluated within the RLLs to assess changes in attitudes and practices, and the lessons learned provided important insights on the knowledge-transfer process within the professional community. Appreciative feedback was voiced out by beneficiaries on the way the pilot project were run (meeting frequency, content of the outputs, steering method…). The short and targeted format of the deliverables was highlighted as well-tuned to their expectations. Beneficiaries also stated that the willingness and commitments of their peers contributed to the success of the research-action. Several stakeholders claimed that if they could do things differently they would encourage more colleagues to join and directly benefit from the RLL. All participants confirmed they had shared the knowledge within their company/organization, the number of other practitioners benefiting from this transfer varying from 3 to 20 per person. In the cases of such co-beneficiaries, knowledge-transfer happened systematically both through informal discussion or meeting and with a direct transmission of the project media (co-produced memos, guides…). Transfer to external partners or sub-contractors was less spontaneous. Half of the respondents mentioned such dissemination, and the latter was never backed-up by the transmission of project documents. However, participants aspired to further disseminate knowledge after the project end. It was therefore suggested that reminders, multi-media

and multi-channel distribution should be organised. From the capacity-builder point of view, evaluating outcomes and impacts with sociology as a backbone was a strong asset to complement the classical costs/benefits analysis performed in usual research projects. This worthy effort provided valuable information and story-telling for the next steps. The approach is now applied in other projects aiming at effective knowledge-transfer to forest companies.

Keywords: knowledge-transfer, capacity building

ANALYSING THE EFFICIENCY OF MECHANISED THINNING IN BROADLEAF STANDS

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Abstract: Timber harvesting in Croatia still mostly relies on motor-manual felling and processing followed by skidding or forwarding of roundwood. Design of present harvesting systems, especially the ones used in broadleaf stands was strongly influenced by close-to-nature forest management principles and buck-to-quality processing of high-value roundwood. But, in recent times labour shortages of skilled and motivated forest workers put intense pressure on introducing mechanised felling and processing beyond the coniferous plantations where they had been introduced a decade ago and successfully applied. The research conducted had a focus on different aspects of efficient mechanised timber harvesting by a harvester (Timberjack 1470D) – forwarder (Timberjack 1710D) system in an 80-year old broadleaf harvesting site (27.35 ha, harvesting density 86 trees/ha and 43 m3/ha – mostly European hornbeam). Harvester's work was video recorded and later analysed on tree level by UmtPlus software. The same software was directly applied in the study of forwarder's work, which was analysed on cycle level. During the research 795 trees were felled and 41 forwarding cycles were recorded. A sub-sample of 94 trees was measured to construct net volume vs DBH equation. The same sub-sample was used to determine the quality of processing the roundwood and to validate the stem data recorded by the harvester. A harvester productivity model was developed, resulting with the productivities from 9 m3/SMH (DBH 12.5 cm) to 16.8 m3/SMH (DBH 42.5 cm). A key factor influencing the productivity was the time to process the crown (on average 75% of the total processing time). Significant differences in volume per tree recorded by the harvester and manually measured were found, namely as a consequence of frequent multiple handling (and measuring) of energy wood processed in the crown. This work method, while being beneficial to productivity, also resulted in »un-standard« form of 15% of the produced number of roundwood assortments. Forwarding productivity ranged

from 11.1 m3/SMH (100m) to 7.3 m3/SMH (800m). Ideal weather conditions led to excellent soil bearing capacity allowing an average load of 13.28 m3. Pre-bunching of roundwood enabled lower time of loading when compared to results of forwarder's work in similar conditions after motor-manual processing. The unit cost of traditional harvesting system (chainsaw+skidder) can be reached by increasing the annual utilisation of a harvester from today's quite modest 1.125 SMH to 3.000 SMH. Those figures will be hard to achieve without a stronger implementation of mechanised felling and processing in natural broadleaf stands which prevail in the structure of Croatian forests. In the meantime, if the labour shortages continue, application of the harvesters will have to be accepted even in the case when they are not the cost-competitive but the only available alternative to complement the motor-manual harvesting in achieving the planned annual cut.

Keywords: harvester, forwarder, productivity, cost, European hornbeam

NATURAL DRYING OF ALEPPO PINE BIOMASS

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Abstract: *Reduction of forest biomass available in the stand and especially on the forest floor is by many researchers identified as a key component of fire prevention. This especially refers to biomass parts with low moisture content that pose a serious treat either in terms of suitable fuel in the ignition phase of a wildfire or as a fuel feedstock capable to transform ground fire to more destructive and dangerous crown fire.*

This research was conducted with the goal to determine the structure of the aboveground biomass of Aleppo pine trees and with the goal to determine trends of natural drying of different parts of the aboveground biomass (stem, living branches, dead branches, shoots with needles).

Study was established in a mixed Aleppo pine stand near the town of Zadar in Croatia, where the transition from the eumediterranean zone to the submediterranean zone starts. A sample of 20 trees were felled and measured in the period starting from April 15th to September 20th. Additionally, 10 trees were felled in the first week of the research and measured and sampled in two week intervals, starting from April 24th and ending on August 28th.

In the observed DBH range (11 cm to 41 cm), the volume of stemwood (> 7 cm overbark) increases from only 0.038 m^3 to 1.123 m^3. Of this volume 0.017 m^3 to 0.784 m^3 net volume of wood assortments per tree was produced. The volume of wood with a diameter of 3-7 cm overbark makes about 10% compared to the volume of the wood with a dimeter > 7 cm overbark. In traditional roundwood harvesting this biomass would be left on the forest floor and could pose a threat in terms of wildfire fuel. In addition, it is possible to expect from 11.8 kg to 203.3 kg of bone dry branch biomass (< 3 cm) per tree.

Based on the research data it can be concluded that the moisture content of biomass components in fresh state does not depend on the month of the felling (in the investigated period).

Duration of natural drying had a significant influence on the reduction of moisture content in some components of the aboveground biomass; stemwood (samples at the first cross-cutting point) reduced the initial moisture content to just one third, below 20%, and moisture content in living branches was reduced to almost a quarter of the initial value, to slightly above 10%. Moisture content of shoots with needles, in the research period, halved to 15% (but due to variation, statistical difference was not proven). Dead branches had a steady 10–15% moisture content regardless of the drying period. Similar insensitivity to drying period was observed for the stemwood (samples at the base of the stem), but in the wide range of 30–55% moisture content.

Research results are expected to have practical application in the field of biomass harvesting in Aleppo pine stands, which is currently still quite limited due to the fact that forests in the research area have a strong protective and recreational function in tourism. But, until intensifying biomass harvesting, the results could hopefully serve as a starting point for forest fire forecast and prevention models.

Keywords: moisture content, stem, living branches, dead branches, shoots with needles, fire prevention

1. Introduction

Aleppo pine (*Pinus halepensis* Mill.) forests cover approximately 2.500.000 ha in the Mediterranean Basin, mostly at low elevations (less than 500 m) and along the coastline (Mitsopoulos and Dimitrakopoulos 2007). In this area, vegetation characteristics and climate are identified as the most important factors (of natural origin) that in the combination with human factors have a decisive role in the occurrence and the spread of forest fires (Španjol et al. 2011). When focused on vegetation characteristics, that forestry can influence the most, appropriate management of forests to reduce the amount of fuel available is considered as crucial in fire prevention. Therefore, intensified harvesting in this area is one of the promising solutions to reduce the number of wildfires and the area burnt. In this respect, suitable thinning regimes should be identified and applied (Ruiz-Mirazo and Gonzalez-Rebollar 2013) to reduce canopy bulk density and to increase canopy base height (Mitsopoulos and Dimitrakopoulos 2007). This is especially important in Aleppo pine stands which according to Quezel (2000) represent approximately 1/3 of the total annual burned area in the Mediterranean Basin.

The structure of aboveground biomass, expected quality of the timber produced and the lack of market in some cases will probably result in using the feedstock mainly for energy. And when biomass in used for energy, moisture content is the most important factor influencing the quality and calorific value (Acuna et al. 2012, Routa et al. 2015). Natural drying of energy wood, as the most convenient way of moisture reduction, has been investigated by number of researchers recently (Anisimov et al. 2017, Routa et al. 2015, Erberet et al. 2014, Erber et al. 2012, Filbakk et al. 2011). But, opposite to main intention to reduce the moisture content of the energy wood as much as possible by natural drying in the stand or at the roadside, in the Aleppo pine stands special attention has to be paid to fire prevention regulation and prompt extraction of harvested biomass.

The reduction of forest biomass is by many researchers identified as a key component of fire prevention, and this especially refers to biomass parts with low moisture content that pose a serious treat either in terms of suitable fuel in the ignition phase of a wildfire or as a fuel feedstock capable to transform ground fire to more destructive and dangerous crown fire.

This research was conducted with the goal to determine the structure of the aboveground biomass of Aleppo pine trees and with the goal to determine trends of natural drying of different parts of the aboveground biomass (stem, living branches, dead branches, shoots with needles) both for harvest planning and fire prevention purposes.

2. Material and Methods

Study was established in a mixed Aleppo pine stand near the town of Zadar in Croatia, where the transition from the eumediterranean zone to the submediterranean zone starts. A sample of 20 trees were felled, measured and sampled in the period starting from April 15th to September 20th. Additionally, 10 trees were felled in the first week of the research and measured and sampled in two week intervals, starting from April 24th and ending on August 28th. Average *DBH* of sample trees was 22.4 cm (11 – 41 cm) and average height was 13.6 m (6.3 – 22.3 m).

Aboveground biomass of each tree was divided to stemwood with a diameter of over 7 cm overbark, stemwood and branches with a diameter of 3 – 7 cm overbark, living and dead branches with a diameter under 3 cm overbark and shoots with needles. Volume of the wood over 3 cm diameter overbark was determined by sectioning method. For wood over 7 cm overbark, bark thickness was determined at mid-sections. For other biomass parts total mass in fresh state was determined. Samples of living and dead branches as well as of shoots were taken. Stemwood was sampled with two sample discs; first at the base of the stem, and the second at the first cross-cutting point. Moisture content of the samples was determined according to HRN EN ISO 18134-2:2015.

Analyses were done to determine the structure of the aboveground biomass and to explore moisture content variation of biomass components in relation to the month of the felling (for 20 sampled trees) and in relation to the period of natural drying (for 10 sampled trees).

3. Results and Discussion

In the observed *DBH* range (11 cm to 41 cm), the volume of stemwood (> 7 cm overbark) increases from only 0.038 m^3 to 1.123 m^3 (Figure 1). Of this volume 0.017 m^3 to 0.784 m^3 net volume of wood assortments per tree (Figure 2) was produced (in average 74%). The volume of wood with a diameter of 3-7 cm overbark (Figure 3) makes in averge 10% compared to the volume of wood with a diameter of > 7 cm overbak, but with a high variation from only 3% to nearly 22%. In traditional roundwood harvesting (when harvesting residues are not extracted) this biomass would be left on the forest floor and could pose a threat in terms of wildfire fuel. In addition, it is possible to expect from 11.8 kg to 203.3 kg of bone dry branch biomass (< 3 cm) per tree (Figure 4).

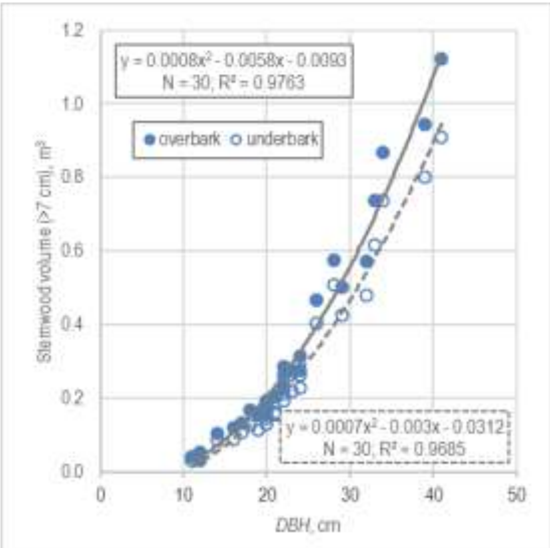

Figure 1 Stemwood volume (>7 cm) vs. *DBH*

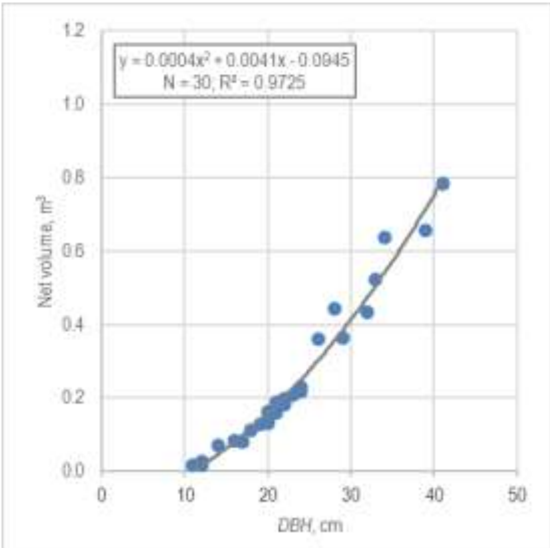

Figure 2 Net volume vs. *DBH*

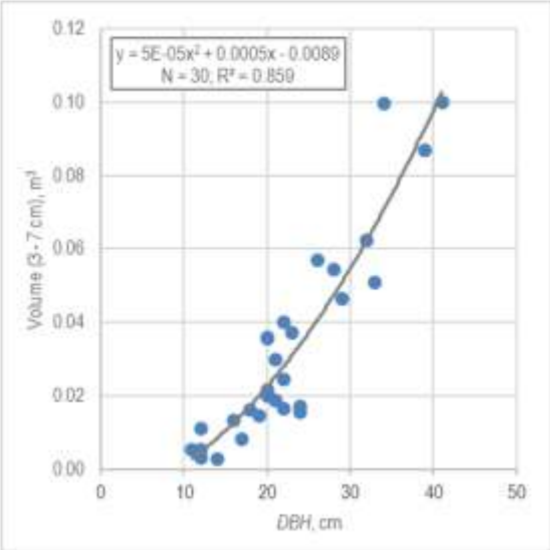

Figure 3 Volume of wood (3-7 cm) vs. *DBH*

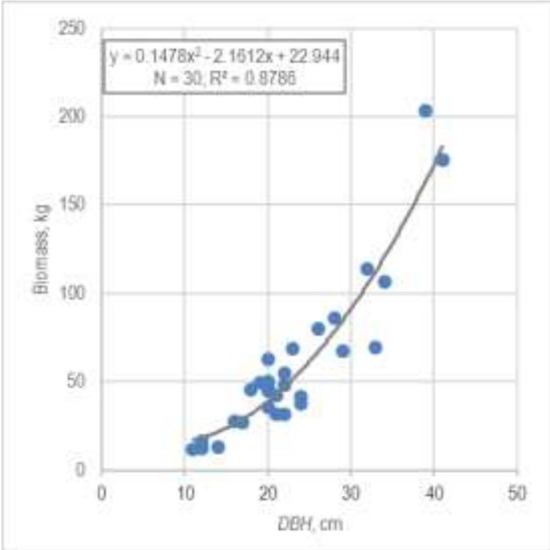

Figure 4 Biomass (< 3cm) vs. *DBH*

No significant statistical difference in the moisture content of biomass components in fresh state between the trees felled in different months of the investigated period was determined. Average moisture content of shoots amounted to 55.2±2.7% (Figure 5), and that of living branches amounted to 51.9±2.3 (Figure 6). Dead branches had significantly lower moisture content of 16.6±6.8% (Figure 7). Stemwood samples showed 44.6±4.5% average moisture content on sample discs cut at the base of the stem, and 51.1± 3.8% moisture content on sample discs taken at the place of the first cross-cut (Figure 8).

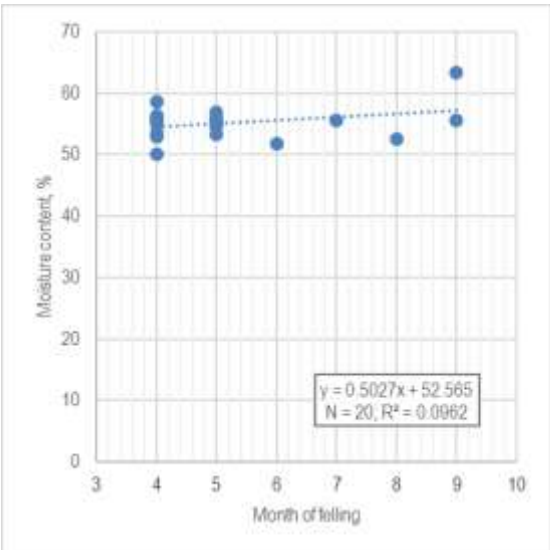

Figure 5 Moisture content of shoots vs.

month of felling

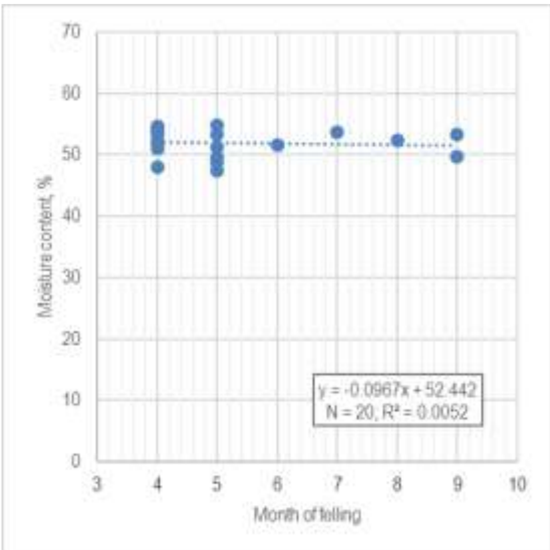

Figure 6 Moisture content of living branches vs.

month of felling

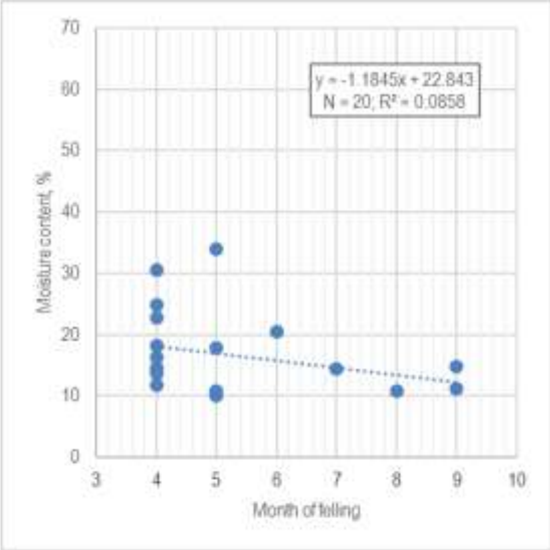

Figure 7 Moisture content of dead branches vs.

month of felling

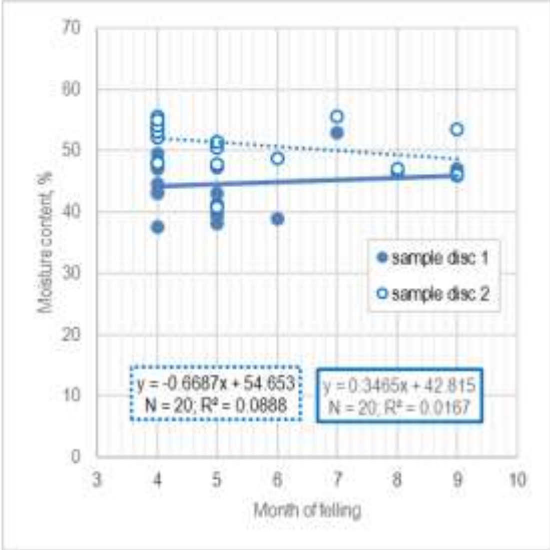

Figure 8 Moisture content of stemwood vs.

month of felling

Duration of natural drying had a significant influence on the reduction of moisture content in some components of the aboveground biomass; stemwood (samples at the first cross-cutting point) reduced the initial moisture content to just one third, below 20% (Figure 12), and moisture content in living branches was reduced to almost a quarter of the initial value, to slightly above 10% (Figure 10). Moisture content of shoots with needles (Figure 9), in the research period, halved to 15% (but due to variation, statistical difference was not proven). Dead branches had a steady 10–15% moisture content regardless of the drying period (Figure 11). Similar insensitivity to drying period was observed for the stemwood (samples at the base of the stem), but in the wide range of 30–55% moisture content (Figure 12).

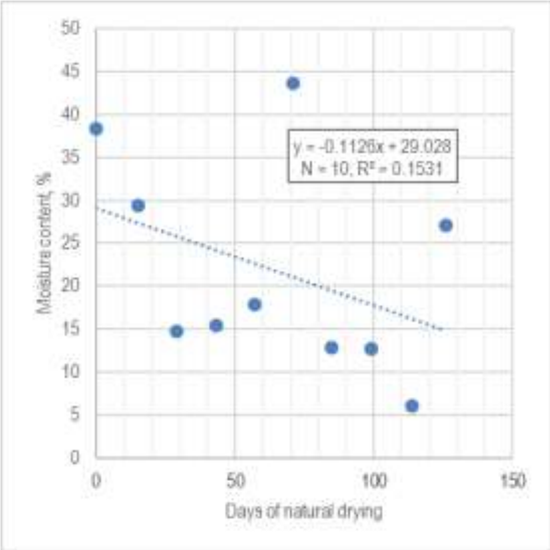

Figure 9 Moisture content of shoots vs.

days of natural drying

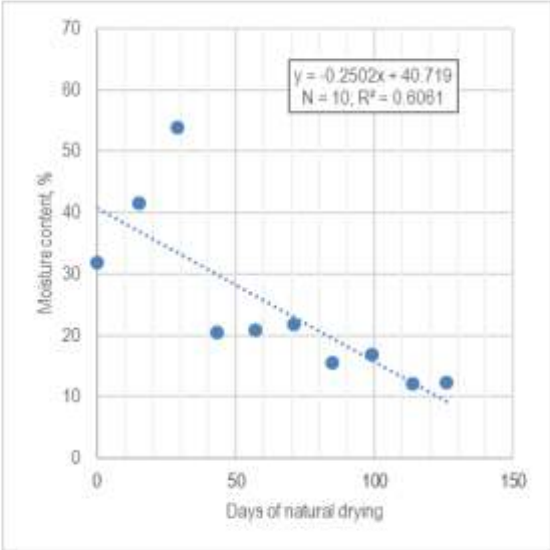

Figure 10 Moisture content of living branches vs.

days of natural drying

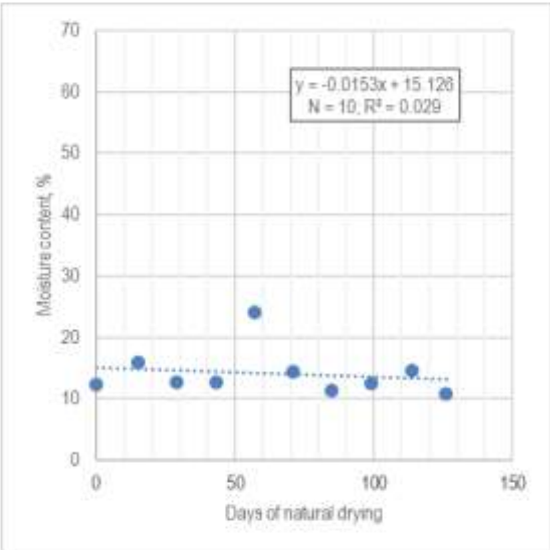

Figure 11 Moisture content of dead branches vs.

days of natural drying

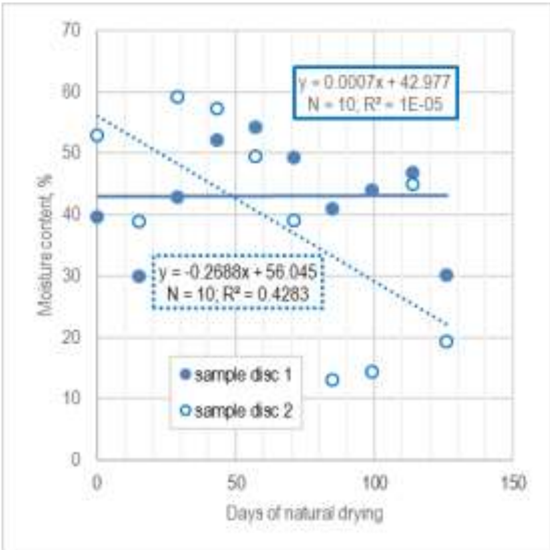

Figure 12 Moisture content of stemwood vs.

days of natural drying

4. Conclusions

Based on the research data it can be concluded that the moisture content of most biomass components in fresh state does not depend on the month of the felling (in the investigated period April – September).

On the other hand, duration of natural drying had a significant influence on the reduction of moisture content in some components of the aboveground biomass (stemwood samples from the first cross-cutting point, living branches and shoots). Quite high moisture content reduction by natural drying of living branches and shoots together with low moisture content of dead branches, i.e. the biomass components that in traditional harvesting systems constitute forest residues indicate that modern biomass harvesting systems should be preferred in Aleppo pine stands in order to extract this feedstock before natural drying occurs thus assisting in the fire prevention efforts.

Research results are expected to have practical application in the field of biomass harvesting in Aleppo pine stands, which is currently still quite limited due to the fact that forests in the research area have a strong protective and recreational function in tourism. But, until intensifying biomass harvesting, the results could hopefully serve as a starting point for forest fire forecast and prevention models.

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MULTIPLE BIOMASS FEEDSTOCK HARVEST AND LOGISTICS IN THE NORTHEASTERN UNITED STATES

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Abstract: A mixed-integer linear programming model was developed to optimize the multiple biomass feedstock harvest and logistics, including feedstock establi shment, harvest, storage, transportation, and preprocessing. The model minimizes the delivered cost of biomass from harvest sites to potential biorefinery facilities with constraints of feedstock availability, materials balance, and facility capacity. The model was applied for analyses of forest residue biomass and three energy crops of hybrid willow, miscanthus and switchgrass at county level among 13 states in the northeastern United States. With a plant demand of 180,000 dry Mg/year of biomass as a base case, the overall average delivered cost ranged from $64.96 /dry Mg to $108.09 /dry Mg with an average of $79.58 per dry Mg. The largest cost components were feedstock establishment (42.3%), harvest (29.4%), and transportation (13.2%). The biomass delivery costs by county ranged from $68.60 to 175.72 per dry Mg across the northeastern U.S. The delivery cost of forest residues averaged $81.78/dry Mg, followed with switchgrass as $84.56/dry Mg, and average delivery cost of willow and miscanthus were $95.90 and $115.08 per dry Mg, respectively. A sensitivity analysis was also conducted to evaluate the effect of feedstock availability, feedstock price, moisture content, procurement radius, and facility demand. A 10 km shorter of biomass procurement radius would reduce 10.68% of the biomass delivery cost. Change of facility capacity from 180,000 dry Mg to 144,000 dry Mg per year (20% decrease) would reduce 13.62% of the delivery cost from $79.62 per dry Mg to $68.79 per dry Mg. Our results indicated that procurement radius, and facility capacity were the most sensitive factors to the biomass delivery cost.

