FORMEC Florence, Italy 2023

55th International Symposium on Forestry Mechanization

7th Forest Engineering Conference

FEC 2023 Forest Engineering Conference Italy

Firenze, 20th-22nd September 2023

UNIVERSITÀ DEGLI STUDI FIRENZE
DAGRI DEPARTMENT OF AGRICULTURE, FOOD ENVIRONMENT AND FORESTRY

REGIONE TOSCANA

ACCADEMIA ITALIANA DI SCIENZE FORESTALI

Consiglio Nazionale delle Ricerche
Istituto per la BioEconomia

55th International Symposium on Forestry Mechanization (FORMEC)
7th Forest Engineering Conference (FEC)

Improving access to sustainable forest materials in a resource-constrained world

BOOK OF ABSTRACTS

FORMEC Florence, Italy 2023

FEC 2023 Forest Engineering Conference Italy

SISEF

Unione Nazionale per l'Innovazione Scientifica Forestale Associazione onlus

IUFRO

AUSF FIRENZE

AUSTRO AFOMA

BOKU

PREFACE

The 55th International Symposium on Forest Mechanization (FORMEC) and the 7th Forest Engineering Conference (FEC) was hosted in Florence, Italy, from September 20th to 22nd, by the University of Firenze and the National Council for Research (CNR), in collaboration with The Tuscany Regional Administration and the Italian Academy of Forest Science.

The topic of the meeting has been improving access to sustainable forest materials in a resource-constrained world. The meeting represented a great opportunity for getting updated about the latest developments in forest engineering, for meeting colleagues and for developing one's network. All stakeholders in the field of forest engineering were invited to join and share their experiences in a pleasant setting and a friendly environment.

Scientists, consultants, industry experts, practitioners, government officials and students have attended and contributed to the conference, sharing their knowledge and experience.

According to their consensus, presented abstracts have been collected in the following book of abstarcts.

ORGANIZERS

UNIVERSITY OF FLORENCE - DAGRI

The University of Florence is an italian research and education institution, with over 1,700 professors and researchers, more than 1,600 technical- administrative staff members, and over 55,000 students. The Department of Agricultural, Food, Environmental, and Forestry Sciences (DAGRI) is committed to developing knowledge and skills for sustainable development based on biological natural resources, focusing on the sustainable management of agricultural, animal, and forestry resources through integrated and multidisciplinary approaches. The aim is to preserve and enhance environmental quality and vital components such as soil, microorganisms, plants, animals, and biodiversity.

TUSCANY REGIONAL ADMINISTRATION

The Tuscany Region dedicates a specific branch to forestry, agro-environment, water resources and climate change mitigation, for setting the political and technical principles for the development of these sectors in Tuscany.

The branch promotes sustainable forest management and forest certification (PEFC and FSC member), as well as forest operator training at the Rincine Training Centre. It also promotes forest planning at all levels and the active management of forest stands, both public and private, by means of regulatory and technical actions. The regional agricultural forestry property is made up of more than 110,000 hectares of wooded land distributed over all Tuscany. Since 2019 the Tuscany Region oversees the management of the Mediterranean model forest network (https://www.medmodelforest.net/en/).

It has exclusive competence in forest fire control, with a focus on prediction, prevention, and active firefighting. Its effective response system, backed by a tradition of specialized training for operational staff at the Regional Center "La Pineta", ensures effective and concentrated efforts. This capacity places Tuscany at the forefront among Italian regions.

ITALIAN ACADEMY OF FOREST SCIENCES

The Italian Academy of Forest Sciences (AISF) is a non-profit organization dedicated to promoting and disseminating research, education, and conservation of forest resources in Italy. Established in 1951, the Academy serves as a significant reference point for scientists, researchers, and expertsin the field of forest sciences.

The Academy organizes conferences, seminars, training courses, and produces scientific publications to share the latest discoveries and information in the field of forest sciences.

NATION RESEARCH COUNCIL - IBE

The National Research Council (CNR) is the main scientific research agency of the Italian Government: it manages 88 Institutes and emplyes 8500 researchers, technicians and administrative officers. Founded in 1923, it is an independent public ogranization conducting research in allfields of science. CNR promotes innovation, technological development, and international collaboration.

The Institute for Bioeconomy (IBE) focuses on the development of innoovative strategies for the sustainable management of natural resources, the enhancement of biological products, and the promotion of innovative solutions in the fields of agriculture, energy, and the environment.