Keywords: Bioenergy, bioproducts, forest operations, modeling, optimization

CALIBRATION OF A HANDHELD CAPACITANCE-BASED MOISTURE METER FOR FOREST FUEL SUPPLY MANAGEMENT

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Abstract*: In forest fuel production management there is a demand for fast, portable, and cost-effective moisture content (MC) determination technology. The handheld Wile Bio Moisture Meter (WBMM), has a potential to be used in such management but has however not been calibrated for forest fuels with high MC (> 45%), which is a common MCs of forest fuels. Our objectives were therefore to calibrate the WBMM for common forest fuels in Sweden having a MC >45% and to investigate if this kind of equipment could meet the requirements for production management of forest fuels.*

On average, calibrations gave a measuredprecision of 1.2 %-units. The overall accuracy of predicting MC was overestimated with 0.3%-units; in general MC of stem wood and medium course logging residues was overestimated and course logging residues was underestimated.

Technologies as the WBMM is suitable for production management were the requirements of accuracy and precision is lower than for trade-based measurements. They should render possibilities to increase precision in logistics management and could also be used for inventory and production management at a fuel yards. However local conditions must be considered meaning that calibration for different assortments and temperature must be done before operational use.

Keywords: bioenergy, dry matter, oven drying, wood fuel

1. Introduction

To make forest fuel a competitive alternative to replace coal as a source for heat- and electricity generation the supply chain for forest fuels has to be managed with strategies that generates high cost efficiency andsimultaneously producing high fuel quality.Supply chain management strategies can be evaluated in monetary terms and therefore can different supply chain management strategies easily be evaluated in terms of wins or losses when comparing different strategies.

The value of comminuted forest fuels is in general set by four quality properties: 1)net calorific value, 2)ash content, 3) share of fines (particles <3mm) and 4) particle size distribution. The heating value is the most important quality property in production management as it affects the pricing of the fuel to a large extent. Heating values are highly correlated to the moisture content (MC) of the fuel which may change throughout the supply chain and therefore needs to estimated/measured at different points in the biomass supply chain (Hartmann and Böhm, 2000). For example, a freshly cut tree can hold up to 60% water (Cédric 2011) and stored uncommuted energy wood can have as low MC as 20% (Volpé, 2013). Thus, the challenge of managing forest fuel supply chains is to maintain, or improve, the quality throughout the supply chain, and in order to achieve that MC needs to be determined frequently over time.

The method used today to determine MC is the thermo-gravimetric method using oven drying (ISO, 2015).Traditional sample preparation for MC analysis is labor intensive and thus is the number of samples that can be analyzed limited, mainly due to cost.To be able to predict the fuel propertiesrepresentative samples of the material has tobe taken. Measurement for trade require high precision and accuracy and measurement for production management less. In general, higher precision requiresthat a larger amount of samples has to be taken. Hereprecisionis defined as: the ability to measure with consistency and that the instrument doesn't have large deviations between each measurement. Here accuracy is defined as: to be able to measure with little deviation from the reference value.

A recognized requirement (accredited) for measurement accuracy is set at a systematic error of less than 1% on an annual basis (Swedish Government, 2014). The Swedish Forest Board states in its regulations that the maximum permissible deviation per batch of wood is 13.5% at a given dry weight between 25-50 t. With a specific dry weight below 25 t, a deviation of up to 18% is tolerated (Swedish Government, 2014). These weights correspond to a single truck load. The Swedish Forest Board has defined what a batch of biomass is in its regulations: "A batch of biomass is a limited amount of wood for which the seller and the buyer has agreed, and which are measured using the same measurement method. The requirements for the properties of the wood are equal to the total amount of wood. Delivery of the wood usually takes place at one time or for a limited time." A truckload is however the smallest amount of biomass that can be managed in the supply chain.The oven drying method is however slow and not suitable for production management were quick results are sought (oven method takes 24-48 hours). The oven drying method also require investments in facilities and ovens. A fast method with "good enough" measurement accuracy could greatly improve time- and cost efficiency in production management of commuted forest fuels.

The Wile Bio Moisture Meter (WBMM; Figure 1)(Farmcomp 2018) allows direct measurement in the chip pile and gives a MC value within 5-10 sec and thus require no sample preparation and is therefore fast. The instrument is provided with five settings which the user can shift between: 1) stem wood chips; 2) fine logging residues chip; 3) medium logging residues chip; 4) course logging residue chips; it also has a program 0 which gives the capacitance value and is used for calibration of the equipment. The WBMM is relatively cheap, ca 1000 Euro, and thus cost-effective. The WBMM has a high potential for determining MC in field conditions for production management and its accuracy is affected by the fuelsparticle size distribution and needs to be calibrated thereof (Volpé, 2013, Fridh, 2017). The WBMMis based on capacitance technology, which measures the ability of the sampled material to store electrical charge. The top of the measuring body acts like a plus pole and the plate acts like a negative pole(Figure 1). The biggest disadvantage of this capacitance technique is that it does not work on frozen material.

Figure 1. The hand held Wile Bio Moisture Meter (WBMM)(Farmcomp 2018).

Volpé (2013) tested the WBMM on hog fuel (coarse chips; 254 samples) and logging residues chips (61 samples). Hog fuel had a MC between 10-70% and logging residues 8-50%. On average 56% of the hog fuel samples was overestimated with5.3%-units, and 44% of the samples was underestimated with6.7%-units.The corresponding values for logging residues was: 46% ofsamples was overestimated with2.3%-units and 54% was underestimated with 1.9%-units.

Fridh (2017) tested the WBMMuncalibratedon stem wood chips divided into four MC classes (Table 1). In class M_CL 2-4was MC underestimated on average with 4-6%-units and in M_CL 5 underestimated with almost 12 %-units. On average, for all MC classes, the WBMM underestimated the MC with 6.0%-units with a deviation of ± 3.8%-units (95% confidence interval (CI)).The WBMM was then calibrated for M_CL 2, M_CL 3 and M_CL4. When the WBMM was calibrated the overall accuracy improved and gave an underestimation of 2.4 %-units.

Table 1. Definition of MC classesused in Fridh (2017)

Moisture content class	Moisture Content %
M_CL 2	≤ 29.9
M_CL 3	30-39.9
M_CL 4	40-49.9
M_CL 5	≥50

The WBMM has however not been calibrated for forest fuels with high MC (> 45%) (cf. Fridh 2017), which iscommon MCs of forest fuels.Our objectives were therefore to calibrate the WBMMfor common forest fuelsin Sweden having a MC >45% and to investigate if this kind of equipment could meet the requirements for production management of forest fuels.

2. Materials and methods

2.1 Study design

The study was designed to create calibration curves for five well defined types of forest fuels (Table 1) and then validate the calibrations on new (independent) sets of samples. Both calibration and validation measurement was carried out in a laboratory environment.

The study was executed in the following chronological steps:

Sampling of fuel assortments for both calibration and validation

Sample preparation to different MC classes

Measuring with WBMM and subsequently the reference method

Creation of calibration curves

Validation of calibration curves accuracy

Analysis of accuracy and precision of calibration curves.

Sampling of fuels

The material used in the study (Table 1) was collected at the fuel terminal of Umeå Energy heat and power plant at Dåvamyran (north of Sweden). The samples were collected in 20 literbuckets and sealed with a lid.The aim was to create two different MC classes for each fuel type. Sampling were done on evenly distributed points across the chip pile to capture variations within the biomass. All samples had MC between 40 and 59.9%. The material were characterized according to Table 2. The samples were either driedor added with water in order to create variations in MC.

Table 2. Characteristics of sampled fuel types using BAS product definitions given in Fridh (2017).

BAS Product	Material	MC (%)	Particle size distribution	Fines	Calibr.(n)*	Valid.(n)*
TRB-7 M_CL4	Stem wood	40-49.9	P16	-	3	2
TRB-7 M_CL5	Stem wood	50-59.9	P16	-	5	4
TRB-8 M_CL4	Stem wood	40-49.9	P45	F15	12	5
TRB-8 M_CL5	Stem wood	50-59.9	P45	F15	4	2
TRB-9 M_CL4	Stem wood	40-49.9	P63	F10	5	5
TRB-9 M_CL5	Stem wood	50-59.9	P63	F10	5	3
TRB-13 M_CL5	Logging residues	50-59.9	P45	F15	7	5
TRB-14 M_CL4	Logging residues	40-49.9	P63	F10	17	5
TRB-14 M_CL5	Logging residues	50-59.9	P63	F10	9	5

*number of samples (n) for calibration and validation.

The stem wood chips constitutes of low grade logs which been chipped on site and had been stored on the fuel yard without coverage for a few days before sampling. The stem woodconsisted of a mixture of hard woods, *betula pubescence* and*alnusincana*.The logging residues consisted tops and branches from clear cuttings mainly of conifers,*pinussylvestris* and *piceaabies* and had been chipped at the fuel yard in June-July 2017.Sampling were performed between 2017-12-01 and 2018-02-28.

2.2 Measuring procedure

The capacitance, MC and particle size distribution were measured for each calibration- and validation sample. The MC (reference value) were determined with the dry oven method (ISO, 2015). The particle size distribution were determined with screening according to the standard method SS-EN 15149-1: 2010. Screen sizes of 45mm, 31.5mm, 16mm, 8mm and 3mm were used.

In this study, the WBMM program 0 was used to determine the capacitance and relate it to the reference MC value. Measurements were done on a 10L subsample taken from the 20 L sample. A rifflebox were used to split the sample.

Before measuring the sample with the WBMM the chips in the 10 L bucket were compacted by lifting the bucket 15 cm above the groundand dropping it down again, refilling to the edge of the bucket, then repeating the procedure until no more compaction occur. The sample was measured three times and the sample were mixed between each measurement. The WBMM measure the sample within a sphere with a diameter of 20 cm. This means that each measurement cover approximately 4 L of a of 10 L sample.

2.3 Analysis

2.3.2 Calibration

Initially each 10L sample were measured with WBMM, each sample was measured three times and an average value was calculated and thereafterimmediatelyovendried to get areference value of the MC. This process resulted in a number of data points in a scatter plot chart with capacitance values (average value of three measurements) as dependent values and the reference valuesas the independent values. The data was then processed with a linear regression given a correspondingequationof which were used in the validation.Calculations were made in Microsoft Excel.

2.3.3 Validation

The validation was done using anindependent set of data and the created calibration models for each products. The material was divided into MC classes 40-49,9% (MC_CL 4) and 50-59,9 %(MC_CL 5). The capacitance value received on the validation material set were then used in the calibration model to predict a MC (MC_pred). This value was then compared with the reference value (MC_ref) received from the corresponding ovendrying method. The deviation of the predicted value were calculated as:

MC_diff = MC_ref – MC_pred [%-points]

The precision of the prediction model was calculated with a 95% confidence interval (CI) in each MC class.

3. Results

On average, the deviation (precision) of all validation measurements from the "true" value was 1 %-units (Table 3 and Figures 3-7) The overall accuracy was overestimated with 0.3%-units; in general MC of stem wood and medium course logging residues was over estimated and course logging residues was underestimated. The created calibration functions have R^2 values above 0.7 (Table 3). The functions are valid for measurements in an environment that holds 20 degrees Celsius.

Table 3. Calibration functionsfor the different products with corresponding R^2 values and average difference between the predicted and reference values (Diff.) and corresponding 95%-level confidence intervals (CI).The response value is given as MC (%) and the x represents the capacitance value given by WBMM with program 0.

BAS Product	Calibration function	R^2	Diff.* (%-units)	CI ** (%-units)
TRB-7 M_CL4	-0.078x+199.33	0.729	1.71	0.45
TRB-7 M_CL5	-0.078x+199.33	0.729	0.43	3.2
TRB-8 M_CL4	-0.119x+281.71	0.706	-0.45	1.87
TRB-8 M_CL5	-0.119x+281.71	0.706	3.03	0.88
TRB-9 M_CL4	-0.090x+225.67	0.728	0.70	0.81
TRB-9 M_CL5	-0.090x+225.67	0.728	1.03	5.06
TRB-13 M_CL5	-0.006x+69.48	0.720	-0.04	0.61
TRB-14 M_CL4	-0.143x+334.46	0.876	0.27	0.78
TRB-14 M_CL5	-0.143x+334.46	0.876	-1.50	1.07

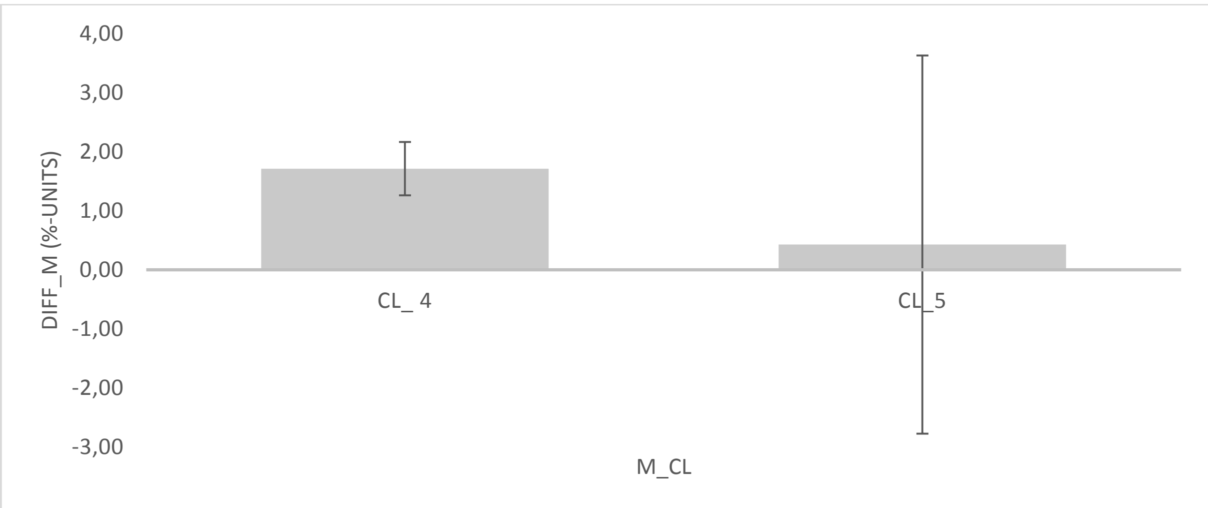

Figure 2. The difference in MC per moisture class of TRB-7. The column showsthe average deviation error the whiskers a 95% confidence interval. All data originates from the validation material.

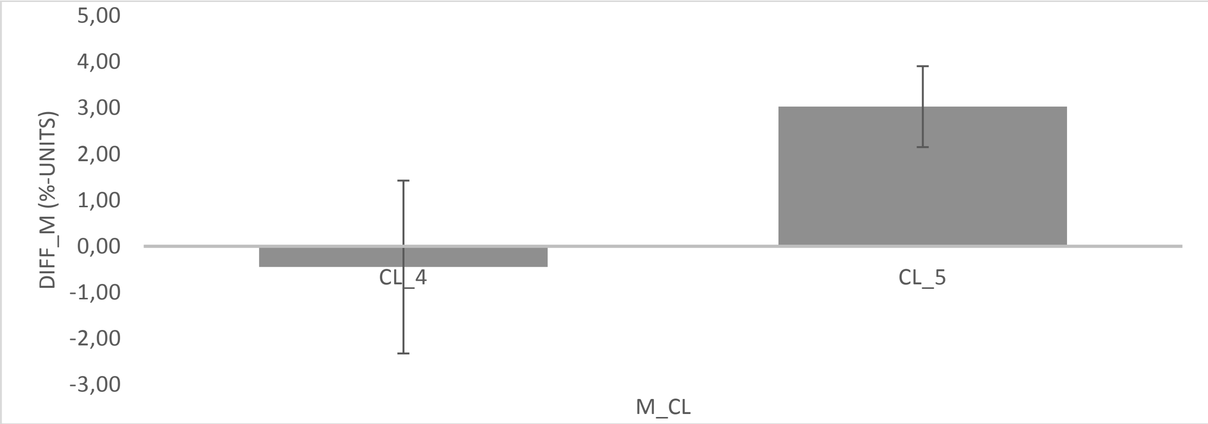

Figure 3. The difference in MC per moisture class of TRB-8. The column shows the average deviation error the whiskers a 95% confidence interval. All data originates from the validation material.

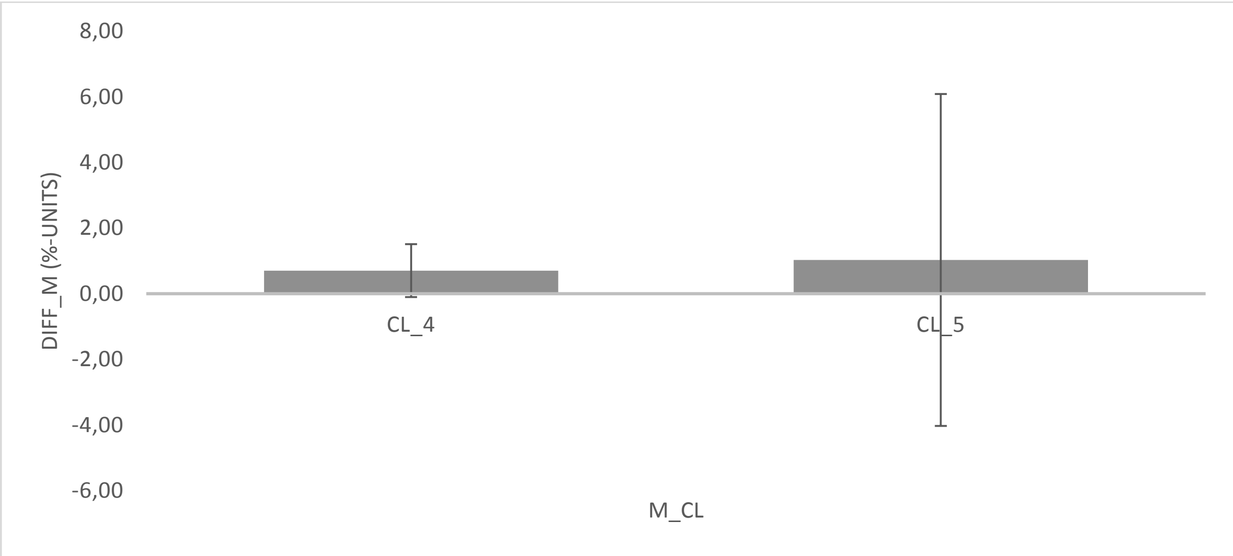

Figure 4. The difference in MC per moisture class of TRB-9. The column shows the average deviation error the whiskers a 95% confidence interval. All data originates from the validation material.

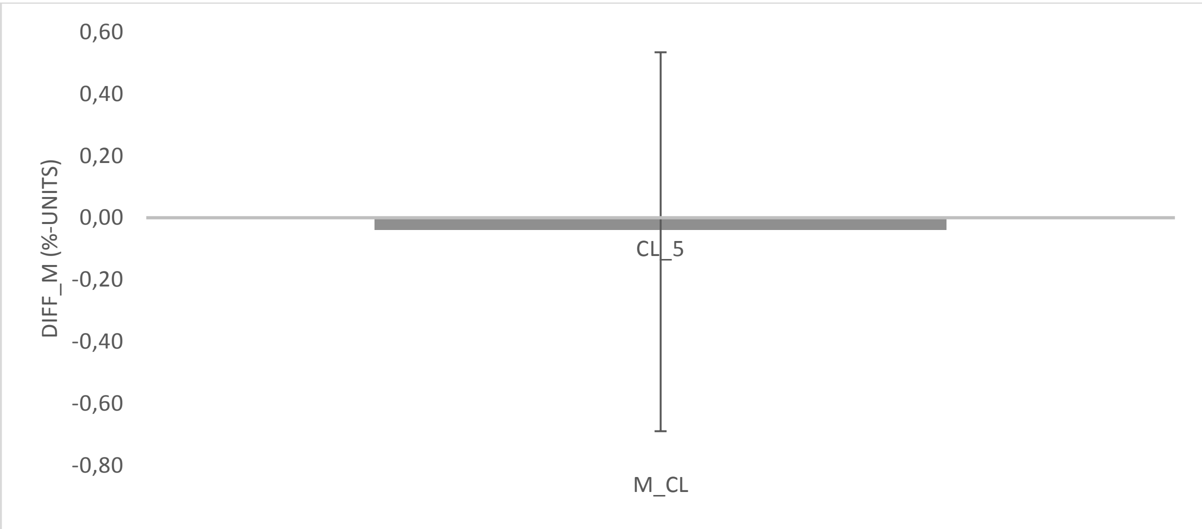

Figure 5. The difference in MC per moisture class of TRB-13. The column shows the average deviation error the whiskers a 95% confidence interval. All data originates from the validation material.

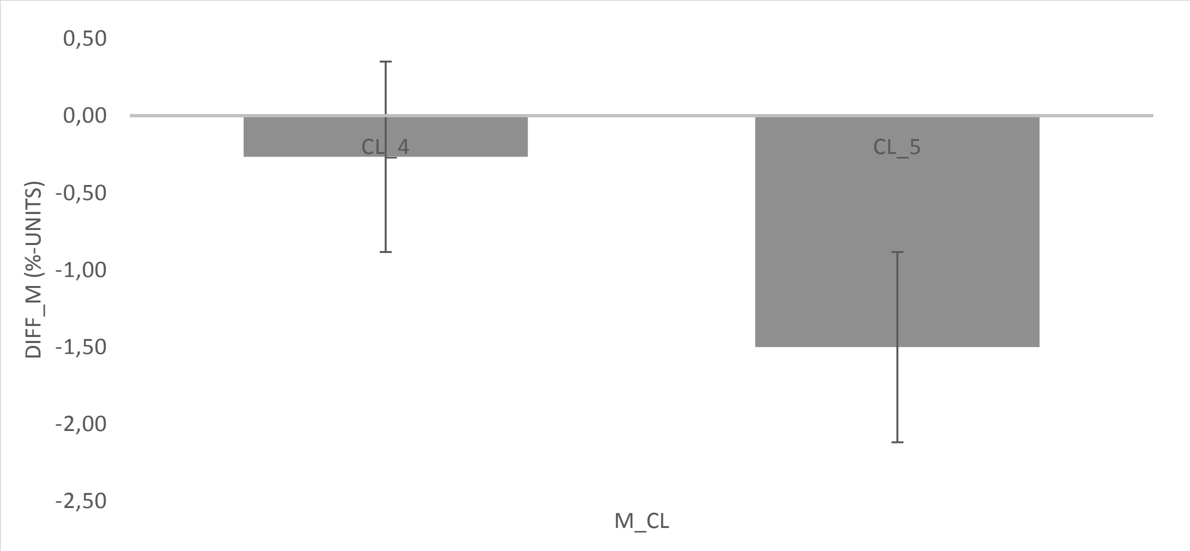

Figure 6. The difference in MC per moisture class of TRB-14. The column shows the average deviation error the whiskers a 95% confidence interval. All data originates from the validation material.

4. Discussion

The objectivewas to investigate if this kind of equipment could be calibrated and meet the requirements for production management of forest fuels. At the Dåvacombined heat and power (CHP) plant a measurement inaccuracy of 5%-units is accepted when determine MC on comminuted forest fuels at the fuel yard (Aronsson, 2018).Our results show thata calibrated WBMM meets such requirements as it on average only overestimatedthe MC with 0.3%-units.The Swedish Forest Board has stated that a measuring method must have less than 1% systematic error on annual basis regarding accuracy. As the studied technology is sensitive to particle sizes Volpé (2013) concludes that at least 10 samples should be taken for course materials and 3 for more homogeneous material in order to fulfill a maximum of 1%-unit deviation.As the WBMM is cost-effective (when it has been calibrated!)relative the oven drying method it possible to take numerous samples and thus render possibilities to reach the same overall accuracy as with a reference method (cf. Fridh, 2017).In present study the aim was to have five calibration samples in every moisture class but due to that some samples were measured at higher temperature than room temperature (samples had not cooled down enough) these measures gave significantly deviated values and was therefore discarded. The result of this was that MC classes with too few calibration samples was excluded from the study.

The calibration functions created in present study are only valid for use in room temperature and if to be used in other temperatures functions needs to be complemented with weights for temperature. If creating calibration curves for production management, were less accuracy is needed, dividing fuel types in many different classes might be overkill. For example,all types of stemwood chips in present study (TRB-7,TRB-8 and TRB-9)and all types of logging residues (TRB-13 and TRB-14) was treated as single products calculationsindicates that it is not of vital importance to classify the material into very specific product categories (see Table 2 and Figures 3-7).

How temperature affects the WBMM should be an issue for further research as the temperature has been observed as an influential variable both in present study and in Fridh (2017). This could be done for example by measuring the same sample(s) at +4, +20 and +35 degrees Celsius then creating functions for MC/capacitance deviation quotas (weights) as a function of temperature. Calibration curves in Table 2can then be adjusted accordingly. In practice, that means that when using the WBMM the temperature at measure should also be taken to adjust the value received, or preferable, the WBMM should have an inbuilt temperature logger.

At Dåva CHP plant log yard, for determining the chipped fuels the common procedure is to take seven small samples (approx. 3 deciliter each) and merge them to a general sample, putthe sample immediately in a freezer until scaled and oven dried for MC determination. This routine gives however no information about the variation in the samples, i.e. calculation of accuracy is not possible. As the cost of MC determination using the oven drying method is highly correlated to how many samples you take and the number of samples handled in practice is kept to “as few as possible”. However, with the WBMM there is insignificantly extra costsbetween taking seven or fourteen samples, and still you can calculate the accuracy. For operational work there is a need of a support for the operator to determine the number of samples that needs to be taken so that the required accuracy can be met, which thus would improve the benefits of using this kind of equipment. For example, number of samples taken has to be judged on basis of e.g. how course the material is (Volpe’ 2013) and the variation in the batch (Fridh, 2017) as e.g. fine fractions may be concentrated to lower parts of a truck load due to how chips have been loaded and due to vibrations during transports.

5. Conclusions

Technologies as the WBMM is suitable for production management were the requirements of accuracy and precision is lower than for trade measurements. They could render possibilities to increase precision infuel logisticsmanagement. They could also be used for inventory and production management at a fuel yard. However, local conditions must be considered meaning that calibration for different assortments and temperature must be done before operational use.

Our study show that the WBMM can be calibrated for various assortments/fuel products with high MC content and give accuracy’s significantly below industry demands (e.g. a 5%-unit limit) for fuel yard management and give complementary knowledge to previous works done by Volpé (2013) and Fridh (2017). Our study also indicate that more general prediction functions for operational use should be made (cf. Fridh 2017).

6. Acknowledgements

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SIMULATION OF MOBILE WOOD CHIP PRODUCTION CONSIDERING UNCERTAINTY INSIDE A SUPPLY CHAIN

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Abstract: The management of uncertainty is an important issue to achieve a stable supply based on a management plan. Although there are the uncertainties outside of the supply chain such as the market situation or global trends that the manager cannot control, the uncertainties inside the supply chain such as operational and quality variances should be evaluated and be controlled as much as possible. Through the simulation of daily mobile chip production at a forest landing by applying stochastic modelling of uncertainties inside the supply chain and queuing theory (M/G/1), this study showed the influence of inner uncertainties that appeared as variances in moisture content, operational time of the wood chip production, and the interval of truck arrival. The cycle time, the daily amount of production, the idling time in chipping process, and the waiting time of trucks were analyzed. There was a certain variance in the amount of production, and it was clarified that the average cycle time extended 1.2 to 1.4 times longer than the theoretical cycle time without considering the inner uncertainties. The waiting time of trucks and idling time in chipping operation occurred because of the inner uncertainties and the more amount would be produced by reducing this wasted time. The stability and production amount of chip supply chain were higher when using smaller trucks because the full use of its volume capacity was realized regardless of moisture content while about a double number of trucks was necessary. It was also proved that the material should be dried for a longer period to utilize the advantage of large volume capacity of larger trucks. As well as the minimization of inner uncertainties by operational improvement, the interval of truck arrival should be optimized.

Keywords: biomass, logistics, moisture content, queuing theory, supply chain management

IMPROVED PLANNING FOR SILVICULTURE AND FORESTRY ENGINEERING IN CABLE CRANE OPERATIONS WITH DRONE TECHNOLOGY - PRECISION ANALYSIS AND VALIDATION OF THE SUITABILITY.

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Assessing the suitability of drone data for the planning of cable lines in skyline logging requires the examination of two aspects. On the one hand, the accuracy of the stem foot coordinates and breast height diameter (DHB) must be known. On the other hand it is important to consider the suitability of the data for the cable line definition in silvicultural and technical point of view.
In this study the accuracy analysis was performed on two “marteloscope areas” where terrestrially surveyed tree attributes are known. The procedural practicability was examined on three harvesting units. Findability and technical suitability of the digitally defined intermediate support trees and anchor-trees were analyzed. The silvicultural point of view by using drone data was also considered.

The accuracy analysis showed a mean deviation by 1.4 m in comparison to the terrestrial reference trees with the defined stem foot coordinates. There exists a clear significance between the social tree classes and the deviation of the stem foot coordinates. It was not possible to verify a relationship between slope and accuracy of the stem foot coordinates. The completeness of the automatically detected trees from the drone image ranged from 61 to 76%, with most non-detected trees in oppressed and dominated tree classes. The root mean square error (RMSE) for the derivation of DHB was between 8.7 and 12.1 cm.

The practicability tests were positive: The delineation of the mainline was possible. Defining the starting point was the biggest challenge but could be managed by using drone generated data and the distance to the first intermediate support tree. All drone data identified structural support trees with only one exception were suitable for the technical realization.
But also the silvicultural planning can be supported by drone-generated orthophotos. Gaps, crowns of isolated trees from higher social tree classes and similar structural elements are clearly visible.
However, structures close to the ground (e.g. regeneration status) are not always identifiable, due shadowing and crown cover. That is why we still need terrestrial surveys.

It could be shown that using drone technology for cable crane operations can improve planning processes in silviculture and forestry engineering. It allows time

and cost advantages. The supplementary-added value of the method is above all that positive cardinal points can be set and the lateral displacement of the line can be avoided by prior analysis of orthophotos.

POSTERS

PRODUCTIVITIES AND COSTS OF CLEAR CUTTING AND REGENERATION OPERATIONS IN UTSUNOMIYA CITY, TOCHIGI PREFECTURE, JAPAN

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Abstract: *This study conducted time studies of clear cutting and planting operations in Utsunomiya city, Tochigi prefecture in 2015 and 2016, and compared productivities and costs of clear cutting and regeneration operations with those by other enterprises. Productivities and costs of clear cutting operations in 2015 were similar to those by other enterprises because processing operations were conducted with processors like other enterprises. On the other hand, productivities and costs in 2016 were lower and higher than those by other enterprises because processing operations were conducted with chainsaws. However, productivities and costs in 2016 were higher and lower than average values in Japan. Productivities of planting container seedlings with dibbles were lower than those with hoes because of inexperience. However, productivities of planting container seedlings were higher than those of planting normal seedlings. Regeneration costs were not reduced despite labor-saving site preparation by grapple loaders at the end of clear cutting operations because of high prices of container seedlings.*

Keywords: clear cutting, planting, productivity, cost, container seedling

1. Introduction

Forest resources, planted after World War II, are getting mature and now ready for harvest in Japan. It is necessary to promote harvesting of matured planted forests in a sustainable manner and re-planting where appropriate (Forestry Agency 2017). However, profit of final felling operations, JPY 1,170,000/ha, did not cover reforestation expenses for the next decade (JPY 1,560,000/ha) (Forestry Agency 2013). EUR 1 = JPY 132 on April 29, 2018

The reason of such low profitability in Japan, the productivity of forestry remains at a low level, particularly due to structural characteristics of small-scaled forest ownership dominance as well as inadequate coordination and consolidation of forestry practices among different forest owners, under-development of forestry road networks, and slow adoption of efficient log production systems (Forestry Agency 2017).

Therefore, some studies have been undertaken on final felling operations (Funaki and Sugihara 2012; Mizuniwa et al. 2016, 2018; Tanaka et al. 2016; Aruga et al. 2016; Katagiri 2018). However, regeneration operations have not been well analyzed. Therefore, this study conducted time studies and analyzed productivities and costs of clear cutting and regeneration operations in Utsunomiya city, Tochigi prefecture, Japan.

2. Study Sites and Methods

The two study sites were in Utsunomiya city, Tochigi Prefecture, Japan. Sites A and B were moderately sloping (Table 1). Utsunomiya city was a capital of Tochigi prefecture and a relatively populated area. Forest ownership in this area is characterized by a large number of small, fragmented, and scattered forest owners. The scale of private forestry contractors is also relatively small. These small forestry contractors use small forestry machines on small forestry operation sites. The operation system of Site A included chainsaw (Zenoah GZ4300EZ) felling, grapple loader (Yanmar ViO55, 5.5-ton weight) bunching, processor (CAT308ECR with Iwafuji GP-25V, 7.4-ton weight) processing, grapple loader (CAT304CCR, 4.8-ton weight) loading, forwarder (Morooka MST-600VDL, 2.8-ton payload) forwarding, and grapple loader (Komatsu PC35MR, 5.0-ton weight) unloading (Photo 1). The operation system of Site B was similar to that of Site A excluding processor (Photo 2). Processing operation was conducted with chainsaw instead of processor at Site B where *Pinus densiflora* was harvested and it was difficult to use processor because *Pinus densiflora* was not straight. The logging contractor was same at Sites A and B.

Planting operation was conducted with dibbles and hoes for 3,000 container seedlings/ha of *Cryptomeria japonica* at Site A whereas that was conducted with hoes for 3,000 normal seedlings/ha of *Chamaecyparis obtuse* at Site B. Planting operation with dibbles for container seedlings was a relatively new method in Japan.

Table 1 Study sites

Site	A	B
Clear felling (year)	2015	2016
Species	*Chamaecyparis obtusa* *Cryptomeria japonica*	*Chamaecyparis obtusa* *Pinus densiflora*
Age (year)	42-70	72
Area (ha)	1.16	0.84
Slope angle (°)	18.2	19.1
DBH (cm)	26	21
Height (m)	19	16
Stem volume (m^3/stem)	0.66	0.33
Stem density (stem/ha)	997	1,300
Felled volume (m^3/ha)	659	424
Extraction rate	0.91	0.81
Extracted volume (m^3/ha)	599	305

Photo 1 Grapple loader bunching (Left), Processor processing (Middle), and Grapple loader loading to forwarder (Right) at Site A

Photo 2 Chainsaw delimbing with grapple loader (Left) and Grapple loader loading to forwarder on a narrow strip road at Site B

Photo 3 Planting operations with dibble (Left) and hoe (Right)

3. Results

3.1 Final felling operations

The cycle times and productivities of chainsaw felling operations are listed in Table 2. The average cycle time and productivity of felling operations at Site A were estimated at 234 s and 13.10 m^3/h, respectively, with an average stem volume of 0.85 m^3/stem. The average cycle time and productivity of felling operations at Site B were estimated at 101 s and 16.11 m^3/h, respectively, with an average stem volume of 0.45 m^3/stem. The cycle times and productivities at Site A were longer and lower than Site B because average slope angles were similar, but some places at Site A were steeper than 30 degrees.

Table 2 Cycle times and productivities of felling operations

Site	A		B	
Moving time (s)	107	(46)	41	(40)
Undercut time (s)	22	(9)	22	(22)
Back cut time (s)	23	(10)	29	(28)
Wedging time (s)	19	(8)	10	(10)
Waiting time (s)	62	(27)		
Cycle time (s)	234	(100)	101	(100)
Stem volume (m^3/stem)		0.85		0.45
Productivity (m^3/h)		13.10		16.11
Labor productivity (m^3/person-h)		13.10		16.11

The figures in parentheses were percentages of operation times.

The cycle times and productivities of grapple loader bunching operations are listed in Table 3. The average cycle time and productivity of bunching operations at Site A were estimated at 162 s and 18.88 m^3/h, respectively, with an average stem volume of 0.85 m^3/stem. The average cycle time and productivity of bunching operations at Site B were estimated at 208 s and 7.84 m^3/h, respectively, with an average stem volume of 0.45 m^3/stem. Grapple loader worked with an additional chainsaw man for delimbing operations at Site B. Therefore, the cycle times and productivities at Site B were longer and lower than Site A because of longer waiting times. Furthermore, labour productivity was 3.92 m^3/person-h at Site B because of two men operations.

Table 3 Cycle times and productivities of bunching operations

Site	A		B	
Moving time (s)	15	(9)	12	(6)
Bunching time (s)	64	(39)	6	(3)
Piling time (s)	50	(31)	38	(18)
Residue handling time (s)	11	(7)	59	(28)

Processing assist time (s)	13	(8)	28	(13)
Waiting time (s)	10	(6)	65	(31)
Cycle time (s)	162	(100)	208	(100)
Stem volume (m^3/stem)		0.85		0.45
Productivity (m^3/h)		18.88		7.84
Labor productivity (m^3/person-h)		18.88		3.92

The figures in parentheses were percentages of operation times.

The cycle times and productivities of processing operations are listed in Table 4. The average cycle time and productivity of processor processing operations at Site A were estimated at 125 s and 22.50 m^3/h, respectively, with an average extracted volume of 0.78 m^3/stem. The average cycle time and productivity of chainsaw processing operations at Site B were estimated at 236 s and 5.36 m^3/h, respectively, with an average stem volume of 0.37 m^3/stem. The cycle times and productivities of chainsaw processing at Site B were longer and lower than Site A with processor processing.

Table 4 Cycle times and productivities of processing operations

Site	A		B	
Moving time (s)	1	(1)	48	(20)
Grabbing time (s)	18	(14)		
Delimbing and cutting time (s)	95	(76)	188	(80)
Piling time (s)	8	(6)		
Residue handling time (s)	3	(2)		
Waiting time (s)				
Cycle time (s)	125	(100)	236	(100)
Extracted volume (m^3/stem)		0.78		0.37
Productivity (m^3/h)		22.50		5.36
Labor productivity (m^3/person-h)		22.50		5.36

The figures in parentheses were percentages of operation times.

The cycle times and productivities of forwarder forwarding operations are listed in Table 5. The average cycle time and productivity of forwarding operations at Site A were estimated at 1,575 s and 9.36 m^3/h, respectively, with an average forwarding distance and volume of 182.4 m/cycle and 4.10 m^3/cycle. The average cycle time and productivity of forwarding operations at Site B were estimated at 2,516 s and 5.72 m^3/h, respectively, with an average forwarding distance and volume of 260.3 m/cycle and 3.75 m^3/cycle. The cycle times and productivities at Site B were longer and lower than Site A because of longer distances and smaller volumes. Forwarding operations were conducted with two operators such as one for loading operations and another for forwarding and unloading operations. Therefore, labour productivities were 4.68 and 2.68 m^3/person-h at Sites A and B, respectively.

Table 5 Cycle times and productivities of forwarding operations

Site	A		B	
Travel unloaded time (s)	183	(12)	209	(8)
Loading time (s)	759	(48)	857	(34)
Travel loading time (s)			11	(0)
Travel loaded time (s)	185	(12)	208	(8)
Unloading time (s)	447	(28)	569	(23)
Waiting time (s)	3	(0)	663	(26)
Cycle time (s)	1,575	(100)	2,516	(100)
Forwarding distance (m/cycle)		182.4		260.3
Extracted volume (m^3/stem)		4.10		3.75
Productivity (m^3/h)		9.36		5.72
Labor productivity (m^3/person-h)		4.68		2.68

The figures in parentheses were percentages of operation times.

Direct operational expenses *OE* (JPY/m^3) were estimated using productivities and hourly operational expenses, consisting of those for labor and machinery (Table 6). Labor expenses *OL* (JPY/h) were set to JPY 2,550/h. Machinery expenses *OM* (Chainsaw, JPY 410/h; Grapple loader, JPY 2,359/h; Processor, JPY 5,220/h; and Forwarder, JPY 3,528/h) consisted of those for depreciation, maintenance, management, and fuel and oil expenses. Bunching to forwarding operations were conducted on a narrow strip road at Site B. Therefore, waiting times were increased (Tables 3 and 5) and costs were also increased (Table 6). Mizuniwa et al. (2016) and Tanaka et al. (2016) reported that costs were JPY 2,234/m^3 and JPY 2,584/m^3, respectively. Therefore, costs at Sites A and B were similar to and higher than other logging contractors. However, costs at Site B were lower than JPY 5,162/m^3 of average values in Japan (Forestry Agency 2010).

Table 6 Costs of clear cutting operations (JPY/m^3)

Site	A		B	
Felling	249	(11)	226	(5)
Bunching	283	(12)	1,237	(28)
Processing	345	(15)	526	(12)
Forwarding	1,425	(62)	2,490	(56)
Total	2,302	(100)	4,479	(100)

The figures in parentheses were percentages of operation costs.

3.2 Regeneration operations

The cycle times and productivities of planting operations are listed in Table 7. At Site A, the average cycle time and productivity with dibble were estimated at 61 s and 59.02 seedlings/h whereas those with hoe were estimated at 39 s and 92.31 seedlings/h. This is the first time for workers of this contractor to use dibble. Therefore, the cycle times and productivities with dibble were longer and lower than hoe. By the workers of other enterprises who were experienced with dibble, the average cycle time and productivity with dibble were estimated at 36 s and 98.90 seedlings/h which were shorter and higher than hoe at Site A.

At Site B, the average cycle time and productivity with hoe were 24 s and 148.76 seedlings/h with three men operations. Therefore, labor productivity of Site B, 49.59 seedlings/person-h was the lowest because workers of Site B were belonging to a logging company and they were not familiar to planting operation. Harvesting of matured planted forests and re-planting where appropriate have been promoted in Japan. Therefore, they have recently commenced planting operations.

Table 7 Cycle times and productivities of planting operations

Site	A				B	
Method	Dibble		Hoe		Hoe	
Moving time (s)	26	(43)	21	(54)		
Clearning time (s)	15	(25)				
Digging time (s)	6	(10)	7	(18)		
Planting time (s)	14	(23)	11	(28)		
Waiting time (s)						
Cycle time (s)	61	(100)	39	(100)	24	(100)
Productivity (seedlings/h)		59.02		92.31		148.76
Labor productivity (seedlings/person-h)		59.02		92.31		49.59
Labor input (person-day/ha)		8.47		5.42		10.08

The figures in parentheses were percentages of operation times.

Site preparation and planting costs were JPY 1,147,434/ha and JPY 873,980/ha at Sites A and B, respectively (Table 8). Labor costs at Site B were reduced from JPY 424,800/ha at Site A to JPY 293,750/ha because site preparation costs at Site B were estimated with grapple loader which were used for clearcutting operations instead of manual site preparation at Site A. Seedling costs at Site A were increased from JPY384,000/ha to JPY 537,000/ha because container seedlings were used at Site A instead of normal seedlings at Site B. Ccontainer seedlings have been newly introduced in Japan and they were relatively expensive. Therefore, costs of site preparation and planting operation at Site A were higher than Site B.

Table 8 Costs of site preparation and planting operations (JPY/ha)

Site	A		B	
Labor	424,800	(37)	293,750	(34)
Seedlings	537,000	(47)	384,000	(44)
Others	185,634	(16)	196,230	(22)
Total	1,147,434	(100)	873,980	(100)

The figures in parentheses were percentages of operation costs.

3.3 Economic balances

According to sales report (Table 9), profits were JPY 39,715/ha and JPY 736,776/ha at Sits A and B with subsidy for regeneration operations and additional one, respectively. In 2014, Tochigi Prefectural Government made additional subsidy to secure regeneration operations with JPY 320,000/ha, which was shortage of subsidy from Japanese government, when using completely felled trees as not only saw logs but also fuel woods. Regeneration included weeding for 5 years in addition to site preparation and planting.

Log sales at Site A was JPY 2,944,713/ha which was lower than JPY 3,899,886/ha at Site B because Site A was caused by snow damage and merchantable log volumes were small. Akaguma et al. (2017) reported that profits were JPY 1,232,419/ha and JPY 2,117,818/ha, respectively. Profits of this study were lower than other logging contractors. Therefore, clear cutting and regeneration costs could be reduced. Furthermore, economic balances excluding subsidy were JPY -1,628,753/ha and JPY -764,250/ha at Sites A and B, respectively and then Japanese governmental budget was limited. Therefore, clear cutting and regeneration costs should be reduced for future budget reduction of subsidy.

Table 9 Economic balances (JPY/ha)

Site	A	B
Log sales	2,944,713	3,899,886
Subsidy	1,668,468	1,501,026
Revenue	4,613,181	5,400,912
Clear cutting	1,702,506	1,822,867
Sales expense	1,199,458	1,299,769
Regeneration	1,671,500	1,541,500
Expense	4,573,464	4,664,136
Balance	39,715	736,776

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THE MECHANISMS FOR FOREST SOIL PREPARATION TO PREVENTWILDFIRES

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Keywords : forest soil preparation to preventwildfires

The mechanisms of forest soil preparation can be used for forest renewal purposes as well as for the prevention wildfires.
Ploughs and mills are the most appropriate mechanisms for the forest soil preparation in order to prevent wildfires. Distinguishing between forest ploughs and mills is hardly impossible, when looking exclusively at the names manufacturers have given to these tools. Therefore, two differing mechanisms are continuously confused. This leads to the actual usage these mechanisms being different from the theoretically intended.
The conducted research summarizes the theoretical operational principles of forest ploughs and mills. This enables the possibility to clarify the application of forest ploughs and mills beyond the forest renewal.
One of the underlying possibilities for forest mill application is the creation of mineralized lines in various soil types. This serves as prevention for wildfires. An application possibility for forest ploughs is the immediate limitation in case of a wildfire.

BENCHMARK VALUES FOR FOREST ROAD NETWORKS

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Abstract: *The analysis aim was to define corridor values for forest road networks needed for a certain area in respect of the existing forest patterns and terrain structures in the cantons of Berne and Argovia (Switzerland) considering the latest harvesting, skidding and transport options.*

Keywords: forest road network, benchmark, forest road density

1. Background situation of the project

Forest roads are the essential tool to provide access to forests. Forest road networks usually were established over a long period of several decades, always in accordance with logging, hauling and transport abilities of that planning and establishment period. These road construction activities culminated in Middle Europe long ago, with now several roads reaching or exceeding their financial depreciation age. This is also true for Switzerland.

2. Aim of the project

Based on newly available harvesting, skidding and transport options it is a good idea to investigate nowadays requirements of forest road networks. This was done in a study, intended to find ideal orientation values for forest road densities for larger areas. The analysis aim was to define corridor values for forest road networks in respect of the existing forest patterns and terrain structures in the cantons of Berne and Argovia (Switzerland).

3. Elaboration of benchmark values for forest road networks

Already existing forest road networks were excluded from the enquiry as they can be considered as fully amortized. The newly elaborated forest road networks are based on an expert-study considering the forest patterns, terrain structures (map-based) and latest harvesting and transport technologies. The resulting database is therefore highly influenced by machine related production factors, thus providing a comparison set towards further needs as coming from other inquiries like tourism, agriculture or water management. To create comparable values, 36 sites were analysed in order to reflect the variability of the relationship of the regarded variables and the resulting road densities in Switzerland. With this database a model was generated which enables the assignment of new sites into the defined road density clusters. In that way it is possible to calculate a corridor for a reasonable road density needed for a specific site to assure a sufficient forest exploitation without any need for surveying or exploring the area in the fields.

ANALYSIS OF TRUNK VOLUME DETERMINATION ACCURACY USING THE WATER IMMERSION TECHNIQUE AND 3D-SYSTEMS

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Key words: trunk volume determination accuracy, optical measuring systems, water immersion technique, principle of Archimedes

Abstract: There are many different ways of single-log measurement of round timber in the forest industry. The aim of these various measuring methods is always the same. The trunk volume has to be determined as precisely as possible. In most cases, there are major simplifications in the quantity and quality of measuring data, which lead to deviations in the results and in the evaluation of measurement procedures. 3D-Systems find one's way into forest industry. The focus of this study is the volume determination accuracy of these measuring methods. Especially, the procedures "water immersion technique" and "3D metrology" are analysed and the results of measurement are shown. The real volumes of arbitrary shaped bodies can be readily ascertained with the help of the Archimedes Principle. This Principle is used in the "water immersion technique". Thus, references of real trunk volume are provided. As a second approach, non-contact measuring methods are used. In these methods, the primary aim is the exact three-dimensional geometric reconstruction of the object as a virtual / digital volume model. Deviations of the virtual models by comparing with the real volume can be determined. These validated digital volume models can be used as basis for further scientific investigations. One conceivable option for using this data is to reproduce the models by using additive manufacturing methods (3D printing). For example, these so-called "Reverse-Trees" can be used as realistic calibration or long-term stable test bodies.

EXPLORE AGENT BASED SIMULATION TO TACKLE CHALLENGES IN CABLE YARDING AND TRANSPORT OPERATIONS LOGISTICS

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Key words: Drainage, Forest Roads, GIS, Peak Discharge agent based simulation, cable yarding, wood transport, logistics, ICT, weather conditio

Abstract: In recent decades, forest owners as well as logging and transport companies are increasingly under pressure due to developments in the forestry sector. The desire for high productivities to keep timber harvesting costs low and to improve the operation led to the increasing mechanization of timber harvesting systems. Often not only the productivity of timber harvesting systems, but rather the inadequately coordinated transport of produced timber, causes problems.\nIn whole tree cable yarding operations with processing of the trees at the forest road, limited storage capacity under mountainous conditions often is challenging. Interruptions caused by changes of cable corridors or machine breakdowns needs consideration in planning as well. Subsequently, transport activities must be coordinated well to avoid standstills of the harvesting system or trucks. If wood transport is carried out despite a cable corridor change, it can come due to lack of quantities of wood to not fully loaded trucks leading to increased costs. Another important aspect are the weather conditions. On rainy weather, harvesting operations are shutdown. Furthermore, a lack of trafficability of the forest roads may arise. \nTherefore, a proper harvest and wood transport planning is essential to carry out efficient and cost effective operations. Beside exogenous influences, organizational structure and communication systems may have an impact on the overall performance. One tool for problem identification could be the agent based simulation (ABS). ABS defines agents (people, machines, vehicles, etc.), specifies their behavior (memory, reactions, states, etc.) and places them in a virtual environment. Furthermore, communication links can be set up and finally simulation runs can be performed for different lengths of time. In ABS, the individual agents have decision making and action options from which system behavior results. \nGoal of this study is to verify, if ABS could be an appropriate tool to simulate cable yarding and transport operations at the same time. The idea is, that through modification of exogenous factors different scenarios could be created, which show effects on efficiency and costs. In addition, the communication technology/structure could be analyzed and the effect of a potential change in information flows and technology could be shown. Altogether, the simulation

should show possible bottlenecks and derive recommendations for a proper harvest and wood transport planning. Within ABS impact of technology changes, introduction of ICT systems, and so on can be tested easily. In the future costs could be reduced and cable yarding and wood transport could be made more efficient and profitable.\n

THE EXPERIENCE OF CLEAR-CUTTINGS AND ITS INFLUENCE ON NATURAL REGENERATION IN THE NORTHERN TAIGA FORESTS OF THE ARKHANGELSK REGION

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Abstract: *To investigate forest regeneration processes, we surveyed four sites, in the years 1993, 1994, 1999, and 2012, whereby experimental clear cuttings with a variety of measures to promote natural regeneration of conifers such soil mineralisation, fire soil preparation, and leaving the seed trees were undertaken. The experimental cuttings were implemented in mature coniferous stands of blueberry forest types, which were formed on the site of the former extensive forest burned area of the last century. At all sites, there was a high variability in the undergrowth number (37-65%), indicating the regeneration uniformity. The greatest number of regenerated trees were noted in the site where soil mineralisation was held (28000±2500 pieces/ha). In four of the five plots, the predominance of birch was marked (84%), and only at the cutting area with the soil mineralization was larch dominated (44%). In the cutting area of 1999, with a mineralised soil, a minimal thickness of the forest floor was noted, which was 2,75±0,20cm, and significantly different compared to the thickness of the forest floor in the other cutting areas. We found a high inverse correlation between the forest floor thickness and the undergrowth amount, and the correlation coefficient is statistically significant ($p<0.05$) and equal to -0,85. As a research result, it can be argued that soil mineralisation has a positive effect on coniferous species' natural regeneration, including larch renewal.*

Keywords: boreal forest, clear-cuttings, ground-based logging, natural regeneration, site preparation

1. Introduction

For sustainable forest management in northern Taiga forests, it is necessary to obtain reliable data that characterises their condition, productivity, and resistance to environmental conditions and anthropogenic influences. Actual data regarding the changes occurring in forest ecosystems is necessary for solving a number of practical and scientific problems associated with management decisions on the forest's use, taking into account the influence of forest management on the various components of forest ecosystems.

The forest fund deterioration in northern European Russia contributed to the clear felling and forest fires of past years, and as a result, primary sustainable ecological systems in large areas were replaced by less stable and productive secondary systems. A useful role of forest fires in this case is to maintain pine as the dominant tree species in natural stands and spontaneous care factor, leading to the formation of pure pine stands.

Over a long period of forest exploitation in the northern-Taiga region, there has been a widespread change of species: pine has been replaced by spruce and birch, spruce by birch and aspen, and such phenomenon in the Taiga zone is noted in 50% - 70% of clear cuttings. This increases the period of target species growing to unacceptable time from an economic point of view. New forest areas are involved in the economic turnover, often at the expense of environmentally and socially valuable landscapes, including intact forest landscapes. To prevent this from happening, it is necessary to pay close attention to the forest stands formation with economically valuable conifers at the reforestation stage.