PARTNERS

ITALIAN SOCIETY OF SILVICULTURE AND FOREST ECOLOGY

ITALIAN UNION FOR SCIENTIFIC INNOVATION IN FORESTRY

INTERNATIONAL UNION OF FOREST RESEARCH ORGANIZATIONS

ASSOCIAZIONE UNIVERSITARIA STUDENTI FORESTALI - FIRENZE

AUSTRIA'S FOREST MACHINE DEMONSTRATION

UNIVERSITY OF NATURAL RESOURCES AND LIFE SCIENCES, VIENNA

ORGANIZING COMMETTEE

Enrico Marchi	University of Florence, Italy
Raffaele Spinelli	Italian National Research Council - IBE, Italy
Karl Stampfer	BOKU Institute of Forest Engineering, Austria
Natascia Magagnotti	Italian National Research Council - IBE, Italy
Elena Marra	University of Florence, Italy
Benno Eberhard	Italian National Research Council - IBE, Italy
Raffaele Cavalli	University of Padova, Italy
Cristiano Foderi	University of Florence, Italy
Elisabetta Gravano	Tuscany Regional Administration, Italy
Stefano Grigolato	University of Padova, Italy
Christian Kanzian	BOKU Institute of Forest Engineering, Austria
Andrea Laschi	University of Palermo, Italy
Rodolfo Picchio	University of Tuscia, Italy
Sandro Pieroni	Tuscany Regional Administration, Italy
Rosario Andrea Proto	Mediterranean University of Reggio Calabria, Italy
Antonio Ventre	Tuscany Regional Administration, Italy

SCIENTIFIC COMMITTEE

CHAIRS

Enrico Marchi	University of Florence, Italy
Raffaele Spinelli	Italian National Research Council - IBE, Italy
Rien Visser	Canterbury University, New Zealand
Karl Stampfer	BOKU Institute of Forest Engineering, Austria

MEMBERS

Kazuhiro Aruga	Utsunomiya University, Japan
Ebru Bilici	Giresun University, Turkey
Mark Brown	University of the Sunshine Coast, Australia
Woodam Chung	Oregon State University, USA
Jean-Francois Gingras	FP Innovations, Canada
Saulo Guerra	University of San Paolo, Brazil
Eric Labelle	University of Laval, Canada
Luc Lebel	University of Laval, Canada
Natascia Magagnotti	Italian National Research Council - IBE, Italy
Tomas Nordfjell	Swedish University, Sweden
Muedanyi Ramantswana	Nelson Mandela University, South Africa
Dominik Roeser	University of British Columbia
Janine Schweier	Swiss Federal Research Institute, Switzerland
Rolf Bjorheden	Skogforsk, Sweden
Jori Uusitalo	University of Helsinki, Finland
Dirk Jäger	University of Göttingen, Germany
Andreas Holzinger	University of Vienna, Austria
Francesco Neri	University of Florence, Italy
Dalia Abbas	University of Minnesota, USA

TABLE OF CONTENTS

LIST OF ABSTRACTS

ANALYSES ON FOREST ROAD DAMAGES BETWEEN 2001 AND 2019 USING RAINFALL EVALUATION WITH RETURN PERIODS IN GUNMA PREFECTURE, JAPAN

KAZUHIRO ARUGA[1]*; ISSEI WATANABE[1]

[1]Utsunomiya University.

Corresponding author: aruga@cc.utsunomiya-u.ac.jp

ABSTRACT

This study acquired governmental subsidized recovery costs from forest road damages over the past 19 years between 2001 and 2019 in Gunma prefecture. Then, this study analyzed correlation coefficients between return periods on soil water index as well as three-layer tank storages and recovery costs per forest road length. Correlation coefficient between return period of first- or second-layer tank storage and recovery costs per forest road length was positive with the 5% significance whereas that between return period of soil water index or third-layer tank storage and recovery costs per forest road length with the 1% significance. It was implied that large forest road damages could occur due to deep rainwater penetration because correlation coefficients between tank storages and recovery costs per forest road length tended to increase according to the deeper tanks.

Keywords: Soil water index, three-layer tank model, forest road length, construction cost, recovery cost

COMPARING THE DISTURBANCES TO THE FOREST SOIL OF BEECH HIGH FORESTS AFTER GROUND-BASED TIMBER EXTRACTION BY SKIDDING AND FORWARDING

FRANCESCO LATTERINI[1]*; ANDRZEJ M. JAGODZIŃSKI[1]; PAWEŁ HORODECKI[1]; RACHELE VENANZI[2]; DAMIANO TOCCI[2]; RODOLFO PICCHIO[2]

[1]Institute of Dendrology, Polish Academy of Sciences; [2]Tuscia University.