The aim of the study was to evaluate natural regeneration of conifers after clear cutting, with various measures to promote natural regeneration of conifers and offer practical recommendations on measures for its promotion.

Objectives of the study: to determine the number and characteristics of the undergrowth at different sites; to trace the influence of the forest floor thickness to natural regeneration; to evaluate the silvicultural effectiveness of different measures to promote natural regeneration of conifers.

2. Materials and methods

2.1 Study Site

The studies were carried out in the north of the European part of Russia. Research facilities are located in the forest department of North Arctic Federal University in the central part of the Arkhangelsk region. The geographical position of the territory is defined from the 62°55` to 63°10` North latitude, and from 40°15` to 40°40` East longitude from Greenwich (Fig. 1).

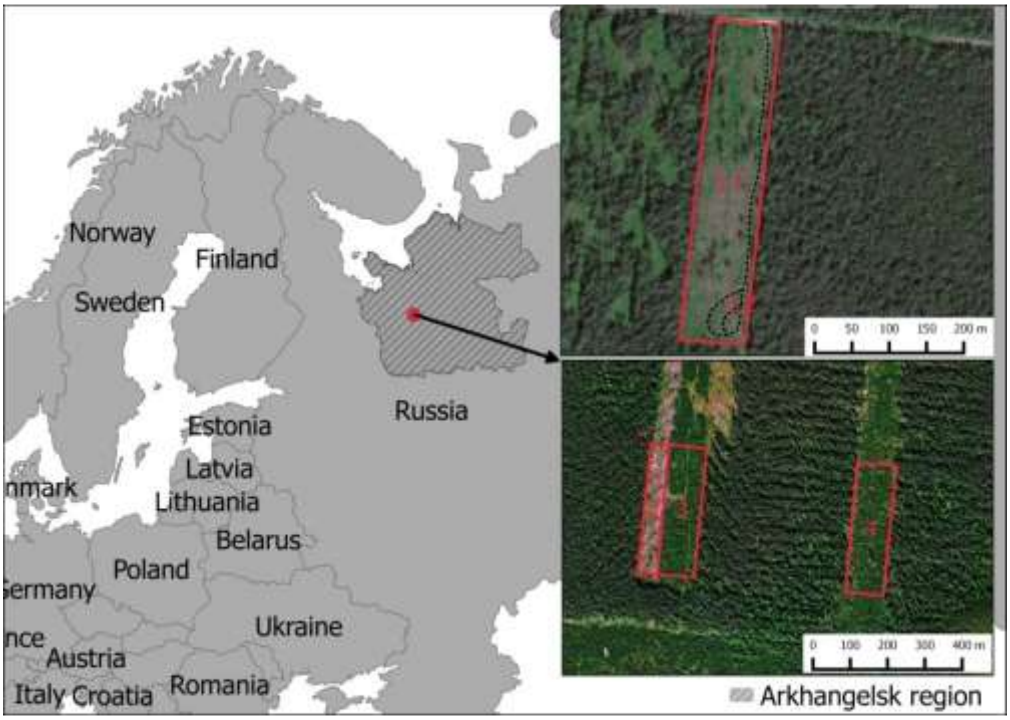

Fig. 1. Location of study area and experimental clear-cuttings

The territory of the training and experimental sub-unit from the first years of its existence serves as a training and research site for testing methods of artificial and natural restoration of coniferous species under the canopy, and in clearings in the northern Taiga forests.

The climate of the research area is moderately continental. The district is dominated by coniferous forest (82.4%) of pine (*Pinus sylvestris* L.) and spruce (*Picea abies* (L.) Karst. x *P. obovata* (Ledeb.)), and occasionally larch (*Larix Sibirica* L.), and fir (Abies sibirica L.). The share of deciduous forests is 17.6%, which consists of birch (*Betula pendula* Roth.), aspen (*Populus tremula* L.), and alder (*Alnus incana* L.).
Forests are mainly growing in Retisols (94%) soils, and the upper genetic horizons are of fine-textured composition (sandy, loamy, sandy, sandy loams),

and the lower are represented by loams and clay loams (IUSS Working Group 2014).

Experimental facilities include past clear-cutting areas with a variety of measures to promote conifers' natural regeneration. The main characteristics of stands before clear cutting are presented in Table 1.

Table 1. Summary of stands characteristics before clear cutting

Experimental object	Stand composition, un.	Average**			Relative stand density, un.	Growing stock, m^3
		Age, year	Height, m	Diametre, см		
Object 1	4P3S2L1B*	160	24	32	0,6	240
Object 2	5P3S1L1B	140	22	26	0,8	270
Object 3	6P3S1B+L	150	22	28	0,6	250
Object 4	5P3S2L+B	140	23	26	0,8	280

*P – pine, S – spruce, B – birch, L – larch. ** – averages data are given for the main species.

Experimental logging was conducted in mature coniferous stands of a blueberry forest type, which formed on the site of the former extensive forest burned area of the last century, and on the forest floor there are coals and old burnt stumps of trees.

Object 1. Clear cutting was conducted in the winter of 1999 (the width of the harvesting site was 100m, the cutting strip was 34m, the width of the skidding trails was 5m, and the direction of cutting was from north to south) leaving a large number of the larch seeding trees. Clean-up logging was conducted by storage of felling residues in piles evenly over the area of deforestation, with the removal of them from the left larch seed trees and burning after felling. The cutting area was divided into two sections: Section 1. Fire soil preparation was conducted by unbroken incineration of soil cover and remaining debris in the fireproof period, in compliance with the requirements for its implementation; Section 2. Mechanised soil preparation was carried out by an anchor-type abrader in the unit with a crawler tractor. The width of the mineralised strips was 4-5m, and the degree of surface mineralisation of the strip was more than 60%.

Object 2. Clear cutting was conducted in the winter of 2012, and is the final stage of the long-term, gradual felling of 1993 (the length of the cutting area was 1000m, the width of cutting area was 50m, the cutting strip was 34m, the width of skidding trails was 4m, and the direction of the cutting area was from north to south), leaving the larch seed trees.

Object 3. Clear cutting was carried out in the summer-autumn period of 1993 (the length of the cutting area was 1000m, the width of cutting area was 100m, the cutting strip was 34m, the width of the skidding trail was 4m, and the direction of the cutting area was from north to south). This cutting was also used as a landing site. The tree stems were transported from a neighbour cutting area that had implemented long-term, gradual felling. The degree of site mineralisation was up to 15%.

Object 4. Clear cutting was carried out in the summer-autumn period of 1994 (the length of the cutting area was 1000m, the width of the cutting area was 100m, the cutting strip was 23m, the width of the skidding trail was 4m, and the direction of the cutting area was from north to south). Similarly, this felling was used as a landing site after the long-term, gradual felling, and the degree of the cutting area mineralisation was up to 25%.

At all sites, tree felling was performed with the tree apex on the skidding trail at an acute angle with the use of gasoline chain saws. This then produced the delimbing, the tops of the trees, which were laid on a skidding trail. Skidding was carried out by a crawler skidder, which passed strictly along the skidding trails.

2.2 Field Data Collection

Field research was based on the ecosystem approach and modern methods of population biology, taking into account classical concepts of silviculture. To assess the impact of logging on natural regeneration in cutting areas in 2016-2017, the account sites (5m by 5m) along a linear transect were established.

The undergrowth took all the plants with $D_{1,3\ m} < 6$ cm. For each individual plant, the type was determined, as was the height class (small, medium, large), viability category (viable, not viable), and microsite type on which it grows. The microsites are related to elements of windfall-soil complex (WSC) (deadwood, holes, bumps) and windfall complex (WC) (stumps, deadwood). Separate microsites were dedicated to aligned areas where there were no WSC and WC elements. Additionally, dedicated microsites were also established, which were formed by cutting. Soil cuts and pits were dug in order to establish soil condition descriptions and forest floor thickness.

In cutting area 1, 70 sample plots were established. The number of sample plots established in the transects with soil mineralisation (section 1) totalled 35 pieces, and in transects without soil mineralisation (section 2) the total was 25 pieces. Cutting areas 2, 3, and 4 were established at 90 account sites (30 at each site). In total, 100 soil pits (20 in each area) were dug, where four replications measured the thickness of the forest floor.

2.3 Statistical analysis

For statistical analysis, we used one-way ANOVA (one-way ANOVA Tukey's HSD test), correlation, and regression analysis. Statistical analyses were carried out with the Statistica 12 (StatSoft Russia) and Minitab 17 Software. All data was checked for distribution normality (Kolmogorov-Smirnov test) and variances homogeneity (Levene's test).

3 Results

The undergrowth in cutting areas is represented by all tree species present in the parent trees canopy (Table 2). At all sites, there was a high variability in the undergrowth number (37% - 65%), indicating the regeneration uniformity. The greatest number of undergrowth (units per 1 ha) was noted on the site where the soil mineralisation (28000±2500) was held, and the smallest for the fresh cutting area (6586±806). The winter cutting did not show soil violations, which contributes to the smooth and rapid seed germination of coniferous species.

However, it should be noted that at four of the five objects, the undergrowth was dominated by birch (27% - 84%), whose share in the composition of the parent forest stands did not exceed 1 unit. Only in cuttings with the soil mineralisation and where larch seed trees were left, did larch dominate (44%), indicating that the positive effect of silvicultural measures facilitate the resumption of conifers in this section. While at the site with fire ground prepare such a result is not reached, and there was a soil turf, and deciduous species, in this case birch, have an advantage over conifers.

Table 2. Undergrowth characteristics on experimental plots (mean±standard error)

№	Experimental object	Measures to promote natural regeneration	Species composition of undergrowth, %	The total number of all species, pieces/ha	Coefficient of variation, %
1.1	Clear cutting 1999 yr.	Soil preparation by fire leaving the larch seed trees	84B10S3P2L	9199±1847[C*]	65
1.2	Clear cutting 1999 yr.	Prepared mineralised band; leaving the larch seed trees	44L27B16P13S	28000±2500[A]	43
2	Clear cutting 2012 yr.	Leaving the larch seed trees	51B40P8S1L	6586±806[C]	47
3	Clear cutting 1993 yr.	Partial mineralisation of the soil by caterpillar tractors; leaving the larch seed trees	55B37P5S3L	13387±1337[B,C]	40
4	Clear cutting 1994 yr.	Partial mineralisation of the soil by caterpillar tractors; leaving the larch seed trees	57B19S17P7L	19067±1841[B]	37

*Different letters show statistically significant differences between the options after one-way ANOVA Tukey's HSD test (P<0.05). Values in a single column, followed by the same letter do not differ at a 0.05 level of significance.

Viable undergrowth dominated in cutting areas (40% - 66%), although for separate species and research sites there was a significant variability (Fig. 2). The greatest number of nonviable and dead undergrowth was marked in the cutting area 1999 with soil mineralisation, which is associated with a large number of young trees and increased interspecific competition for space power. Therefore, the pine trees undergrowth is represented by 50% of nonviable individuals and 15% dry; 45% of spruce undergrowth is nonviable and 15% is dry; and 32% of birch is non-viable and 20% dry. Only the undergrowth of larch is presented on 80% of viable individuals.

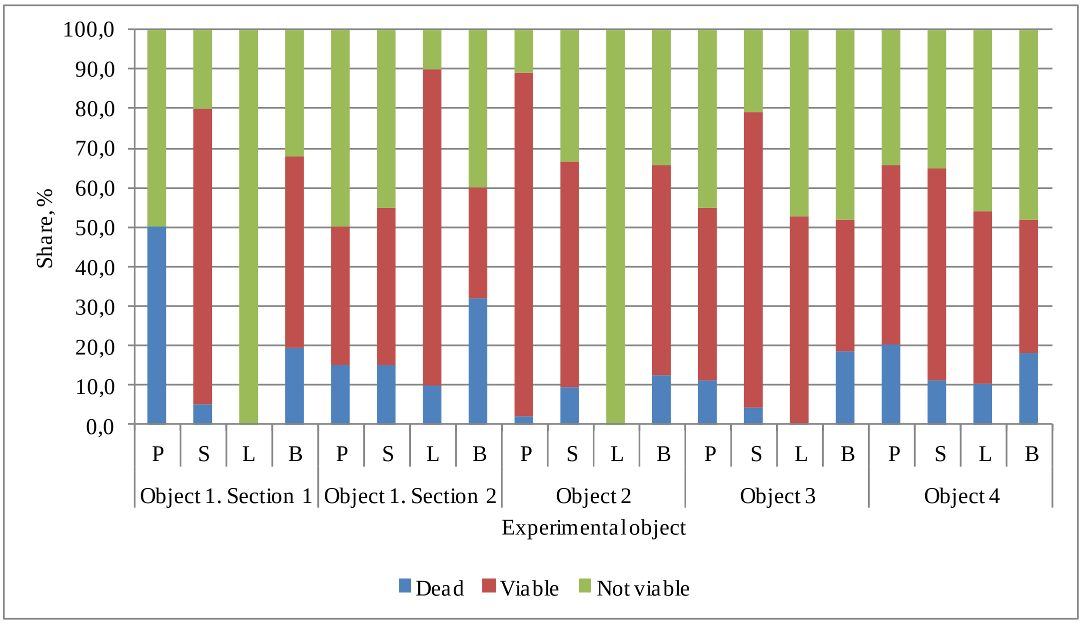

Fig. 2. Undergrowth distribution on vital condition

Analysis of undergrowth distribution of height showed that most small undergrowth in the cutting area 2012, and the variation of its population depending on tree species, ranged from 11% to 100%. It also noted a small number of pre-generating large undergrowth of all species.

In cutting area 1999 with the mineralised soil, the share of small undergrowth varies from 44% to 86%, and on cutting 1999 without soil mineralisation there is a variation from 4% to 56% (Fig. 3). The share of large undergrowth on old clear cuts 1993-1994 varies from 21% to 89% and is represented by the next generation plants of all breeds. The exception is the spruce undergrowth, which is represented at 50% by small undergrowth category on the logging site of 1993. In all cases, the birch undergrowth is dominated by the large category (37% - 89%), except for the plot with soil mineralisation (10%).

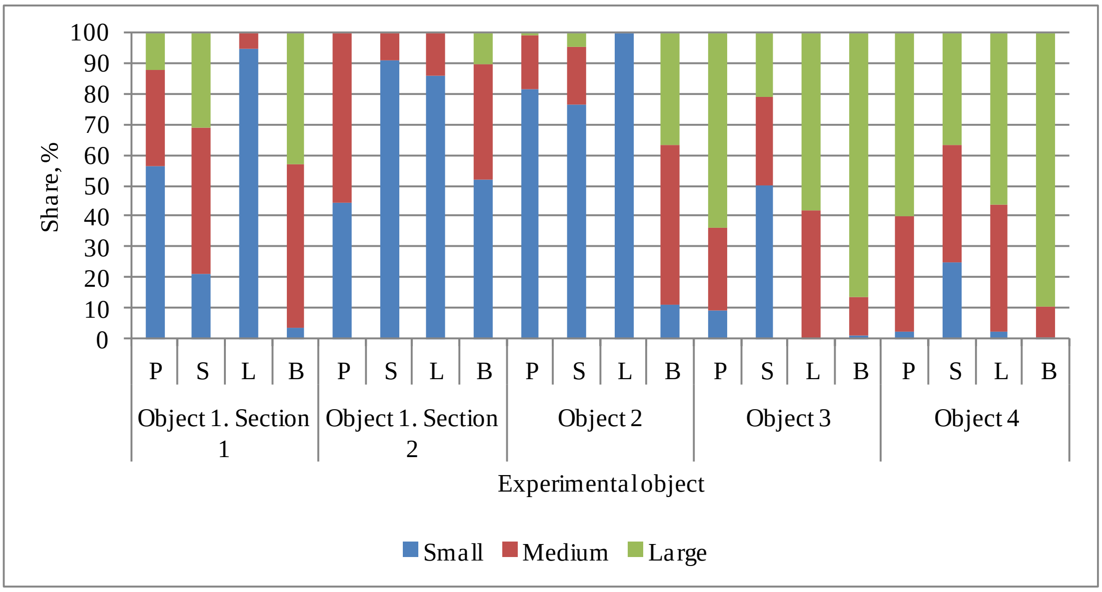

Fig. 3. Distribution of undergrowth by height

Analysis of the undergrowth spatial distribution in cutting areas showed that they belong to microsites: from 39% to 75% of individuals grow on aligned areas, and increase significantly in a specially prepared mineralised zone (cutting area of 1999). In the pits (depressions), there are 15% to 21% of the individuals, then on the mount around 8% to 14%, and the least marked at tree trunks "micro elevations" of living trees were 2% to 12%, the dead trees at 2% to 10 %, and finally the stumps at around 1% to 8%.

Successful coniferous tree regeneration is influenced by the thickness of the forest floor. In the study sites, its thickness varies from 1cm to 7cm. On the cutting area of 1999, with soil mineralisation, it was marked as the smallest thickness of the forest floor (Fig. 4), which is 2.75±0.20cm, and significantly different from the thickness of the forest floor on the same cutting site without soil mineralisation.

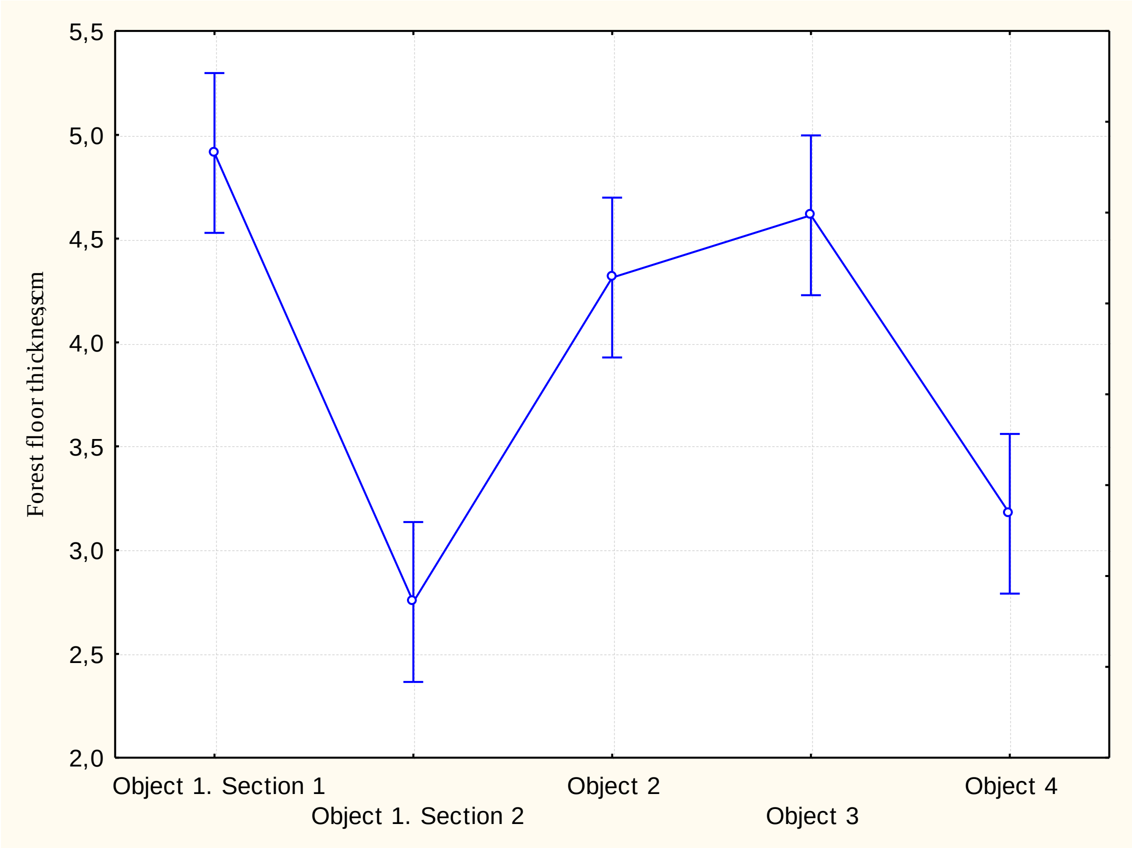

Fig. 4. The thickness of the forest floor on cutting areas

In addition, the difference with the thickness of the forest floor in fresh cutting of 2012 and old cutting of 1993 ($p<0.0001$) was defined. Thus, after the removal of the layer of the forest floor, on specially prepared strips, after almost twenty years the forest floor had not reverted to its original size.

However, the distinction is not determined in comparison to the thickness of the forest floor at the old clearing in 1994 ($p=0,53$). Likewise, the thickness of the forest floor on this site differs compared to other felling ($p<0.001$).

We found a high inverse relationship between the thickness of the forest floor and the undergrowth amount, that is, the smaller the capacity of the forest floor, the greater the undergrowth number (Figure 6). The main part of the experimental values fit within the confidence interval of the selected model (R2=0,72), and thus we can discuss the existence of the exponential dependence. The correlation coefficient is statistically significant ($p<0.05$) and equal to -0,85.

The dependence of the undergrowth amount of tree species on the forest floor thickness in cutting areas is characterised by the following equation:

$$N = 85804{,}3225 \cdot \exp(-0{,}4866 \cdot F) \quad (1)$$

where *N* is the Undergrowth number, units/ha;

F is the Forest floor thickness, cm.

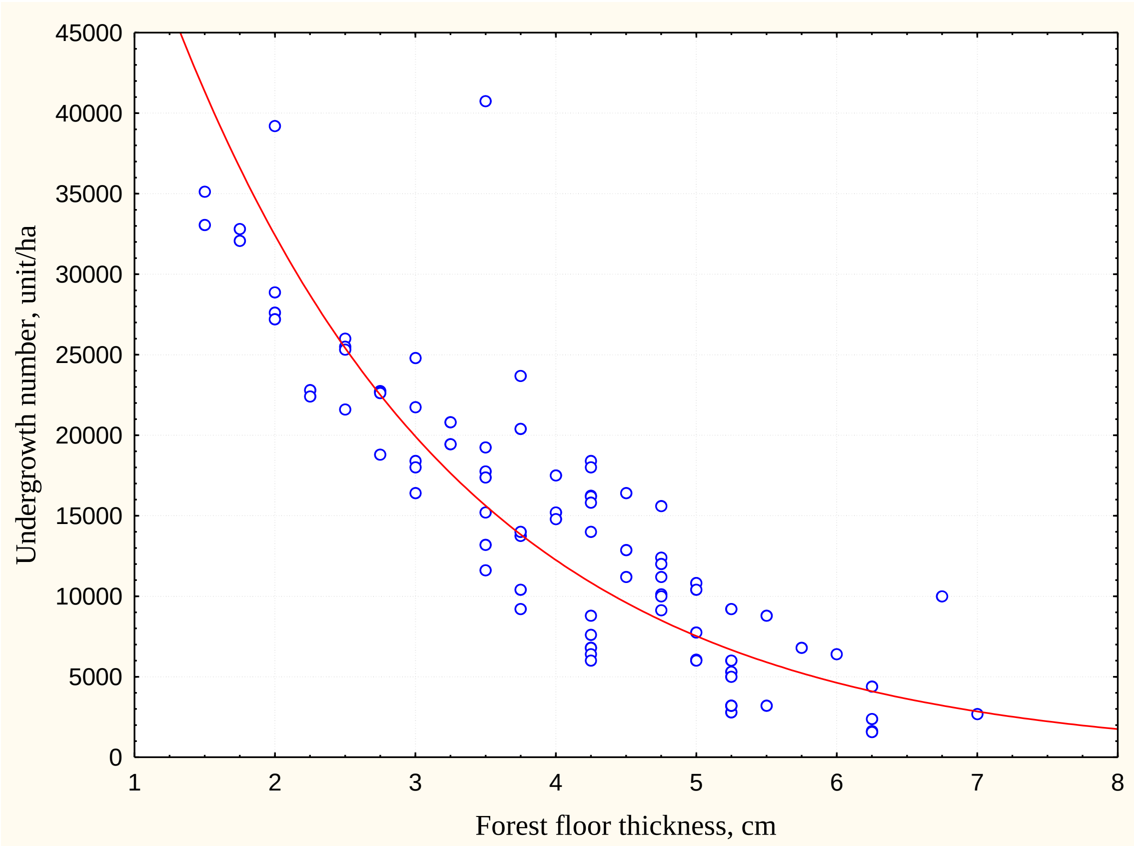

Fig. 6. The dependence of the undergrowth amount of tree species on the thickness of the forest floor in cutting areas

4. Discussion

After clear-cutting in coniferous stands in the northern European part of Russia, there is a natural regeneration of deciduous species (Melehov 2002), which affects the future health and productivity of secondary forests. Therefore, in the conditions of forestry intensification and reduction of indigenous coniferous forests, it is necessary to pay special attention to the resumption of the economically valuable coniferous species on cutting areas.

Forest regeneration processes depend on a complexity of factors: biological and ecological properties of tree species, forest conditions, relief, soil type, structure of cut down forests, seed sources, the width of forest cutting sites, time after logging, harvesting season, logging technology, cutting technology operations, and other factors.

Forest renewals considered in connection with cutting lead to an important issue regarding what wood species (or any species) need to grow in deforested areas. Consideration should be given to growing conditions, corresponding to different breeds, and economic importance (market demand) of different assortments. Therefore, in the northern European area of Russia, the largest economic importance of coniferous species are pine and spruce, and larch to a lesser degree.

In the conditions of northern Taiga, the birch is a pioneer of cutting areas, and it appears faster than pine and larch. It is easier for birch to find suitable conditions and has an advantage in most cases, as it is not damaged by early spring and late summer frosts. Favourable light conditions, frequent and abundant seeding, high reproductive capacity in the vegetative reproduction form, and fast growth enables birch to occupy a dominant position in the forming stand (Melehov 2002).

The development of forest harvesting, a large permitted area of clear cutting (up to 50ha), and harsh climatic conditions often hamper reforestation processes. To ensure the guarantee of forest restoration, it should be coupled with mature forest cutting and additional measures to promote natural regeneration.

Different studies (Melehov 2002, Valtanen 1995, Löf et al. 2012, Fløistad et al. 2017) have shown that the most favourable conditions for mass seed germination under the forest canopy and in the open site are created in mineralised soil. However, in extreme conditions, in the absence or excess of moisture, and in unsuitable temperatures for germination, the environment for subsequent renewal processes also become unfavourable in this case.

The results of many studies show (Karlsson and Örlander 2000, Hörnfeldt et al. 2012, Fløistad et al. 2017) that the mineralisation should be timed with the expected seed harvest year to facilitate their germination, before competing vegetation appears on the mineralised areas. It is necessary to take into account the season of mineralisation that is directly associated with seed yield (Hörnfeldt et al. 2012).

Soil mineralisation (partial treatment) is most appropriate with the presence of seeds trees in poor soils of light granulometric composition. The soil mineralisation process must avoid root damage of seed trees. The share of the mineralised soil surface should be dependent on forest type groups, and vary from 10% to 30% of the site area with a steady cover (Recommendations 2005).

5. Conclusions

We have established a close relationship between the forest floor thickness and the undergrowth amount. As a result of this research, it can be argued that soil mineralisation has a positive effect on natural regeneration of conifers, including larch renewal. In mineralised sections, conditions are also favourable for germination of deciduous species seeds, and the total undergrowth amount for all species in areas with soil mineralisation increases. The regeneration after clear cutting is provided from retained seed trees and from the neighboring “forest walls”.

The research results showed that the unsatisfactory natural regeneration of coniferous species is observed in clear cutting areas with fire soil preparation, and in the areas without soil mineralisation.

In order to eliminate competition from deciduous tree species and maintain the conifers participation in the growing stock, it is advisable to take care of the formation of forest stands at an early stage. Carrying out treatments is possible to achieve the formation of highly productive stands of the most promising tree species. Therefore, in 15 to 20 years in northern Taiga after clear cutting, it is necessary to carry out regulated care, which will allow the achievement of an optimal density of the promising coniferous stands of determined quality.

Thus, a close cycle of forest management operation, including logging and care of forest, needs to be executed. Conducting science-based forestry practices will increase the efficiency of forest management.

6. Acknowledgements

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USE OF LINE INTERSECT SAMPLING METHOD FOR QUANTITATIVE ESTIMATION OF LARGE WOODY DEBRIS

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Abstract

The line intersect sampling (LIS) method is usually used to estimate logging residues. This article examines the possibility of applying the LIS method to estimate the volume and quality of large woody debris.

The purpose of this article was to assess the accuracy of the LIS method for estimating both the volume and quality oflarge woody debris.

The studies were carried out using computerized simulation methods.

The tasks being set while carrying out simulation experiments with the model are as follows:

1. To determine the required number of sample lines, depending on the number of pieces of stem wood in the cluttered area.

2. To determine the way the law of distribution of stem woodpiecesaround the cluttered area influences theestimation accuracy.

3. To determine the way the law of distribution of the orientation angle of stem wood pieces influences the estimation accuracy.

In the models, the large woody debris was presented as pieces of cylindrical shape distributed on the site. The laws of the distribution of lengths, diameters, orientation angles and their position on the site were determined upon carrying out field measurements.

During the simulation procedure, the following laws of distribution of the characteristics of clusters of large woody debrispieces were used:

The coordinates of the pieces - uniform, with “clutterings”, normal.

The angle of orientation of the pieces - uniform, normal.

The angle of orientation of the sample lines – uniform.

The coordinates of the sample lines - uniform, systematic.

Upon carrying out a number of simulation experiments, it was established that the LIS method theoretical formulas prove to be suitable for determining the volume and quality oflarge woody debris. According to the results of simulation experiments, the sample lines should be systematically laid across the site, while the angle of orientation of the sample lines should be set randomly. In this case, the estimation error does not exceed 20% for all laws of distributions of pieces oflarge woody debris.

Keywords: Line intersect sampling (LIS); simulation model; sample line.

1. Introduction

The term “cluttering of the forest”means the presence of non-merchantable wood in forest stands calledlarge woody debris (Fig. 1).

The volume of large woody debrisin the urbanized forests of central Russia is estimated at 5 to 15% of the overall wood volume. According to the Forestry Committee of Moscow Oblast, the forests of Moscow Oblast alone have accumulated about 20 million cubic meters oflarge woody debris.

Fig. 1Forestclutteringintheformoffallen deadwood(the author’s photo)

Urbanized forests are used for not only logging, theirprimary functions being sanitary, hygienic and health-related functions, as such forests are protective strips along the railways and highways. Inurbanized forests, large woody debris removal for aesthetic, fire-prevention and phyto-protective purposes, as well as for the safety of visitors should be carried out on a regular basis.

The large woody debris removal is regulated by sanitary rules and is assigned according to the results of the forest health monitoring. One of the main objectives of forest health monitoring is the determination of large woody debrisvolume. At present, a visual method is being used in Russia to assess thelarge woody debris. The visual method is subjective and based on the tallying employee’s experience.

In this paper, the statistical method, as being the line intersect sampling (LIS) method, is proposed for estimating the volume of large woody debris(S.P.Karpachev, V.I.Zaprudnov, M.A.Bykovskiy, E.N.Scherbakov2017).

The LIS method is used to assess logging residue. The simplicity and sufficient accuracy of this method has attracted the attention of both scientists and practitioners (C.E. VanWagner1968, G.R.Bailey 1969, 1970, S.O. Howard andF.R. Ward 1972, P.G. DeVrie 1973, 1974, C.E. VanWagner1976, S.G.PickfordandS.W.Hazard1978, 1986, M.E.Harmon, etal. 1986, S.P.Karpachev, E.N. Scherbakov 1990-2013, S.P.Karpachev, E.N. Scherbakov, A.N. Slinchenkov 2010, S.P.Karpachev, E.N. Scherbakov 2013, S.P.Karpachev, V.I.Zaprudnov, M.A.Bykovskiy,E.N.Scherbakov 2017).

The essence of the method lies in the fact that a line, called a sample line, is laid in a certain direction on the cutting area. All intersections of the stem wood with this sample line are then to be counted and the overall volume of forest residue on the site is to be estimated.

The LIS method has never been applied to estimate thelarge woody debris. For the practical use of this method for estimation oflarge woody debris, theoretical and experimental studies were carried out. Some of the results of these studies, including practical recommendations, are given in this article.

2. Theoretical Approach

TakingintoconsiderationthemainprinciplesoftheLIStheory (S.P. Karpachev, E.N. Scherbakov 2013), we are to analyze its specificfeaturesintermsofitsapplicationforthepurposesoflarge woody debrisestimation.

Now we will determine the cluttering oflarge woody debris, such as tree stems fallen to the ground, their pieces and large branches with a diameter of more than 4 cm.

In theoretical studies, pieces of stem wood and large branches (hereinafterstems) will be represented as regularconoids. Then the volume of the stem will be equal to:

$$v = \frac{\pi \cdot l}{12}\left(d_1^2 + d_2^2 + d_1 d_2\right), \qquad (1)$$

where d_1– diameter of the upper end of thestem;

d_2– diameter of the lower end of thestem;

l–length of thestem.

AccordingtotheLIStheory, the number of pieces of stems can be determined using the formula:

$$N = \frac{M[m]}{p}. \qquad (2)$$

where$M[m]$ –expected value of the number of intersections of the stems with the sample line;

p – probability of intersection of the stem with the sample line.

In practice, the expected valueis estimated according to the average number of intersections of the stems with the sample line, then:

$$N \approx \tilde{N} = \frac{1}{n} \cdot \sum_{i=1}^{n} \frac{m_i}{p} \qquad (3)$$

wherem_i– the number of stems that intersected the $i$sample line,

n – the number of sample lines.

In general, when stems are on a site of an arbitrary shape with an area$S$, the sample lines can be of the same or different length. In this case, the probability of intersection of the stem with the sample line depends on the length of the sample line. If thesample lines are of the same length, then *m* in Formula (3) can be understood as an average number of intersections of stems with a sample line of a length L_{int}:

$$m(L_{\text{int}}) = N \cdot p(L_{\text{int}}), \qquad (4)$$

The variance of the estimate can be made using the formula:

$$s^2 = \frac{1}{n-1} \cdot \sum_{i=1}^{n} (N_i - \tilde{N})^2, \qquad (5)$$

The required number of sample line will be equal to:

$$n = \left[\frac{V \cdot t_\alpha(\infty)}{P} \right]^2, \qquad (6)$$

where$P$ – accuracy index, %,

$t_\alpha(\infty)$– certainty index,

V–coefficient of variation, %.

In order to use Formulas (2-6) for estimating the number of stems on a site, it is required to determine the probability of intersection of the stem with the sample line.

Let us consider a flat site of an arbitrary shape. Let the site have an area of S. Let us suppose that there is a stem of a length$l$ (Fig. 2).

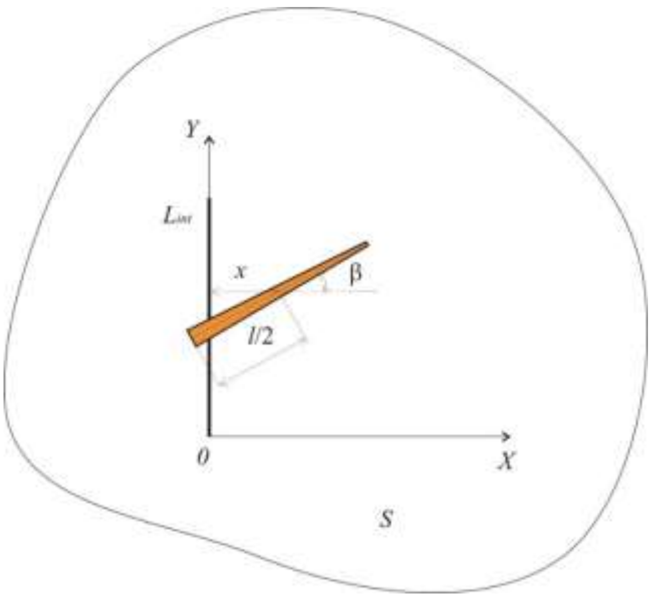

Fig. 2Analytic model

Now let us find the probability degree that the line of selectionL_{int}, being arbitrarily laid across the site, will intersect a stem oflength$l$.

Upon choosing the coordinate systemXOYa sample line is laid, thus aligning it with the OX axis. Let us denote:

- $x$as the distance from the middle of the stem to the sample line;

- β as the angle between the stem and the normal to the sample line, connected to the *x*coordinate so that there the intersection or at least the contact of the stem with the sample line.

Let the orientation of the stems follow the distribution law $f(\beta)$, while the coordinates of the position of the stem on the site follow the uniform law. Then the probability that the stem oflength *l*will be intersected by the sample line is:

$$p(+\,|\,l)=\frac{L_{\text{int}}\cdot l}{S}\int_{-\pi/2}^{+\pi/2}d\beta\cdot f(\beta)\cdot\cos\beta. \qquad (7)$$

The formula for the probability (7) is valid provided all the stemshave the same length *l*, which in practice is not so.

Let us assume that on the site *S*the length of the *i*stem is $l_i = \{l_1 \le l \le l_2\}$, where l_1, $l_2$being the length limits of thestems. If the length distribution of the stems follows the distribution law $f(l)$, then the probability of intersection of the stem by the sample line according to the total probability formula is:

$$p=\int_{l_1}^{l_2}dl\cdot f_l(l_i)\cdot p(+\,|\,l_i), \qquad (8)$$

Should the *p*probability be known, it is possible to estimate the volume of all the large woody debrisupon estimating the totalvolume of stems intersected by the sample line (1):

$$\tilde{V}=\frac{1}{p}\cdot\left(\frac{\sum_{j=1}^{k}v_j}{n}\right), \qquad (9)$$

where v_j - thevolumeof *j*stem, being intersected by the sample line.

Formula (9) allows to estimate the volume oflarge woody debris. However, as it can be seen from Formula (9), in order to estimate the above-mentioned volume, one needs to know theprobability *p*, which depends on the law of distribution of the angle (7) of the orientation of the stemswith respect to the sample line and the length distribution of the stems (8).

To establish these laws, field surveys of several forested areas were carried out.

Experimental data on the characteristics of the stems on the sites made it possible to conclude that, on the whole, it is possible to regard the law of distribution of the orientation angles of the stems as a uniform one (Fig.3), as well as length following the normal law.

Fig. 3 Large woody debrisstems oriented according to theuniform law (the author's photo)

If we accept the law of distribution of the orientation angles of the stems as being uniform, and the length of the stems as a discrete set of lengths, then Formula (8) will be written as follows:

$$p = \sum_{i=1}^{m} p(l_i) \cdot p(+ \mid l_i), \qquad (10)$$

Where $p(l_i)$ is the probability that the stem intersecting the sample line will be of length i,

m is the whole set of stem lengths that intersect the sample line.

Taking into account Formula (7) for the uniform law of distribution of the angles of orientation of the stems, Formula (10) can be written as follows:

$$p = \frac{2 \cdot L}{\pi \cdot S} \cdot \sum_{i=1}^{m} p(l_i) \cdot l_i. \qquad (11)$$

The probability of intersection of a piece of the stem of the i length l_i with the sample line can be defined as their share in the sampling of all the pieces intersected by the sample lines.

Formula (11) is applicable only for the case of a uniform distribution of the angles of orientation of the stems. However, field surveys of forested areas showed that in some cases the stemswere oriented mainly in one direction (Fig. 4) due to windfalls. In this case, the application of Formula (11) is considered to be problematic.

In some cases, stemswere concentrated in one place ("cluttered") (Fig. 5), which also makes application of Formula (11) complicated.

Fig.4 Wood stemsoriented in one direction (the author's photo)

Fig.5 Cluttering of large woody debris stems (the author's photo)

To be able to use Formula (11) in case stems are oriented mainly in one direction (Fig. 4), we decided to orient the sample lines according to the uniform law. This approach seems legitimate, since if a random variable (angle of orientation of the sample line) is added to the constant (orientation angle of the stem), then a random value (the orientation angle of the stem relative to the sample line) is obtained.

Concerning the cases of stems "cluttering" (Fig.5), we suggest placing the coordinates of the sample lines on the site systematically.

The accuracy of the LIS for estimating the volume of large woody debrisfor the cases listed above was tested on mathematical models using methods of computer simulation.

3. Methods

The developed mathematical model simulated generation of stems with a set of specified characteristics on the site. The main adopted characteristics were as follows:

- the size of the site LxB;
- densityofthestems clutteredonthe site N_s, pc./m^2;
- the coordinates of the position of one of the ends of the stem on the site x_1, y_1;
- orientation angle of the stem □;
- the length of the stem l;
- diameters of the piece of the stem in the lower and upper cuts d_1, d_2.

The assignment of characteristics to pieces of stem wood in the model was carried out according to the following algorithm:

1. Thenumberofstems was found according to the formula:

$$N = L \cdot B \cdot N_S \tag{12}$$

2. The coordinates of one end of the stem x_1, y_1 were assigned in accordance with the accepted distribution law within: $0 \le x_1 \le L$; $0 \le y_1 \le B$.In the model, two distribution laws were used: the uniform and normal ones. The normal law made it possible to simulate “density” of stems on a cluttered area.

3. The orientation angle of pieces of stem wood □ in the model was set according to the uniform law with different limits of the angle variation □(□$_1$≤□□□≤□□$_□$).

4. The length of the stems/was set according to the normal distribution law with different mean values and variances.

5. The diameters of the pieces d_1, $d_2$were set according to the uniform law, taking into account their correlation with each other.

In the model, the procedure for recording all stemsand the true values of their characteristics (the number of stemsand their volume) was implemented.

To implement the accounting procedure in the model, the following algorithm was adopted:

1. For each stem n_i, the volume$v_i$was calculated as the volume of a conoid using Formula(1).

2. For the generatedstems, the average volume and variance were calculated:

$$v_{cp} = \frac{1}{N} \cdot \sum_{i=1}^{N} v_i \tag{13}$$

$$\sigma = \frac{1}{N-1} \cdot \sum_{i=1}^{N} (v_i - v_{cp})^2, \tag{14}$$

3. The true volume $V$of all stems$N$was found as the sum of the volumes of individualstems:

$$V = \sum_{i=1}^{N} v_i \tag{15}$$

4. For eachstem, the coordinates of its end y_2, x_2 were found.

5. Then the equation of the stem axis was constructed as a straight line passing through the two given points (x_1, y_1) and(x_2, y_2) as follows:

$$(y_1 - y_2)\cdot x + (x_2 - x_1)\cdot y = (x_2 \cdot y_1 - x_1 \cdot y_2) \qquad (16)$$

The model implemented the accounting procedure of stemsand estimating the values of their characteristics, as well as the procedure for comparing the results of their estimation using the LIS with the true value of the characteristics of the stems(the number of stemsand their volume).

The following algorithm was adopted:

1. For each sample line and stem, the coordinates of the point of their intersection x_{int}, y_{int} were found. The point of intersection of the stem may not lie on the sample line. Depending on the ranges of the angle of inclination of the stem □□and the angle of inclination change of the sample line□, the four cases are possible where the intersection point lies on both the sample line and thestem. The following ranges of angleswereconsidered:

□□□≤□□□□□□□□and□□□≤□□□≤□□□□□□□□□□≤□□□≤□□□□□□and□□□□ □≤□□□≤□□□□□□

□□□□□≤□□□≤□□□□and□□□≤□□□≤□□□□□□□□□□□□≤□□□≤□□□□and□□□ □□≤□□□≤□□□□□ □□□□

An example of the intersection can be seen in Fig. 6.

Analysis of the conditions for intersection of the sample line and the stem (17), allowed us to proceed to the generalized logical condition of intersection (entry in Delphi):

((((Y_1<= y_{int}) and (y_{int}<=Y_2)) and ((y_1<= y_{int}) and (y_{int}<=y_2)))
and
(((((0<=□) and (□<=1.57)) and ((X_1<= x_{int}) and (x_{int}<=X_2))) and
((((0<=□) and (□<=1.57)) and ((x_1<= x_{int}) and (x_{int}<=x_2))) or
((1.57<=□) and (□<=3.14)) and ((x_2<= x_{int}) and (x_{int}<=x_1))))
(18)
or
((((1.57<=□) and (□<=3.14)) and ((X_2<= x_{int}) and (x_{int}<=X_1))) and
((((0<=□) and (□<=1.57)) and ((x_1<= x_{int}) and (x_{int}<=x_2))) or
(((1.57<=□) and (□<=3.14)) and ((x_2<= x_{int}) and (x_{int}<=x_1)))))));

2. Based on the results of intersections of a piece of stem wood with the sample line, the total number of stem wood pieces N was estimated on the entire site according to Formula (3), while the probability p was found using Formula (11) as follows:

$$p = \frac{2 \cdot L_{int}}{\pi \cdot S} \cdot \frac{\sum_{j=1}^{n} \sum_{i=1}^{m_j} l_{ji}}{\sum_{j=1}^{n} m_j} = \frac{2 \cdot L_{int}}{\pi \cdot S} \cdot l_{mean}. \qquad (19)$$

where l_{mean} is the average length of thestem, obtained from the intersection of all sample lines;

m_j is the number of the stemsintersected by the j sample line;

n is the number of sample lines.

3. For the generated stems, the mean value and variance were calculated using Formulas (13-14).

4. For each intersected stem n_i, the volume was calculated as the volume of a cylinder of diameter d_{int} at the point of its intersection with the sample line:

$$v_i = \pi \cdot l_i \cdot \frac{d_{int\_i}^2}{4} \qquad (20)$$

5. The total volume V of all the stems N was estimated using Formula (9), in which the probability p was calculated using Formula(19).

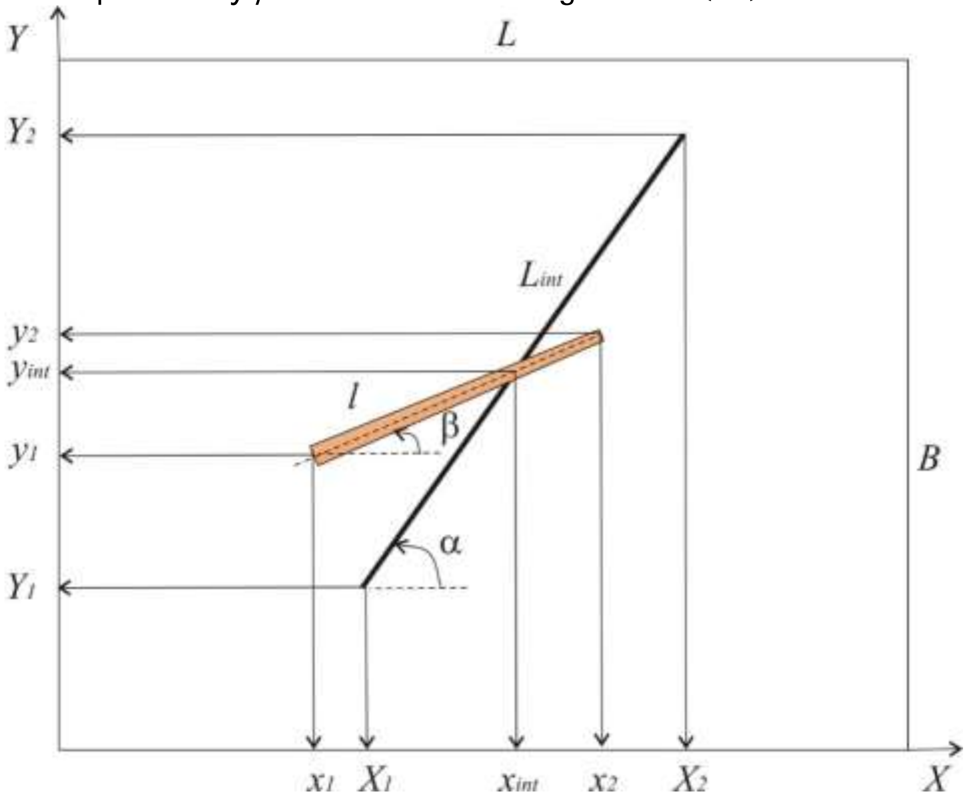

Fig.6Intersection of the sample lime and thestem

□□□≤□□□□□□□□□and□□□≤□□□≤□□□□□□

6. Estimation of the total volume was compared with the true volume of all the stems on the site, then the error was calculated:

$$error = \frac{V - \tilde{V}}{V} \cdot 100\% \qquad (21)$$

The model of stemsaccounting procedure using the LIS was implemented in the Delphi software environment.

4. Results and discussion

During the simulation experiments, the following tasks were set:

1. To check the validity of the formulas for estimating the volume of stems (large woody debris) thus obtained theoretically.

2. To determine the influence of the law of distribution of the orientation angle of the stems on the accuracy of the estimate.

3. Determine the influence of the law of distribution of stems on the site on theestimation accuracy.

The most significant results of the experiments are presented in Table 1 and as graphs in Fig. 7-9.

Table 1 shows the results of the simulation experiment with the LIS stem estimation model. In this case, the laws of the distribution of characteristics of stems and sample lines were adopted, for which the LIS theoretical formulas were obtained:

- coordinates variation of stems - uniform,
- coordinates variation of the angle of stems - uniform,
- coordinates variation of the orientation angle of sample lines - uniform,
- coordinates variation of sample lines- uniform.

Table 1The results of the simulation experiment with the LIS stems estimation model

True number of stems	Required number of sample lines (theoretical)	Required number of sample lines (estimated)	Estimation of the number of stems	Average number of intersections with stems per line	Standard deviation	Estimation of stems volume, m^3	Truestems volume, m^3	Estimation error of stems volume, %
1	2	3	4	5	6	7	8	9
25	240	241	27.3	0.329	0.521	8.847	6.749	-31.1
50	140	139	46.7	0.557	0.671	11.294	10.967	-2. 9
75	110	109	63.3	0.763	0.786	12.284	15.202	19.2
100	60	63	94.8	1.067	0.861	18.630	20.892	10,8
125	40	34	136.5	1.525	0.905	23.814	27.246	12.6
150	36	38	152.6	1.694	1.064	26.677	33.065	19.3
175	33	34	179.5	1.909	1.128	31.241	38.000	17.8
200	28	29	208.4	2.250	1.236	38.336	43.548	11.9
225	25	25	229.0	2.480	1.262	39.580	47.359	16.4
250	25	27	261.7	2.800	1.500	49.920	54.446	8.3
275	25	26	266.4	2.840	1.491	50.408	60.694	16.9
300	21	22	296.6	3.090	1.480	57.244	67.722	15.5

Table 1 data analysis allows us to conclude that the theoretical formulas for the adopted laws of distribution of characteristics of stemsand sample lines are in good agreement with the data of simulation experiments. The required number of sample lines, obtained theoretically, practically coincides with the calculated values obtained from the results of processing the experimental data. The error in estimating stem volumes in only one case exceeded the absolute value of 20%.

Fig. 7 shows the dependence of the required number of sample lines on the number of stemson the site (Table 1). It can be seen from the graph that as the number of stemsincreases, the required number of sample lines decreases. With the number of stemsof more than 100 pcs/ha, the required number of sample lines does not exceed 50. If the number of stemsof 200 pieces per 1 ha is exceeded, then the required number of sample lines is up to 25. Provided the length of one line is 20 m, then the total length of the sample lines does not exceed 500 m, which is quite acceptable in terms of practical use.

We considered the case where the stems are oriented mainly in one direction with insignificant deviations. For that, the normal law of variation of the orientation angle of pieces with an average angle of 90° and standard deviation of 15°was introduced into the model. In addition, the laws of characteristics distribution of stemsand sample lines were adopted:

- coordinates variation of stems- uniform,
- coordinates variation of the angle of stems- normal,
- coordinates variation of the orientation angle of sample lines - uniform,
- coordinates variation of sample lines- systematic.

The results of the experiments are presented in Fig. 8. In the case of the systematic arrangement of the sample lines according to the uniform law of distribution of the orientation angle of the stems (1), the calculated required number of the sample lines coincides with the required number of the sample lines provided sample lines are arranged uniformlyand according to the normal law of distribution of the orientation angle of stems(2).

According to the results of simulation experiments, the estimation of the volume of stem wood in only one case exceeded the absolute value of 20%, which can be considered acceptablein terms of practical use.

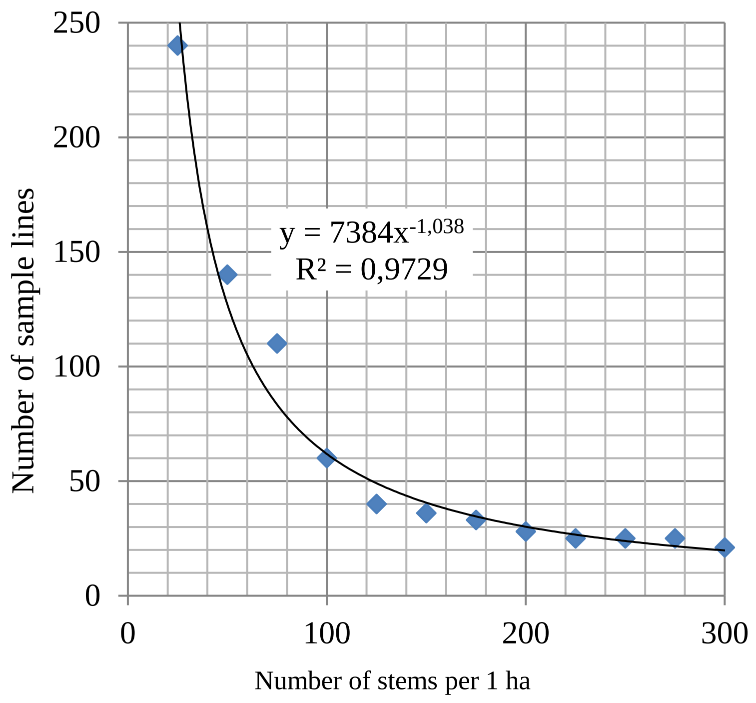

Fig. 7 Dependence of the required number of sample lines on the number of stems on the site

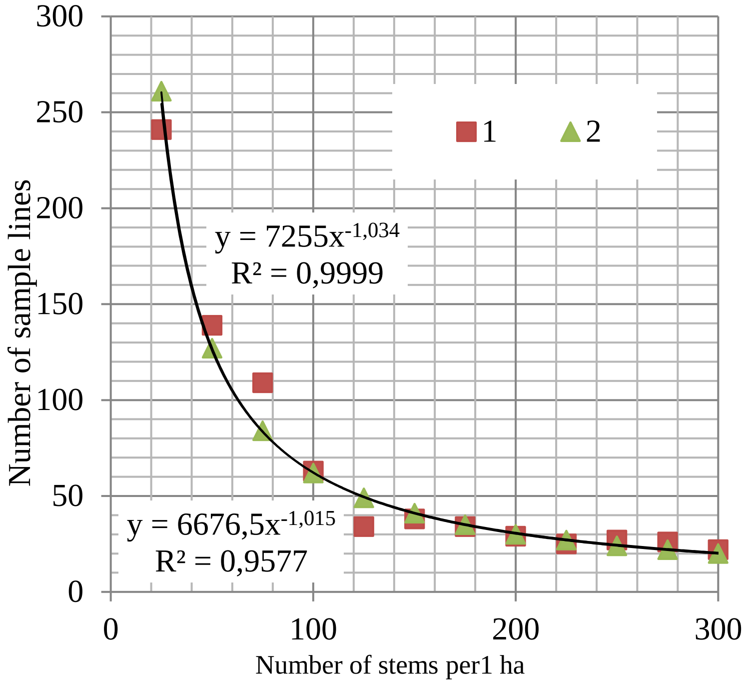

Fig. 8 Combined graph of dependence of the required number of sample lines on the number of stems on the site

The effect of the law of the stems distribution on the site on the estimation accuracy in the model was carried out by local "cluttering" of the stems along the site axes *X*, *Y*. For that, coordinates distribution of stems on the site was modeled not according to the uniform but normal law with an average value of 50 m and an standard deviation of 15 m. In that case, most of the stems were concentrated in one place.

To reduce the effect of local stems cluttering both along the *Y*-axis and *X*-axis, it was decided to lay sample lines systematically. To do that, a grid was applied to the site, its the nodes being the beginning of the sample lines. The grid edges were assumed as being equal to the length of the sample lineL_{int}.

The results of the estimation of "cluttered" stemsgroups along the sample lines distributed uniformly on the site according to the uniform law (2) and obtained along the sample lines being laid systematically (3) are shown in the combined graph (Fig. 9). The same graph shows the curve (1) for stems distributed on the site according to the uniform law.

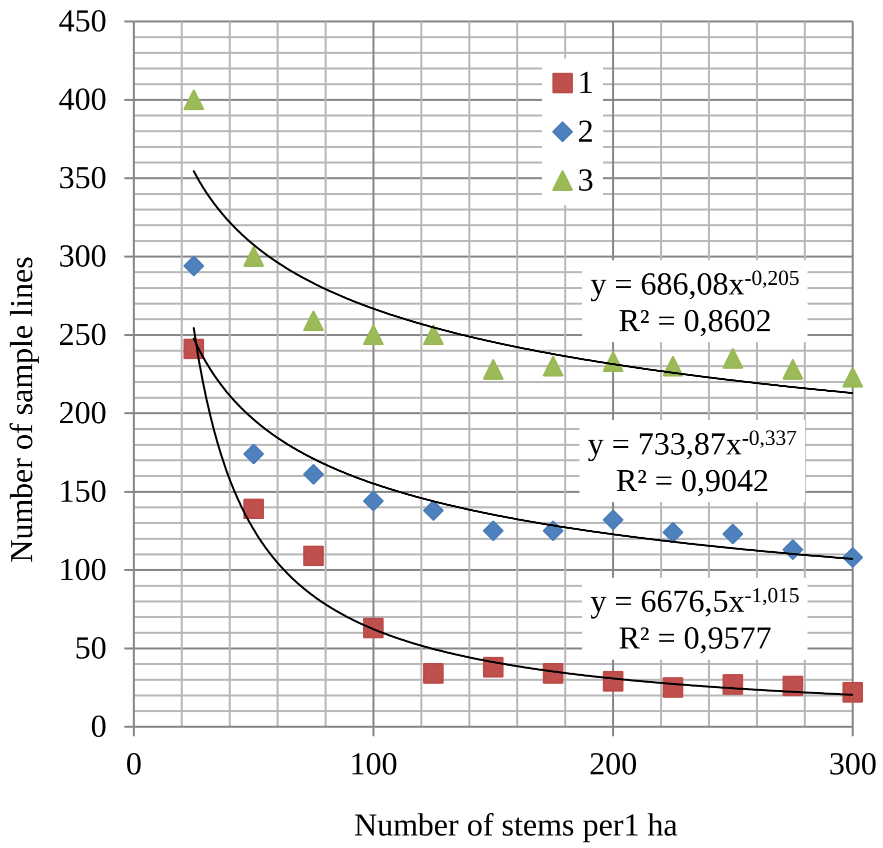

Fig. 9 Combined graph of dependence of the required number of sample lines on the number of "cluttered" stems on the site

In cases (2-3), the required number of sample lines is much larger than in the case of the uniform distribution of stems on the site (1). This can be explained by the fact that, provided there is a "cluttered" distribution of stems on the site, the estimation variance is much larger compared with the uniform distribution.

The results of the experiments also showed that in the case of the "cluttered" distribution of stems and random arrangement of sample lines on the site, the estimation error of the stems volume was not less than 70%, which is unacceptable.

For the case of a systematic arrangement of sample lines, the estimation error of stem volume did not exceed 20%.

5. Practicalrecommendations

The above-mentioned theoretical and experimental formulas as well as the developed LIS methods for estimating large woody debriswere tested in practice in the forests of Tver Oblast. Large woody debrisestimation was carried out on the experimental site. The parameters of the experimental site are as follows: L = 90 m, B = 40 m. The site was divided into strips. The strips were assigned along the long side of the site (Fig. 10).

The adopted sample line had a length L_{int} of 20 m. The width of the strip was assigned as being equal to the length of the sample line B_l, i.e., 20 m. In total, two strips were made. The length of each strip was assumed as being equal to the length of the side's site *L*.

On the experimental site, the sample lines were grouped in pairs. The direction of the first line in the pair was determined by the orientation angle □, which was set according to the uniform law with variation limits of □□≤□□□≤□□□□. The second line in the pair was the continuation of the first one and was laid at an angle of □/2to the first line, so that the end of the second line would return to the strip line, as shown in Fig. 10. This made it possible to reduce to a minimum the time it takes an employee to move while estimating.

The beginning and the end of each sample line on the site were fixed by pegs.

The field work technology was as follows: the tallying employee moved along the sample lines (Fig. 10). The estimation of stems, their pieces and large boughs was checked visually according to the fact of their intersection with the sample line. Only wood with a butt diameter of more than 4 cm was subject to estimation.

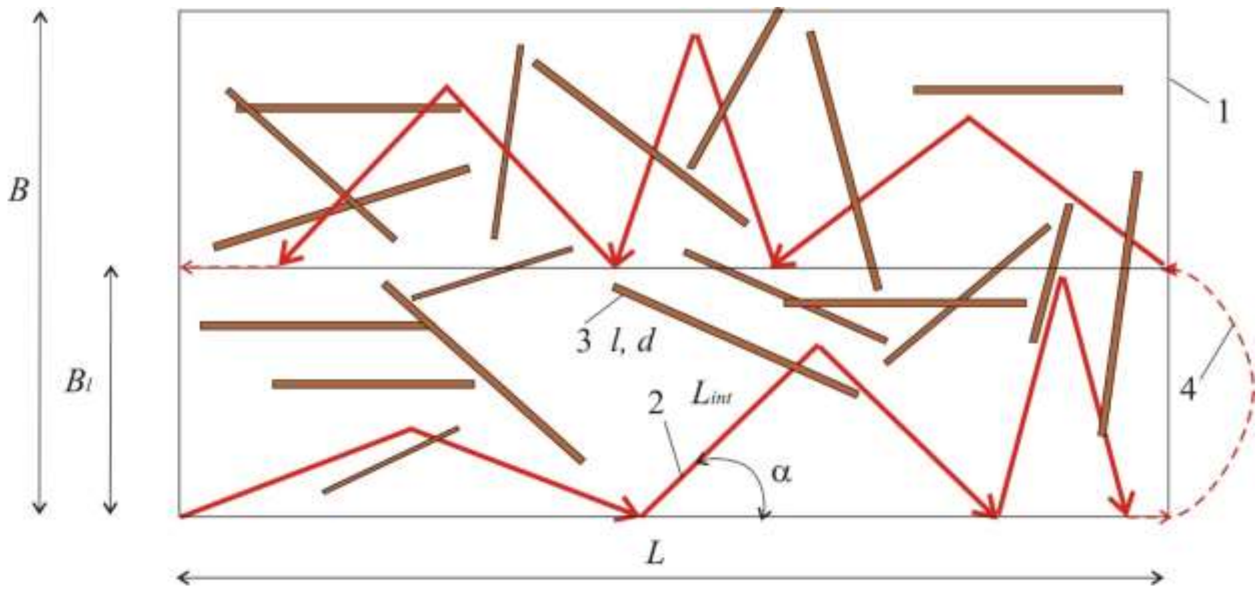

Fig. 10Scheme of large woody debrisLIS estimation on the experimental site

1– boundary of the site; 2 –sample lines; 3 – pieces of stemlarge woody debris; 4 –tallying employee's line of movement

In the logbook, for each stem that was intersected by the sample line, its diameter was put down at the intersection point using calipers, as well as its length using a tape-measure (Fig. 11).

As a result of the experiments that were carried out to estimate the volume of large woody debrisusing the LIS, it was found that the discrepancy between the true value of large woody debrisvolume (V_{real} = 22.90 м^3) and its estimate (V_{estem} = 24.77 м^3) with a significance level of 5% and an accuracy of 20%, amounted to 7.6%, which can be considered a good result.

The data concerning the large woody debris volume obtained using the MLP may be the basis for developing a technology for cleaning up cluttered forested areas.

Fig. 11Counting and measuringlarge woody debrison the sample lines (the author's photo)

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ASSESSING INTER VISITOR-GROUP CONFLICT POTENTIAL ON FOREST ROAD NETWORKS

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Key words: traffic counting, conflict, forest road, visitor management

Abstract: In Hungary anyone is allowed to use the forest road network by walk, by bicycle, on horseback and by horse pulled vehicles. Motorized public traffic is only permitted on dedicated roads. The forestry companies use the network mainly by cars, trucks and heavy machinery. Mixed traffic can lead to conflicts between different road user groups and between individual visitors. It was our aim to assess intergroup conflict potential based on traffic count data. A digital photo based traffic counter provided date, time and user group data from a sample road section. The numbers of intergroup encounters were calculated as the sum of two passages within a minute. An online questionnaire survey was conducted to know the judgement of the encounters by people belonging to specific road user group. Higher number and worse judgement of the encounters indicate higher risk of intergroup conflicts. An index number was developed so the conflict potential of the sections of a forest road network has become comparable and the management interventions can be prioritized.

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MODERN EQUIPMENTS FOR FOREST SURVEYING AND MAPPING

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Abstract: Traditional survey tools were used in forestry mapping until the early 2000s in Hungary. Later on, electronic total stations, laser scanners, ortho-photography and GNSS based survey became predominant. The accuracy, performance and price of these high expertise demanding instruments vary greatly. Forest mapping requires simple, cheap, yet sufficiently accurate survey tools. It was the aim of this research to assess the properties of distance and angular measurements of state-of-the-art professional survey tools and handheld rangefinders. The accurate position of trees and roads within the research area was determined by terrestrial laser scanning. The measurements of the assessed tools were compared to this reference measurement. Based on the experiences of the research, recommendations were formulated concerning the application of the assessed survey tools for forest mapping.

Acknowledgement: This article was made in frame of the „EFOP-3.6.1-16-2016-00018 – Improving the role of research+development+innovation in the higher education through institutional developments assisting intelligent specialization in Sopron and Szombathely".

Keywords: forest mapping, survey tools, range finders, accuracy assessment

THE EUROPEAN FOREST FIRE FIGHTING COUNCIL (EUFORFIRE) AS CONTINENTAL REFERENCE POINT FOR DISCUSSION ON FIRE FIGHTING ORGANIZATION AND TRAINING ACTIVITIES

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Key words: big fire, international collaboration, MEFISTO project, forest fires

Abstract: In many European countries, especially in Mediterranean region, the last decades have been characterized by deep changes in land use, mainly due to land abandonment, which have modified both forest extension and structure, causing a general increment of fuel accumulation. These changes, added to climate change conditions, are causing an increasing dramatic wildfire spread year by year. Catastrophic fire events are characterized by being often beyond the suppression capacity in large areas, including the wildland urban interface (WUI), generating heavy damages on goods and people, including fatalities. In these conditions the task of managing a wildfire is becoming more complex than in the past years, requiring well trained fire fighters able to deal with the new operative conditions. In this context, improvements are required, and it is fundamental to enhance the efficiency and effectiveness in forest fire prevention and fight by means of international collaboration. In the surroundings of MEFISTO project (Mediterranean forest fire fighting training standardization) a very important Memorandum of Understandings have been signed by some of the most important Mediterranean organizations involved in fire fighting and fire fighter training, founding EUFORFIRE – European forest fire fighting council. EUFORFIRE is a new volunteer organisation interested in creating and enlarging a group of stakeholders in the field of forest fires, and especially in the field of training activities. It has been created to answer to the increasing needs of new solutions and better preparedness level of fire fighting organizations against forest fires. The main aims of EUFORFIRE are: i) to share organizational models and their development; ii) to collaborate in exchanging information on trainings of forest fire fighters and evaluation procedures; iii) to develop a list of figures comparable with each national structure; iv) to improve collaboration between countries, especially against big fires. In this contribution the structure, the role and the functions of EUFORFIRE are reported and explained in detail.

PLANTING AND AGRO-TECHICAL TENDING PRODUCTIVITY COMPARISON IN DIFFERENT SOIL PREPARATION METHODS USING DIFFERENT PLANTING MATERIAL.

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Key words: planting productivity, agrotechnical tending productivity, planting on mounds, planting in trenches

Abstract: In 2016 more then 12 500 ha of forest was sowed or planted in Latvia. Mainly two soil preparation methods are used – mounding and trenching. In areas with normal water regime trenching method is used, while in wet areas mounding is used. All planting is done manually by hand tools (spade and planting tube) and after planting agrotechnical tending (cleaning) is done by forest clearing saw (bush cutter). Job productivity highly depends on soil preparation method and planting material type. The aim of the study was to compare planting and agrotechnical tending productivity in different soil preparation methods (mounding and trenching) by planting different planting material (containerized seedlings and bare root seedlings with improved root system). Planting and agrotechnical tending time studies were done in 12 sites. Average planting productivity for containerized seedlings on mounds were 9.2 seconds per seedling, while in trenches – 10.3 seconds. Containerized seedling planting productivity in different sites may vary, in mounds it vary by 23% and ranges from 7.9 to 10.3 seconds per seedling. In trenches it vary by 67% and ranges from 4.6 to 13.9 seconds for seedling. Average planting productivity for bare root seedlings on mounds were 28,3 seconds per seedling, while in trenches – 18.2 seconds. Bare root seedling planting productivity in different sites may vary, in trenches it vary by 37% and ranges from 13.5 to 21.4 seconds per seedling. Lower productivity is in sites where planting spots are in wet places or covered with forest residues (tree tops, branches, roots) what leads to extra time spent on searching and cleaning planting spot. Planting with containerized seedlings take less time in seedling picking up and sorting. In agro-techical tending studies GPS devices were used, where area, distance and time (productive and rest) was counted from GPS data. Agrotechnical tending in trenches was done faster then in mounds. Time spent for 1 ha tending varied between sites and in mounds were 8.0 – 10.3 hours, while in trenches 4.5 – 9.0 hours, what is 25% faster. Average walking distance in 1 ha tending in mounds were 5.6 – 5.8 km, while in trenches 3.9 – 4.5 km, what is 27% less. In all sites productive work time, what

included only tending was 85-89%, while refueling, rest and maintenance time was 11-15% from total work time. Tending in trenches is faster because less time is spent for searching planted trees and looking around in which part of the site tending is already done and where it is still needed. Data from planting and agrotechnical tending time studies could be used for better work planning and suitable planting material selection in particular soil preparation method.

THE MOISTURE CONTENT OF FOREST FUELS DURING FIRE SEASON IN HEMIBOREAL FOREST ZONE IN LATVIA

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Key words: fuel moisture, hemiboreal, FWI

Abstract: The knowledge and ability to predict forest fire characteristics like occurrence, intensity and severity is crucial information for forest fire prevention and management system. Canadian Fire Weather Index (FWI) system is one of the most widely used forest fire danger systems around the world. Yet, the relationship between fuel moisture content and FWI danger classes vary regionally depending on forest composition, climate and topography. To implement the FWI system for operational purposes calibration of FWI values to regional specifics are needed. In Eastern Baltic Sea region such information is limited, therefore the aim of our study was to assess relationship between FWI system and fuel moisture content in the hemiboreal forests of Latvia. \nThe data were collected in three sites located in different parts of Latvia in Scots pine (Pinus sylvestris L.), Norway spruce (Picea abies), silver birch (Pendula Betula), common aspen (Populus tremula) dominated stands in several forests types and age classes. At each study site volumetric soil moisture samples were taken several times during fire season (May–October) for two years. A portable weather station recorded daily temperature (C°), precipitation (mm), wind speed (km/h) and relative humidity in air (rh) every 30 minutes at each of study sites. The relationships between a soil moisture content and Canadian FWI were assessed by multiple linear regressions. Significance of differences between groups were assessed by ANOVA analysis and Tukey's HSD test. \nThe forest type had a significant effect on the relationship between FWI and fuel moisture content. FWI equations well described moisture content in dry oligotrophic and dry mesotrophic sites; yet, poorly described fuel moisture content in drained mesotrophic sites, which might have linked to drainage caused local soil moisture heterogeneity. The tree age class did not significantly improve multiple linear regression model, suggesting a minor influence on the moisture exchange processes within stand, especially in Scots pine stands. The results from this study show that Canadian FWI System can characterize fuel moisture conditions in different forest types in hemiboreal forest zone, suggesting that FWI could be a part of National fire danger management system.

EXTREME METEOROLOGICAL PHENOMENA AND THEIR IMPLICATIONS ON FOREST ECOSYSTEMS IN TRANSYLVANIA (CENTRAL ROMANIA)

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Key words: extreme meteorological phenomena, forest fires, adaptive management

Abstract: The 2015 Paris agreement acknowledges that climate changes pose an immediate, maybe irreversible threat to human societies as well as the whole planet, and it requires the best possible partnership on behalf of all countries, as an international and efficient respond required in order to accelerate the process of diminishing global greenhouse gas emissions. Its aim is to limit the increase of global average temperature with 2°C by 2020 regarding pre industrial level and in short terms to limit its growth by 1.5°C.\nLong periods of atmospheric instabillity were recorded between 2001 and 2010, with torrential rains and massive floods, canicular episodes (heatwaves), and repetead droughts, blizzards and intense frosts, sudden changes to contrasting atmospheric conditions, which were real shocks to forest vegetation, resulting in death and damage to trees. \nWe find it very curious that the „hottest decade" was followed by a hotter period of seven years (2011-2017), and that the year 2015 was the hottest so far (with an average annual air temperature of 9.4°C in relation to the long term average of 7.8°C, 1961-2017), and that extreme meteorological phenomena from the past decade continued to appear, but with higher frequency and intensity. \nThe present paper analyses meteoclimatic phenomena which favor the start and maintains forest fires, as well as using an adaptive management system to prevent and lower the effects of forest fires.

EVALUATION OF HEARTROT CAUSED PHELLINUS PINIAND RELATED YIELD LOSS IN PINUS SYLVESTRIS STANDS WHEN WOOD POLES FOR POWER LINES ARE HARVESTED

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Abstract: *Tree wounds are the starting points that may lead to heartwood discoloration and decay caused by invading micro-organisms such as heartrot caused Phellinus pini. Phellinus pini most frequently occurs on douglas–fir (Pseudotsuga menziesii), pine (Pinus sylvestris) and spruce trees (Picea abies). According to investigations made in this area, infection by Phellinus pini entries through felling scars or broken tops when Phellinus pini fruiting bodies (conks) on other trees are realising airbone spores. When spores land on a freshly wounded stem, the infection processstarts.*

Internal decay is often difficult to detect because only Phellinus pini conks indicateitspresence.In most cases the number of conks doesn't exceed one-two pieces on the surface of inficiedPinus sylvestris stems. When wood poles for power lines are harvested in length from 10 to 16m in wood felling areas where the average height of Pinus sylvestris trees is more than 27m, the local distribution of heartrot doesn't exceed for more than 1.5m above and below each conk, the conk is located in the middle part of the pole length, the speeed of pruning exceeds 4m/sek, the hight level of risk exists that the damaged with heart rot wood pole will be accepted as appropriate to quality requirements toward heartrot because after pruning the presence of conk would be vanished but the top and butt surfaces of pole's won't indicate heartrot. The evidence of heartrot will be checked only in the technological process of debarking before impregnation when Phellinus pini conk place indicates.

The purpose of this study is to predict the influence of Phellinus pini on Pinus sylvestris stems and to provide operational and safety recommendations concerning the risky assessment and management of infected felling areas in harvest planning processes.

Key words: Phellinus pini, Pinus sylvestris, wood poles for power lines

1. Introduction

Pinus sylvestris is the world's most widespread conifer after *Juniperus communis*. Its native range includes Albania, Andorra, Armenia, Austria, Azerbaijan, Belarus, Bosnia & Herzegovina, Bulgaria, China, Croatia, Czech Republic, Estonia, Finland, France, Georgia, Germany, Greece, Hungary, Italy, Kazakhstan, Latvia, Lithuania, Macedonia, Mongolia, Montenegro, Norway, Poland, Portugal, Romania, Russia, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, and the United Kingdom.[3].

Phellinus pini is one of the most common stem and butt decay fungi in conifers. According to investigations [1;10], its distribution spreads across the north temperature zone. *Phellinus pini* most frequently occurs on Douglas – fir (*Pseudotsuga menziesii*), pine (*Pinus sylvestris*), spruce (*Picea abies*) and western larch (*Larix occidentalis*) [7]

Decay dynamics and damage will vary with host species and age [12]. According to literature data, the evaluation of *Phellinus pini* has not been studied extensively. Infection through adaxial twigs and branches usually occurs in late fall or early spring when the bark is loose. As the result itcauses redring rot.Developing of heartrot in hardwood can take over 100 years.The early stage of decay appears as a reddish-purple stain in the heartwood. During incipient decay the surrounding wood tends to be discoloured when the wood strenght parameters doesn't significantly changed [1;10;16]. Decay is usually confined to the heartwood of mature trees and the most extensive deccay occurs in the trunk [9;16]. Decay develops after *Phellinus pini* fungus causes the springwood. The fungi firstly destroying lignin and later cellulose [11]. From this stage fruiting bodies may develop at branch stubs or wound faces along the stem. The appearance of conks are usually brownish, hard, woody and hoof–shaped. According to investigation results [16] only *Phellinus pini*consistentlyproduce the conks that indicate heartrot decay.

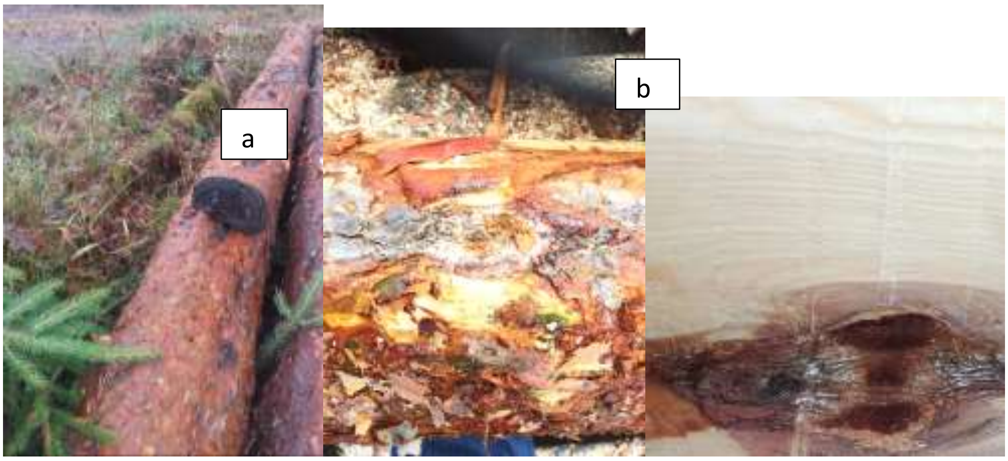

Fig. 1.*Pinus sylvestris* stem with heartrot indicator - *Phellinus pini* conk, where:
a - conk on the growing tree; b-conk place after harvesting; c-conk place after debarking

Pinus sylvestris separate the wound and subsequent decay by forming barrier zones of cells in the pholoem and c xylem to prevent fungal spread. Therefore, the wound usually won't exceed the diameter of the tree at the time the damaging happened (Fig.2). *Phellinus pini* may overcamethese barriersresulting in canker enlargement [6]. There is no approved information in literature if the amount of decay correlates with the wound size and age [18].

If the tree is unsuccessful to prevent fungal spread, decay will spread further into the heartwood. In trees with advanced decay conks are often seen along the lenght of the stem (Fig.1.)

According to investigation results [9; 14] *Phellinus pini* is one of the most descrustive heartrots in North America, especially in old growth forests [1]. According to investigation results [5] the average loss due to *Phellinus pini* decay is about 10% of the volume of interior stands, less than 5% in stands on Vancouver Islans and the Queen Charlotte Islands and about 15 % of the gross volume of Douglas fir stands western Oregon and Washington state. Unfortunately, the studies addressing *Phellinus pini* investigation is limitedin Latvia [2;3;4;13;17;19].

Therefore, the risk related to *Phellinus pini* is underestimated when harvesting is managed in old growth forests. The quality problems related to heartrot reveals in manufacturing process of wood poles for power lines in the technological stage of debarking when places of *Phellinus pini* conksreveal visible on wood poles surfaces (Fig.1).

2. Study Goal

The goal of this study was to evaluate and predict the effects of *Phellinus pini* infection on structural stability of wood poles for power lines. The following objectives were set to achieve the study goal:

- **(i)** to verify the presence of *Phellinus pini* by laboratory analysing of wood samples from conks places;
- **(ii)** to correlate the presence of visible indicators-conks of infection by *Phellinus pini* towood poles structural condition as extend of decay, observed average shell thickness, number of annual rings in sound shell zone, in barrier and hardwood zone, required shell thickness, etc;
- **(iii)** to collect and analyse all measurement results;
- **(iv)** to prepare the technological recomendations concerning risk assessment of felling areas infected by *Phellinus pini* in forestry operations

3. Materials and Methods

A field study was carried out at the period May - December of 2017, in Vidzeme region of Latvia and in energy company JSC “Sadales tīkli”. Wood poles which were harvested in Vacciniosa and Myrtillosa forest types where the age of pine stands according to the forest inventory description was more than 105 years old were selected in the investigation. The quality control of each of selected 4863 pcs. wood poles was done in each stage of technological process in JSC “Sadales tīkli”. Traceability of wood poles was ensured. In order to gather information about impact of *Phellinuspini*on wood pole’s strenght parameters, the following approach, methods and data was collected:

- data characterized the wood felling area: coordinates of wood felling area; forest type; growing stock; growth conditions; site quality classes; species composition index and the age of species;
- data characterized the wood pole's visual quality parameters: lengh of wood pole; wood pole top and butt diameter; wood pole diameter at a conk positions; a conk possition measured from the wood pole butt and a conk location place dimensions on infected tree surface;
- data characterized wood pole's quality parameters at the position on the wood pole where *Phellinuspini* conk or blid conk was visible: number of annual rings in sound shell zone; number of annual rings in barrier and hardwood zone damaged by *Phellinuspini*; total number of annual rings; mean thickness of annual rings in sound shell zone; mean thickness of annual rings in barrier zone; mean distance of heart rot measured from conk position toward to wood pole butt; mean distance of heartrot measured from conk position toward to the wood pole top; mean distance of internal wood staining area (indicative of incipient decay) measured from conk position toward to the wood pole butt; mean distance of internal wood staining area (indicative of incipient decay) measured from conk position toward to the wood pole top; Required Shell Thickness; observed Average Shell Thickness and calculation of mean AST/RST ratious.

4. Results and Discussion

When wood poles for power lines are harvested in length from 10 to 16m in infected by *Phellinus pini* wood felling areas where the average height of pine trees is more than 27m, the conk is located in the middle part of the pole length, the speed of pruning exceeds 4m/sek, the hight level of risk exists that the damaged with heartrot wood pole will be accepted as appropriate to quality requirements toward heartrot. After pruning the presence of conk would be vanished but the top and butt surfaces of pole's won't indicates heartrot. The evidence of heartrot will be checked only in the technological process of debarking before impregnation when Phellinus pini conk place indicates (Fig. 1)
For the long period, in the process of quality evaluation of wood poles before impregnation, the conk places were evaluated as the unspound knots. Only when the heartrot as a cause of breaking of wood poles was checked, the problem started to be explored.
For investigation of the reason of heartrot, the sample of damaged wood was taken and analysed (Fig. 2) in the laboratory of molecural genetics LSFRI Silava.

Fig. 2. The example of examined wood taken for molecural genetics analyse

The results of the laboratory analyses revealead the reason of heartrot in infected wood poles - *Phellinus pini.*
According to the investigation objective, the dimensions of *Phellinus pini* conk's location places were measured on infected wood poles surfaces (Fig.3). The measurement results are given in Table 1.

Fig. 3. The measurement of conk location place dimensions on infected wood pole surface

All wood poles on which surfaces were indicated *Phellinus pini* conk's were cross or/and longitudinally sectioned at the position of the visible conk's or blind conk's (Fig 4; Fig. 5; Fig. 6). In some cases wood poles were cross sectioned above and below the conk's in order to evaluate AST at these positiions. The investigation results is given in Table1.

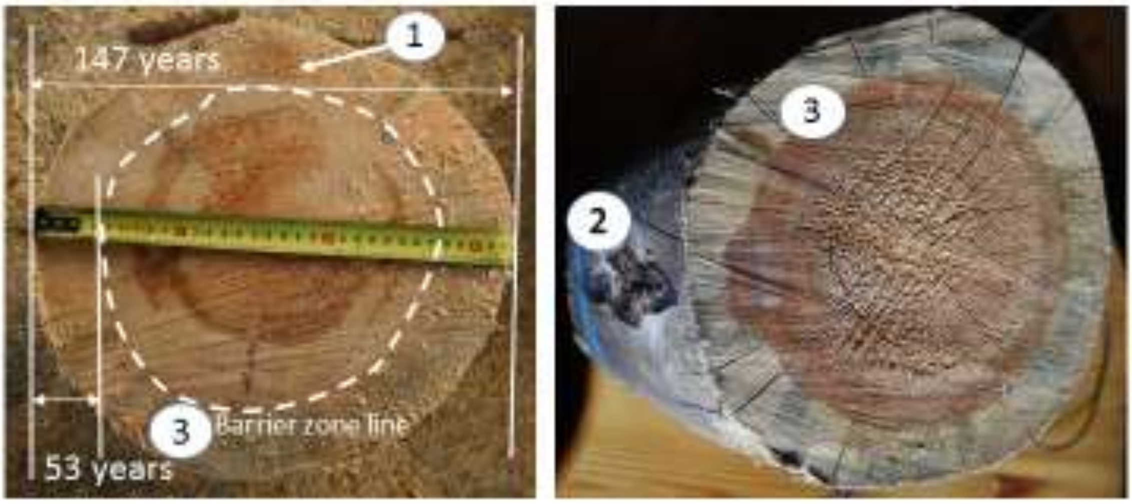

Fig. 4.Cross sections of infected Pine wood poles upper Phellinus pini conks possition. where:

1- entry point of fungus at old branch stub, 2- conk possition, 3- barrier zone line which indicates the outer limit that heart rot would have extended in this tree[15;18]

Fig. 5.The analyses example of cross section of infected pine wood pole taken at a conk position, where:

D_1 - wood pole diameter at conk position, mm; **D_2** - diameter of hardwood damaged by Phellinus pini, mm; **B**- number / thickness of annual rings in barrier zone, mm; **A**- number / thickness) of annual rings in sound shell zone, mm

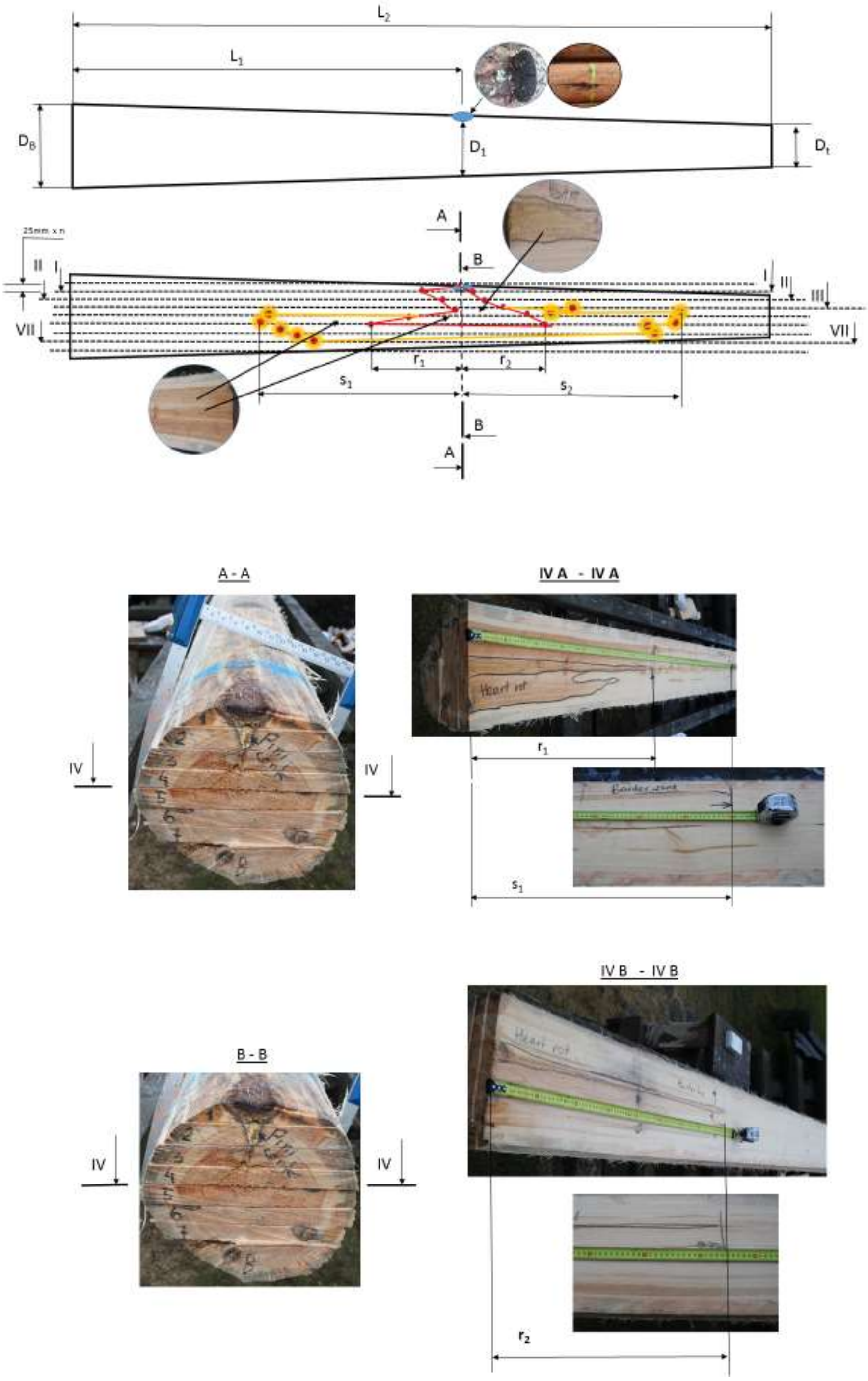

Fig. 6.The analyses example of longitudinal section of infected pine wood pole taken at conk position, where: **L_1 -** distance of conk possition measured from butt, cm; **L_2**- lenght of wood pole, cm; **D_1**- wood pole diameter at conk positions, mm; **r_1**- distance of heart rot measured from conk position toward to wood pole butt, mm; **r_2**- distance of heart rot measured from conk position toward to wood pole top, mm; **s_1**- distance of wood staining

(indicative of incipient decay) measured from conk position toward to wood pole butt, mm; **s_2**- distance of wood staining (indicative of incipient decay) measured from conk position toward to wood pole top, mm

The measurement results characterized damages of pine wood poles caused by Phellinus pini

Table 1

Mean conk location place dimensions on infected tree surface, cm^2 (n=128)	24.8 (range 16.3 -28.7)
Mean /Median distance of conk possition measured from wood pole butt, cm (n=83)	4598/4250
Median lenght, cm (73 wood poles)	10000
Mean / Median wood pole diameter at conk positions, mm (n=83)	280/268
Mean /Median wood pole top diameter, mm (73 wood poles)	205/204
Mean /Median wood pole butt diameter, mm (73 wood poles)	310/315
Mean diameter /Median of hardwood damaged by P.pini, mm (n=128)	101/95
Mean thickness of annual rings in sound shell zone, mm (n=128)	0.7
Mean thickness of annual rings in barrier zone, mm (n=128)	1.4
Mean age of trees, years (n=128)	111 (range 105-147)
Mean AST*, mm (n=128)	35.4 (±SD 5.22) (±SE 0.46)

***AST** - observed Average Shell Thickness. Calculated as the average of actual wood pole sound shell width measured at 3 points around the pole at a given height positiion. This positrion corresponds to the position of the defect indicator (i.e.,conk) above pole height,*

Mean RST*, mm (n=128)	30.2 (±SD 9.44)
RST *- Required Shell thickness. Calculated as a wood pole radius at a conk position (D_1/2)x 0.30 (Fig.5.)*	(±SE 0.83)
Overall Mean AST/RST * ratio /(n=128)	0.81 (±SD 0.22)
An AST/RST *ratio of 1.00 or grater means that the actulal average stem shell thickness is equal to the required minimum of shell thickness andsoundwoood shell ensures columnar strenght and structural stability. When ratio AST/RST<1.00, wood pole have relatively thin stem shell walls andtherefore have insufficient sound stemwood shell to maintain columnar strenght and structural stability.*	(±SE 0.019)
Mean AST/RST ratio of wood poles with blind conks (n=4, 4 wood poles)	1.86
Mean AST/RST ratio of wood poles with multiple conks (n=14, 4 wood poles)	0.72
Mean distance of heart rot measured from conk position toward to wood pole butt, mm (59 wood poles)	875 (±SD 185.43)
	(±SE 24.14)
Mean distance of heart rot measured from conk position toward to wood pole top, mm (65 wood poles)	850 (±SD 176.31)
	(±SE 21.87)
Mean distance of internal wood staining area (indicative of incipient decay) measured from conk position toward to wood pole butt, mm (43 wood poles)	2370
Mean distance of internal wood staining area (indicative of incipient decay) measured from conk position toward to wood pole top, mm (65 wood poles)	2240

5. Conclusions and Recomendations

The results of the study indicated the following:

- About 1.5 % of inspected 4863 pcs wood poles harvested in felling areas in Vacciniosa and Myrtillosa forest types where the mean age of pine trees were 111 years old were infected by *Phellinus pini.*
- Wood poles for power lines are building structure which characterize strenght parameters. Strenght parameters by standard BS 1990; ANSI/ASTM D 1036 - 58 are: bending limit σ_l=53.8N/mm^2; modulus of elasticity E=10480 N/mm^2 [17].

  Wood poles strenght parametrs mainly dependent of wood density. When wood pole's structural stability is being impacted by heartrot caused by *Phellinus pini* when Overall Mean AST/RST <1, theexpluatation risky will be actual because of low parametrs toward bending limit and modulus of elasticity.

- There are advisable to evaluate the pine trees external quality before harvesting of wood poles for power lines inVidzeme region of Latvia in felling areas in *Vacciniosa* and *Myrtillosa* forest types where the age of pine stands is more than 100 years old (Fig.7). In cases when the *Phellinus pini* are being indicated, wood pole's should be harvested using motor saws.
- To eliminate expluatation risky of wood poles for power lines, new information related to infected by *Phellinus pini* felling areas is required for harvesting planning.

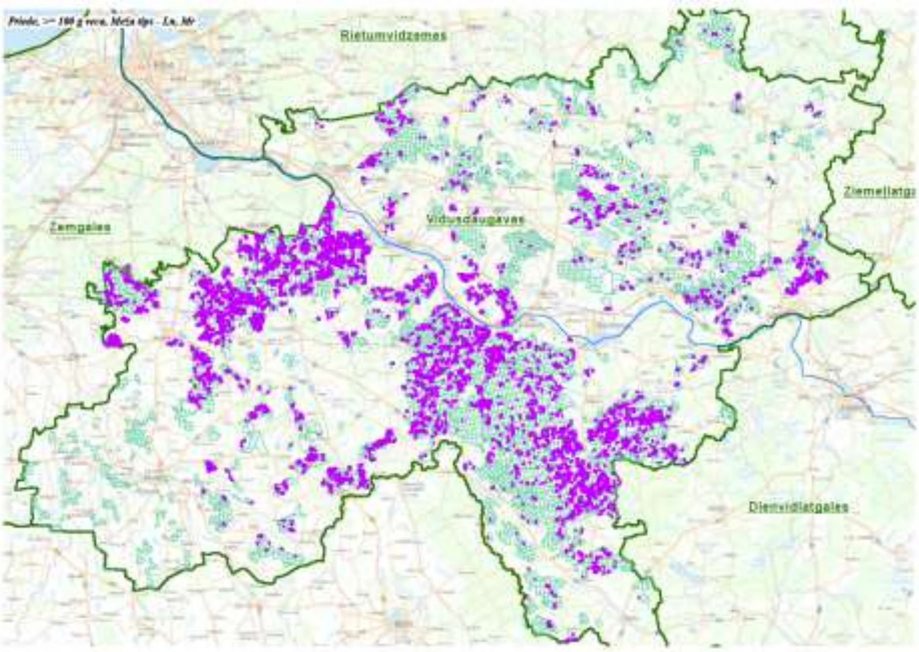

Fig. 7. The felling areas in *Vacciniosa* and Myrtillosa forest types in Vidzeme region of Latvia where the age of pine trees is more than 100 years old

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DEVELOPING INFORMATION SHARING SYSTEM FOR JAPANESE FORESTRY

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Key words: information sharing system, StanForD

Abstract: This study aimed to develop an information sharing system for Japanese forestry on developing a new harvester head with the aid of ICT and robot technology. To that end, we did hearing investigation about the current procurement and necessary information of raw woods for sawmills in domestic and foreign forestry areas. It is clear that 1) StanForD (Standard for Forest machine Data and Communication) would be also a useful tool for Japanese forestry, 2) information of the location and time of all logs for both processing and transporting would be necessary, 3) not only information of length and top end diameter but also butt end diameter, young's modulus and wood density would be necessary. Consequently, we made a prototype of information sharing system implemented in relation to StanForD for Japanese forestry.

CHOOSING THE MOST SUITABLE SPECIES FOR PLANTATION USING MULTI-CRITERIA DECISION ANALYSIS

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Abstract

Selection of a species for forest plantation is one of the strategic decisions for sustainable forest resource management. In this regard, a Fuzzy Analytic Hierarchy Process (FAHP) is developed. Breaking down the decision problem leads to a hierarchy with four levels. The first level is devoted to the goal for the hierarchy. At the second level, we have inserted six criterions. At the third level, the subscales (indices) are inserted. Finally, three different species as alternatives are inserted at the last level. Results showed that among the criteria, the protective- environmental function obtained a higher score value. The diagonal class transmittance of each species get a higher score value among subscales at the third level. The final ranking of alternative proved that oak was the most suitable species for plantation activities at the study area. Results of this paper are useful for decision-making process and many valuable purposes such as rehabilitee of forests and planning.

Keywords: Forest plantation, Fuzzy AHP, Multi-criteria decision analysis, Iranian Caspian forests

Introduction

Forest is one of the natural resources that are important forthe human life. Trees provide many benefits, especially, for producing oxygen and absorbing carbon, thus, making human beings to breathe well and remaincomfortable in the living environment. Besides that, if a forest is managed properly, it provides economic opportunities like creating job from a socio-economic perspective and maintains environmental advantages. In other words, demolishing of the forests can lead tounavailability of oxygen and the increaseof carbonconcentration in the atmosphere. Hence, it causes global warming, which in turn is definitely an uncomfortable environment evenhuman life can be destroyed. On the other hand, forest manager encounters many challenges such as alters forest land to the other land use, like housing, infrastructure, and agriculturalpurposes (Herawati 2001; Kandari et al. 2015). Furthermore, according to Diniyati et al. (2006) theconversion of forest land to the other land use may decrease theecological benefits of forests e.g., erosion control, reduce surface runoff and soil fertile. Thus theneed of continuous maintain of existing forests using increased plantation efforts should be sustainablyconducted in order to achieve socio-economic andenvironmental benefits (Kandari et al. 2015).

Indicesof sustainable forest management can be addressed as astandard criteria for assessing quality of a forest in which they represent the changes due to different management activities. Sustainable forest management is a criterion for measuring quantitative and qualitative changes of forest, which have been adopted in last two decades. It is an agenda for defining, assessing and evaluating shift towards sustainable forestry. Seyed et al. (2014) developed Scales and indices of sustainable forest management for seven regions such as European countries, Montreal Process, dry areas of Africa, Tropical forest, Tarapoto process and Middle East countries. Iran is one of the innovative countries in Middle East regards proposing criteria and indices of sustainable forest management.To achieve sustainability in managing of forest resources, forests lands must be managed in a way that ecologically maintain survival and sustain for a long period of time. Also, it should meet social andeconomic needs of current and future generations (Seyed et al 2014; Hassanzad Navroodi 2015). Sustainable forest criteria include, but are not limited to: 1) vast forest resources, 2) biodiversity, 3) survival and well-being of forest, 4) producing function of forest resources, 5) protective function of forest resources, 6) socio-economic function, and 7) legal, political, and institutional frameworks.

General framework of forestry has been changed since last 20 years. Forests must providean acceptable profit while considering protection and recreational concerns. Therefore, using a Multiple Criteria Decision Analysis (MCDA) in plantation activity is necessary (Kangas 2005). The MCDA refers to making decisions in the presence of multiple, usually conflicting, criteria. The field of decision support for multiple criteria problems has been advanced significantly in the last 20 years (Shih et al. 2007). These techniques are used in a wide variety of application domains.

The reliability of the AHP as a powerful management paradigm has been acknowledged by many researchers in various fields, including natural resource management. This method, has come increasingly under intense inspectiondue to various reasons, when applied to practical cases because (1) using this approach, the decision-maker sometimes is limited to using an ordinal or ratio scale (e.g., a set of crisps fixed score between 1 and 9: Saaty's scale) to express his/her preferences for pairwise comparisons of criteria/sub-criteria/factors/alternatives. To cope with these shortcomings, a few researchers have suggested that decision makers may be more confident in providing an interval preference (i.e., a range of linguistic number) instead of a fixed value (i.e., a single linguistic number) by incorporating "fuzzy linguistic scores" into the traditional AHP.Fuzzy theory allows decision makers to use qualitative and uncertain data in evaluating different scenarios.

Jasbeck et al. (2007) used statistical analysis and hierarchical method to evaluate quantitative and qualitative characteristics of *Fagus Sylvatica in order*to identify the best possible location in six reigns, and found that Ukrainian province havemore consistency compared to Croatian pronounces.

Zare et al. (2012) evaluatedthe potential of habitat to identify proper species of forestation in the south ranges of Alborz mountains in Iran using Geographical Information System (GIS) and showed that due to consistency of native and non-native of species with area and their ecological needs, species for forestation of 26 ecosystems were introduced which ecological needs of suggested species and were aligned with ecologic condition of expandable units. Mohammadian et al. (2009) used the Analytical Network Process (ANP) onthebasis of analysis of benefits, Opportunities, Costs, and Risks (BOCR)model to selectthe most suitable regions for forest plantation activities in the Markazi province.Their results indicated thatrisk and cost priorities are more important in final ranking compared to the benefits and opportunities.Kandari et al. (2015)used multicriteria approaches to land suitability evaluation for the plantation of forestand the development of forest land uses for future period.

The literature available showed that only limited studies have addressedmulti-criteria evaluation of management methods in forest plantation and the selection of suitable species for this purpose especially in our country. To address this scientific gap, this case study was designed to determine the best suitable species for forest plantation according to multiple criteria decision analysis as we fully described in this article.

Material and methods

Study area

This research was carried out in a temperate mixed deciduous forest Iranian Caspian forest which is located in north of Iran. The study site is situated in Darabcola watershed at the southwest of Sari province (between 53° 09' 54"E and 53° 21' 40" E longitude and 36° 27' 55" and 36° 39'08" N latitude) that covers an area of approximately 4,741 ha. The average altitude is 450 m, which represents typical lowland forest types of temperate deciduous forests (Fig 1). The forest vegetation is mainly manmade planted forest with a mixture of*Acer Velutinum, Fraxinus Excelsior, Acer Cappadocicum, Alnus Subcordataa, Pinus Brutia, Quercus Castaneifolia, and Juglans Regia*. (Anonymous, 2008)

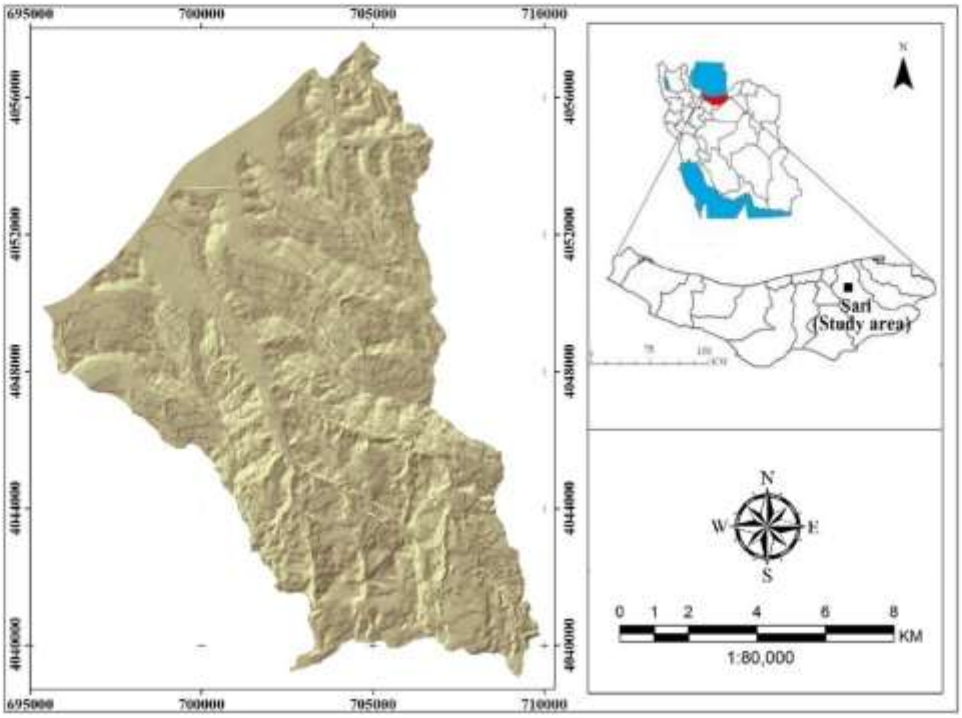

Fig.1 Location of the study area (Refrence: Authors)

Methodology

Following steps are designed to achieve the purpose of this research:

Step 1: Identification of the alternatives species. Hence,those species which has been adapted to the area since many years ago were chosen such as: Maple (*Acer Velutinum*), ash (*Fraxinus Excelsior*), Coliseum maple (*Acer Cappadocicum*), walnut (*Juglans Regia*), oak (*Quercus Castaneifolia*), alder (*Alnus Subcordata*) and pine (*Pinus Brutia*).

Step 2: Selection of indices and criteria. In this step we have triedto focus on those of criteria and indices that have already been suggested in literature (e.g., see, Fao 2010, Seyed et al. 2014, Goleij et al. 2016). The criteria forsustainable management scales of theMiddle East region. Are 1) extent of forest resources, 2) biodiversity conservation function, 3) productive function, 4) protective-environmental function, 5) socio-economic function, 6) forest health and vitality. (Table 1)

Table1 Criteria and indices

Criterion of sustainable development	Index
Extent of forest resources	Evaluation of ecologic benefits for each species after developing ecological plan
Conserving biodiversity	Diagonal class transmittance of each species
Productive function	Mean annual germination– biomass body– basal area
Protective-environmental function	Carbon sequestration – role of forest in protection of soil, erosion control, increaseing soil fertility
Socio-economic function	Economic value of wood products– recreational services– jobs creating
Forest health and vitality	Height extension coefficient

Step 3: Designing of a questionnaire

After identifying relevant criteria and indices, a specific questionnaire was designed. Criteria and factors were compared in each level of the hierarchy with respect to the parent node using pairwise comparisons. An example of pairwise comparison using fuzzy scales is illustrated in Eq. (1): (Buyukozkan et al, 2012)

$$\widetilde{A} = \begin{bmatrix} (1,1,1) & (l_{12}, m_{12}, u_{12}) & \dots & (l_{12}, m_{12}, u_{12}) \\ (l_{21}, m_{21}, u_{21}) & (1,1,1) & \dots & (l_{2n}, m_{2n}, u_{2n}) \\ (l_{n1}, m_{n1}, u_{n1}) & (l_{n2}, m_{n2}, u_{n2}) & \dots & (1,1,1) \end{bmatrix} \quad (1)$$

Step 4: Quantitative measurement using FAHP: The decision hierarchy is developed using different levels containing goal, criteria, sub-criteria and alternatives. The goal for this hierarchy is to evaluate different sites for forest plantations with respect to sustainable development criteria, at the second level, five criteria are located. These are including expansion of forest resources, conserving biodiversity, productive function, protective-environmental function, socio-economic function, and forest health and vitality.At the third level, we included or sub-scaledassociated with each criterion. At the fourth level, we positioned the species as alternatives for this hierarchy. After, developing the decision tree, the priority score value of each criterion wascalculated. Fifteenquestionnaires out of 15 was received back and investigated for this research project. Each questionnaire included 15 pair matrix (contains three comparison of factor's features and one forthe main criteria, the rest of them were belonging tothe alternatives).Then, the global score weights were calculated using MATLAB 2014 usingan arithmetic mean function (Niknejad, 2015). Noteworthy, an arithmetic mean function was used to combine results of the questionnaires (Table 1 and Fig. 2).

Table 2 Verbal fuzzy linguistic scales

Fuzzy numbers		Fuzzy linguistic scale
(1, 1, 1)		Just equal
$(\frac{3}{2}\ 1, , \frac{1}{2})$	1	Equally Important (EI)
$(1, \frac{3}{2}, 2)$	3	Weakly more Important (WMI)
$(\frac{3}{2}, 2, \frac{5}{2})$	5	Strongly more Important (SMI)
$(2, \frac{5}{2}, 3)$	7	Very strongly more Important (VSMI)
$(\frac{5}{2}, 3, \frac{7}{2})$	9	Absolutely more Important

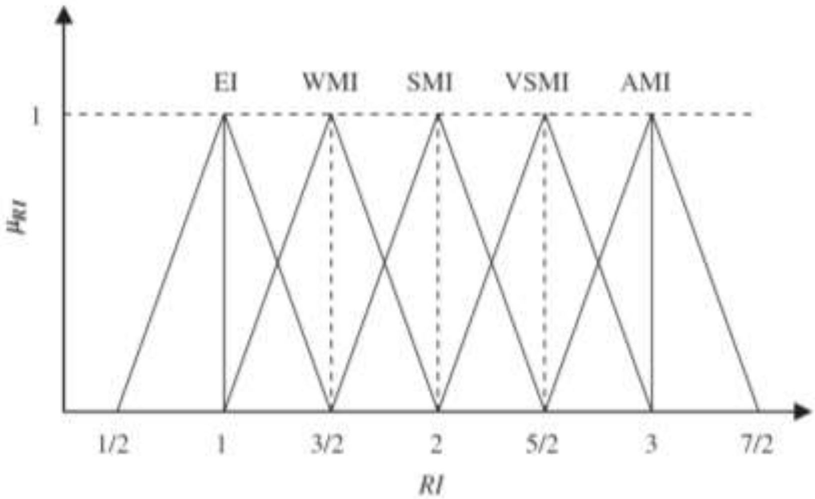

Fig.2 Scales of language to express the grade of importance

Step 5: Consistency of judgments

Inconsistency coefficient is a mechanism which measures validity of responses in comparison matrix in the MCDAapproach. This mechanism shows the rational validity of responds to the comparison of criteria/sub-criteria with respect to alternatives. According to Saaty's (1980) suggestion, this value must be equal or less than 0.1.

Step 6: Sensitivity analysis

Sensitivity analysis is a technique used to determine how different criteria impact different alternatives (e.g., final ranking) under a given set of assumptions

(Saaty & Vargas 2006). If a change has no impact on outputs, ratings are authentically performed on options (Ghodsipour and Abrian 2001).

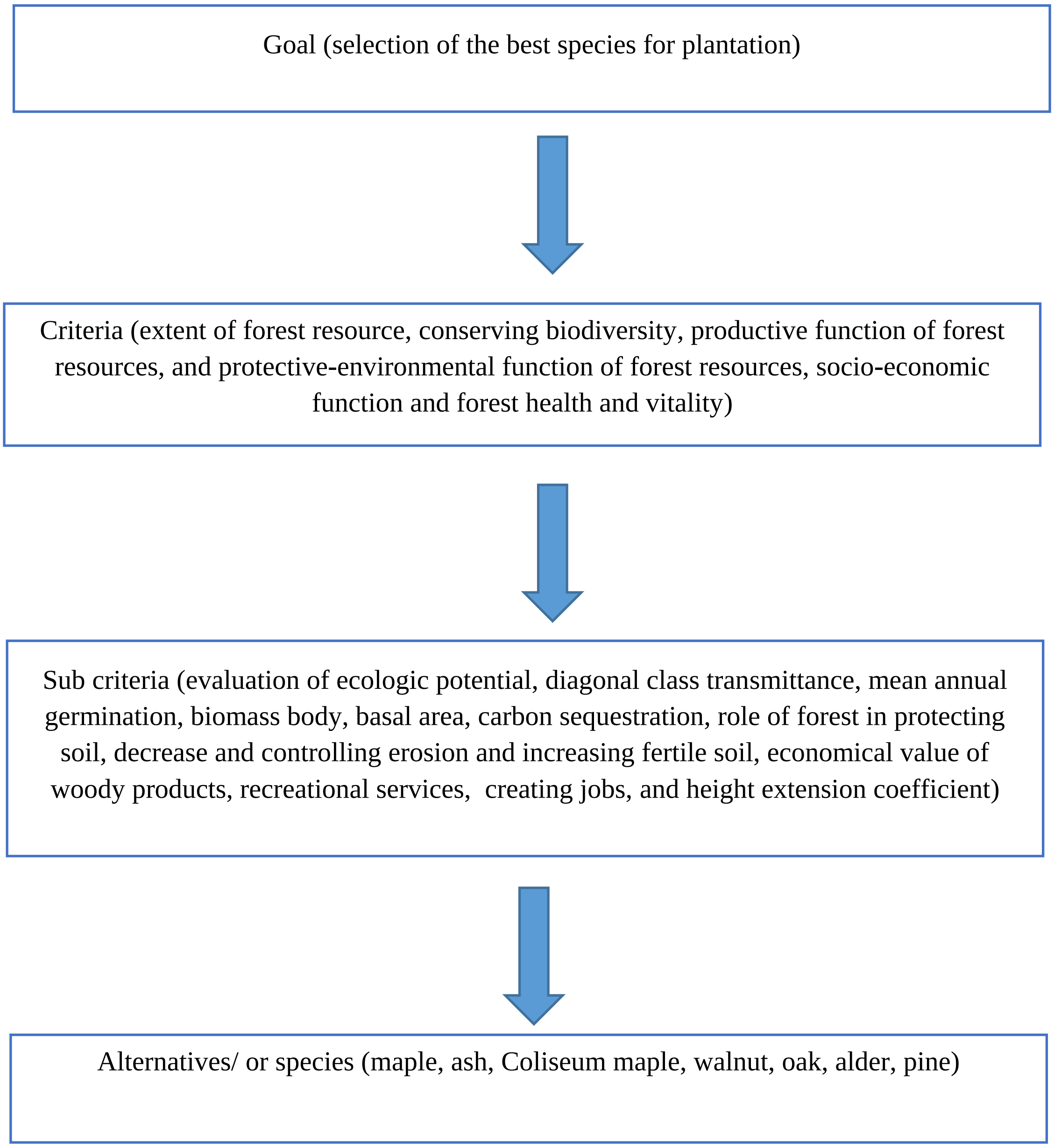

Fig. 3 A schematic diagram of the FAHP process

Results

Relative score values of all criteria were calculated, with respect to identify relative contribution of each criteria in finding most suitable species for the forest plantation (Table 4). Results of the expert judgment showed that protective-environmental function had most score value (0.2538) and extent of forest resources had a lowest relative score (0.0771). Other criteria weights are falling between these two extremities (Table 4).

Table 4 Relative score value of considered criteria

Criterion	Relative score value
Extent of forest resources	0.0771
Conserving biodiversity function	0.203
Productive function	0.1255
Protective-environmental function	0.2538
Socio-economic function	0.1708
Forest health and vitality	0.1697

At the next step, the weight of subscales underwent expert judgment are calculated (Table 5). The results showedthat distribution of diameter classes for each forestation had most score or importance (0.203) and basal area had a less (0.0125) score or importance.

Table 5 Relative score value of the considered sub criteria

Sub criteria	Relative score value
Evaluation of the ecologic potential	0.0771
Diagonal class transmittance of each species	0.2030
Mean annual germination	0.0502
Biomass body	0.0627
Basal area	0.0125
Carbon sequestration	0.0888
Role of forest in protecting soil, decrease and controlling erosion , and increasing fertile soil	0.1650
Economical value of wood products	0.0174
Recreational services	0.0611
Producing jobs in rural and forest sections	0.0922
Height extension coefficient	0.1697

The synthesis of full network with respect to consider all values belonging to all criteria/sub criteria and alternatives are given in (Table 6). Results showed that oak species (relative weight = 0.2311) was ranked as most suitable species for forest plantation. Other species like maple, alder, and pine were the best option with relative weight of 0.191, 0.1837, and 0.0434, as latter priority for plantation.

Table 6 Global score values for the whole decision hierarchy

Species	Global score value
Walnut	0.121
Maple	0.191
Coliseum maple	0.1022
Oak	0.2311
Pine	0.0434
Ash	0.1275
Alder	0.1837

Sensitivity analysis

A series of sensitivity analysis was conducted in order to find the effect of changing weights and final rankings of the weight vector. The results are given in Fig. 7. For example, it was shown that, while 25% of the changing extent of forest resources which includes about 7.7%of total weight of other criteriaand consequently final weight of this option. Such a change can for example lead to decrease the weight of protective function and biodiversity function from 20.3% to 16.5% of the total weight. Accordingly, 12.1% of the total weight for walnut option leads to increase the weight to 12.7%of the total weight. However, this sensitivity analysis did not effect on priority.

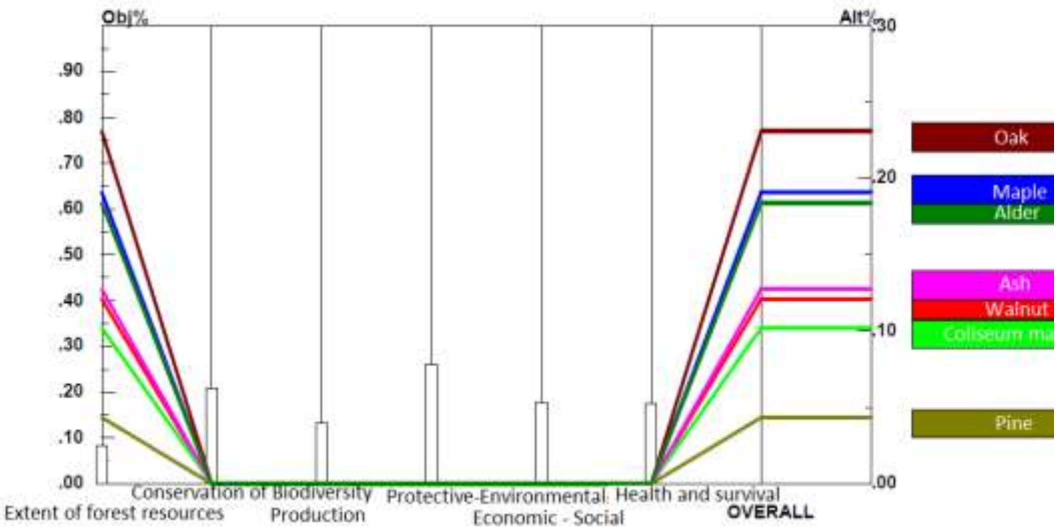

Fig.4 An example of sensitivity analysis conducted in this study

Discussion

Natural resources managers, conservation organizations and governments need to prioritize suitable species in order to manage and achieve the best socio-economic and ecological benefits. Here, we have presented a prioritization system on species selection and species are thus ranked according to the scientific decision makers. Using scientific information of species, this prioritization system can ensure the highest priority species for management.

Within the context of existing best management practices (BMPs), sustainable forest plantation needs to address the best way to select the suitable species, estimate the value, and subsequent utilization for a particular species group (Franzel et al. 2008). This is a complex and challenging decision, especially in mixed hardwood forests, because each species group has its own ecological demand (Franzel et al. 2008) and a particular use for a wood specific industryMultifaceted decision problems mostlyencompass a number of decision-makers (interest groups) either as a single person or a group of people, such as the government or corporate organizations (Malczewski 1999).

Since the selection of suitable species for plantations affects a wide range of environments, a multi-criteria approach is required to address such a problem, and it need to be convenient to use, especially in a situation where different species group need to be prioritized. Inthecurrent study, we usedthe Fuzzy multi-criteria technique approach (FAHP) for evaluating different criteria and ranking different species alternatives with respect to site-specific environmental factors. . According to the results of this research, we can conclude that the FAHP is a useful to evaluate and select suitable species for forest plantations. In fact, this method is simple and flexible. Hence, it is expected that the proposed method in this study may have more potential management applications in future research. Results obtained in this research are useful for decision-makers to select the suitable species for the plantation activities. The method also suggest a scientific way to conquer uncertainty and vagueness in the decision-making process, where a large amount of information is in the form of qualitative, and there is no scientifically accepted approach to quantification except for expert judgments (Ertugrul and Karakasoglu 2006; Ezzati et al. 2016). In the case of the large number of decision makers being involved, theproposed approach can obtain the rankingfaster. Results are supported by thestudies conductedby Shih et al.(2007), Wang and Chang (2007), Reubens et al. (2011), Basir (2014) and Ariapour et al. (2014) who emphasizes on the significant Fuzzy-MCDM as the well-known multiplecriteria decision making method.

One of the management paradigms for enrichment of forests is theexpansion of the forest lands using either native or introduced species, which compatible with the reign for many years. To this reason, there is a need to concurrently consider a large amount of information with different aspects such as ecological demand of species, weather condition etc. to do so, we developed a fuzzy-based multi-criteria decision analysis to evaluate different species and propose a best possible species for future forest plantation in the north east of Iran. Our results have showedthat oak, maple, and alder were the top three priorities for forest plantation in this region. Being native species and adaptation with the site conditions for a long time can describe superiority of these species, which the results are in support of the previous researches (Najafifar 2007). Also, results showed that according to the expert's judgment, Brusika specie had a least priority weight andare recognized as the worst species for forestation of this region.This could be associated with not much interest to the use of exotic species in the forest plantation. As studies shownby Riazi & Shakoori (2007), percentages of native softwood species are less than broad-leaved species. Aminpoor (2010) evaluated expansion of forestation and green spaces in dry and half dry lands and found that native species had more chance of the habituation in forest lands.

These results are in support of the findings of Ananda (2007), Jazback (2001), Najafifar (2007), Kandari et al. (2015) who havenoted choosing native species have preferred for forestation according to the ecological potential of forestation units in the relative regions.

Conclusion

This research project confirmed that FAHP is a powerful management paradigm to help decision-maker, especially in which a large amount of information is in qualitative form and no-quantitative scales for measurement except for the expert judgments. Fuzzy AHP method assists with the decision making process by providing decision makers with a structure to organize and evaluate the importance of various criteria and the preferences of alternatives solutions to a decision. In comparison with fuzzy-AHP, the traditional AHP method cannot really reflect the human preferences and is problematic in some situations, because the users have to use an exact value to express his/or here preferences. In the fuzzy-AHP procedure, the pairwise comparisons in the judgment matrix are taking fuzzy numbers, which much more adapts with the designer's emphasis.

To this end, according to the opinions of the expertsandprofessors of Faculty of Natural Resources, Sari University in questionnaire form and by using fuzzy AHP method, our results are realistic and consistent with the condition of forest in this region, which the best plant types is oak. However, maple, alder and ash are also in the next order.

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THE INDUCTION FROM MANMADE JAPANESE LARCH FOREST TO NATURAL REGENERATION LARCH FOREST -COMPARISON OF THE COST WITH PLANTING-

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Key words: Japanese larch, Natural regeneration, cost, strip clearcutting, seedling growth

Abstract: Japanese larch (Larix kaempferi) is an important plantation species adapted to cold climates and high altitude in Japan. Especially in Nagano prefecture, natural larch forest are distributed much, so Nagano prefecture is known as the birthplace of Japanese manmade larch forest in Japan. The manmade larch forest account for about 50% in all of manmade forest in Nagano prefecture. Currently, over 50 years old larch forest exceed 82% of it. The use of larch logs are promoted, but the cost of reforestation becomes the problem in Japan, because it is about 10 times costs of other developed countries. Natural regeneration is mentioned as one of cost reduction methods of reforestation. Frequently, larch of natural regeneration observed in closed skiing area, slid land, slope of forest road and etc., so larch has high potential for natural regeneration. According to the past knowledge, larch has following ecological features: 1) it can get into the bare ground easily, 2) they are light demander and weak about suppression, 3) the harvest cycle of seed is long. But management technic of natural regeneration is not established artificially and surely, and the cost of regeneration is not considered. In this study, we did strip clearcutting in manmade larch forest and induce that to be natural larch forest. And we compared its cost with the regeneration by planting, and investigated the relations of seedlings growth and width of cutting.

In the spring of 2014, we confirmed female flowers of larch in Minamimaki village, so we did strip clearcutting by 10 m, 20 m and 40 m width, and did ground treatment by bucket excavator until September, before larch seeds dropped. In next year, 2015, number of larch seedling was confirmed. Thereafter, we investigated the seedling number and size continuously. Moreover, we separated strip clearcutting area and planted large planting stocks and containerized planting stocks of larch to compare cost of natural regeneration and plantings. As a result, there were many larch seedlings and the survival rate was higher when the cutting width was narrow. In addition, the relative photon flux density decreased as the cutting width narrowed, and the average tree height decreased as well. The lower vegetation of the logging zone was mainly bamboo grass (Sasa senanensis), but the reproduction of it was suppressed in the natural regeneration area where the surface treatment was done. In the planting area, because the height of the large planting stocks exceeded the height of the bamboo grass, we did not weeding, but the height of the tree of the containerized planting stocks was smaller than the height of the bamboo, so we had to do weeding. Therefore, the reforestation cost when 3 years have elapsed since the natural regeneration is, natural regeneration: expenses of surface treatment, large planting stocks: planting stocks and planting expenses, containerized planting stocks: planting stocks and planting expenses and weeding.

DENDROMASS4EUROPE (D4E) - SHORT ROTATION PLANTATIONS FOR THE BIOECONOMY

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Key words: biomass, agroforestry, poplar, coppice

Abstract: D4EUis a large project launched within the scope of the Bio-Based Industry Joint Undertaking (BBI-JU), a public-private partnership supported by the European Union with a total budget of 3.7 billion €, as part of the H2020 initiative. BBI sponsors pre-industrial projects that will open the way to a thriving bioeconomy, and it is one of the main mechanisms supporting applied research in Europe. \n\nD4EU aims at establishing sustainable, Short-Rotation Coppice (SRC)-based regional cropping systems for agricultural dendromass on marginal land that feed into bio-based value chains and create additional job opportunities in rural areas. For that purpose, 2,500 ha of short rotation poplar plantations will be established on marginal or currently unused land in rural areas of the Slovak Republic. These plantations will provide the feedstock for the establishment of four new bio-based value chains based upon products from wood and bark from poplar trees: (1) functionally adapted lightweight board manufactured by IKEA Industries (Slovakia). The new structure gives more stability to the boards, which will be lighter and consuming fewer resources. Poplar bark, which currently serves primarily as a source for energy, is processed by Pulpack (Poland) into (2) eco-fungicidal moulded fibre parts. These fibre parts can replace plastics in packaging and can also be re-used without any problems. At the same time, Energochemica Trading (Slovakia) plans to incorporate the bark into (3) bark-enriched wood-plastic composite and (4) wood-plastic granulate. \n\nThe researchers of the National Council for Research (Italy), Ökoforestino Ltd. (Hungary), the Swedish University of Agricultural Sciences (Sweden) and Technische Universitaet Dresden support the industrial partners involved, with their expertise in the fields of agriculture, forestry and wood sciences. The Kompetenzzentrum Holz GmbH (Austria) and Daphne, Institute for Applied Ecology (Slovakia) are providing expertise on ecological questions of management. Stakeholders, especially the respective scientific and industrial communities, e.g. those of forest sciences, agricultural and forest policy, nature conservation and bio-based materials research will be informed and involved during the entire project for example via field demonstrations, publications and a project website as well as social media. The project started in June 2017 and has a duration of 5 years. Total budget is 20.5 Million €, half of which is contribution from the industrial partners. The project is coordinated by the

Technical University of Dresden (Germany) and gathers 9 partners from 5 European Countries.

TECH4EFFECT (T4E) - PROFITABLE AND SUSTAINABLE EUROPEAN FOREST MANAGEMENT

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Key words: mechanization, benchmarking, fuel saving, productivity, yarding

Abstract:T4E is a new R&D project launched within the scope of the Bio-Based Industry Joint Undertaking (BBI-JU), a public-private partnership supported by the European Union with a total budget of 3.7 billion €, as part of the H2020 initiative. BBI sponsors pre-industrial projects that will open the way to a thriving bioeconomy, and it is one of the main mechanisms supporting applied research in Europe. \n\nT4E aims at increasing the amount of biomass produced in Europe, in order to support meeting the EU climate change targets and reduce Europe's dependency on fossil based products. The next breakthrough in efficiency gains in European forest management will come through knowledge-based management for better informed planning and decision making. Timber harvesting is the most cost intensive and fuel consuming part of forest management and results in the most severe impacts on forest ecosystem services. Relatively small improvements in forest harvesting can lead to potentially large gains in cost, work and fuel efficiency. \n\nTECH4EFFECT focuses on increasing access to wood resources through more efficient silviculture and a better understanding of the business models in the procurement of forest operation services. The project further considers increasing efficiency in forest harvesting and collection, and the reduction of soil impact from forest operations, making environmental considerations a measurable and integrated part of operational efficiency. TECH4EFFECT offers the potential to revolutionize forest operations with a state-of-the-art knowledge-based benchmarking tool. Based on the large amount of data available in modern industrial forest management this benchmarking tool will provide easily accessible decision support.\n\nCoordinated by NIBIO, nine research institutes and universities, three industrial partners and seven SMEs are participating in TECH4EFFECT. The consortium shows strong industrial participation and includes leading machine manufacturers and logistics experts, as well as large forest owners and associations of small owners and contractors. Academic institutions from all over Europe represent the main forest regions.\n\nThe project started in October 2016 and has a duration of 4 years. Total budget is 5 Million €. The project is coordinated by the Natural Resources Institute of Norway (NiBio) and gathers 19 partners from 8 European Countries.

THE DYNAMICS OF CHANGES IN THE RANGE OF PERIPHERAL BLUE STAIN IN SCOTS PINE WOOD (PINUS SYLVESTRIS L.) OBTAINED WITH THE USE OF THE HARVESTER

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Key words: wood harvesting, harvester, blue stain, pine wood

Abstract: The aim of the study was to determine the dynamics of development of peripheral blue stain in Scots pine wood (Pinus sylvestris L.) damaged by the operation of the harvester head. Changes taking place in timber obtained with the use of the chainsaw were adopted as a reference level. The development of blue stain was related to the date of felling, the microclimatic conditions of the wood storage place and the age class of the stand. The average surface area of blue stain in the wood obtained with the use of the harvester amounted to almost 35 cm2 and was approximately 30% higher than the wood obtained by using the chain saw. In stands of the 4th age class, where the average thickness of the breast-height diameter is about 8 cm (about 30%) larger as compared to stands of the 3rd age class, the surface of blue stain was more than twice larger. The average area of blue stain in the wood stored after spring felling (19.3 cm2) was about 50% lower than after summer felling (38.2 cm2). Particularly dynamic development of blue stain in wood obtained with the use of the harvester was visible between the 6th and 9th week after spring felling and between the 3rd and 6th week after summer felling. The range of blue stain for both felling dates was dependent on air temperature around the wood stack and the number of days of wood storage.

THE MECHANISMS FOR FOREST SOIL PREPARATION TO PREVENTWILDFIRES.

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Key words: forest soil preparation to preventwildfires

Abstract: The mechanisms of forest soil preparation can be used for forest renewal purposes as well as for the prevention wildfires.\nPloughs and mills are the most appropriate mechanisms for the forest soil preparation in order to prevent wildfires. Distinguishing between forest ploughs and mills is hardly impossible, when looking exclusively at the names manufacturers have given to these tools. Therefore, two differing mechanisms are continuously confused. This leads to the actual usage these mechanisms being different from the theoretically intended.\nThe conducted research summarizes the theoretical operational principles of forest ploughs and mills. This enables the possibility to clarify the application of forest ploughs and mills beyond the forest renewal.\nOne of the underlying possibilities for forest mill application is the creation of mineralized lines in various soil types. This serves as prevention for wildfires. An application possibility for forest ploughs is the immediate limitation in case of a wildfire.

REGIONAL NETWORK DEVELOPMENT FOR SUSTAINABLE WOOD MOBILIZATION

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Key words: Wood mobilisation, EU regions, best practices

Abstract: ROSEWOOD, an EU-funded coordination and support action, is designed to develop regional networks that will connect actors of the wood mobilization value-chain from forest owners to relevant regional authorities but also forestry industry to cover and find answers to the main challenges in the field, especially the sustainability of the wood mobilization. Through the sharing of technological and non-technological innovations, best practice cases and RDI results, this multi-actor approach will close knowledge gaps and create new opportunities for economic partnerships between stakeholders and (inter)regional authorities. The aim is transferring know-how and information to enable and support foresters and regional authorities to exploit innovations and best-practices and facilitate the capture of grass root ideas for forestry development. Providing practitioners with development skills (educational and entrepreneurial) will facilitate organizational innovations leading to novel exploitation chains through customized coaching methodologies facilitating the uptake of new ideas and best practices. Further possible synergies between R&I investment and European Structural and Investment Funds to support the uptake of innovations within the value chain will be assessed. All these actions will contribute to an economically viable and sustainable development in forestry and thereby in rural areas towards the enhancement of an EU Bioeconomy. Coordination and support actions will be implemented via Wood Mobilization Regional Hubs located within 4 communities across Europe providing greater opportunities for forestry to align its activities with local and regional development plans. First results from project phase I, the screening of innovative mobilization solutions, will be presented in a poster.