Corresponding author: latterini@man.poznan.pl

ABSTRACT

Beech is one of the most important tree species in Europe and its ecology and silviculture has been widely investigated. On the other hand, studies dealing with sustainable forest operations in beech high forests are still limited and mainly set up in Western Asia. The assessment of the environmental impacts, with a particular reference to soil disturbance, related to ground-based timber extraction in European beech forests is properly the main goal of the project AIMSUSFOR, a Marie Curie fellowship financed by the Horizon 2020 programme and The Polish Ministry of Education and Science. In the framework of the project five studies areas were identified in Italy and Poland in order to compare the soil disturbances to soil physicochemical and biological features related to ground-based timber extraction by skidding and forwarding in shelterwood interventions in beech forests. This presentation deals with the preliminary results from one study area located in Italy (Mount Amiata, Tuscany). The obtained results showed a clear disturbance related to both skidding and forwarding just after the logging activities, while forwarding presented a faster recovery time.

Keywords: soil bulk density, penetration resistance, organic matter, QBS-ar index, sustainable forest operations

CAN MOTION CAPTURE SUIT HELP US UNDERSTAND THE CENTER OF MASS POSITION? A CASE STUDY OF MOTOR-MANUAL WORK WITH A CHAINSAW

MATIJA LANDEKIĆ[1]*; MARIN BAČIĆ[1]; ZDRAVKO PANDUR[1]; MARIJAN ŠUŠNJAR[1]; JOSIPA NAKIĆ[2]; MARIO ŠPORČIĆ[1]

[1]Faculty of Forestry and Wood Technology of the University of Zagreb, Department of Forest Engineering; [2]Faculty of Kinesiology University of Zagreb, Department of Kinesiology of Sport.

Corresponding author: mlandekic@sumfak.hr

ABSTRACT

Despite the development of mechanization and the application of high technologies in logging work systems, motor-manual work with a chainsaw in the countries of southeastern Europe, but also beyond, is still prevalent. Biomechanical workload of forest worker in such operations is categorized as “very heavy”. The Center of Mass assessment has important role in understanding the exposure of forest workers to postural and occupational risks, either as a part of the entire work process or as a part of an individual element of the work technique. Accordingly, the aim of this research is to investigate the Center of Mass position of the chainsaw workers regarding three key work elements at tree felling operations (performing undercut, preforming final cut, and hammering a wedge with an axe) and its association to personal and occupational factors. For the Center of Mass position measurement (n=28 forest sites) the Xsens MVN Link motion capture suit was used as a cutting-edge technology that allows data collecting in real field conditions. For the field data analyses, descriptive and inferential statistical methods were used. Occupational factors (like work method, management model and chest diameter of the tree) and personal factors (like age group, height group and body mass index group) resulted with statistically significant difference regarding measured Center of Mass values. Based on all the above, further kinematic research in forestry must contribute to a stronger inclusion of Industry 5.0 solutions within logging operations, especially motor-manual work, through the application of virtual reality technologies during the training of workers or through using the latest technological solutions in the form of strengthening human labour on the one hand and increasing safety and health protection on the other.

Keywords: forestry, chainsaw worker, Xsens technologies, Center of Mass, Croatia

OPTIMAL WIDTH OF FOREST FIRE VEHICLES FOR ACCESS TO SLOVENIAN FORESTS OUTSIDE FOREST ROADS

JAŠA SARAŽIN[1]*

[1]Slovenian Foresty Institute

Corresponding author: jasa.sarazin@gozdis.si

ABSTRACT

Slovenian forests are classified into four wildfire risk categories. About 13% of all Slovenian forests are classified as high or very high fire endangered. In these forests, the network of fire roads mostly ensures the access of forest fire vehicles to the forests. However, other 87% of Slovenian forests are also affected by forest fires, although with lower frequency and severity. In the less fire-prone forests, where there are no fire roads and in fire-prone forests were fire road network is not sufficient, the firefighting vehicles have to use forest roads, skidding trails and other thoroughfares designed for forestry mechanization. To this end, a comprehensive study of the dimensions of mechanization for forest management on the one hand and protection and rescue on the other was conducted to determine the optimal width of forest fire vehicles for access to Slovenian forests outside forest (or fire) roads.

The vehicles and machines intended for forest management tasks and protection and rescue tasks are very diverse, both in their shape and in the dimensions and quality requirements of the thoroughfares on which they move. The types of mechanization discussed include: agricultural tractors, specialized forestry mechanization, trailers on tractors, trucks, cars, and construction machinery. By reviewing various databases and legal restrictions, interval data on the mass and width of representatives of each category were given. It was estimated that among forest owners, the most numerous mechanization was up to 200 cm wide, while among professional contractors the most numerous mechanization was up to 230 cm wide. It was also found that mechanization and vehicles up to 230 cm wide can perform all forest management tasks (personnel access, wood felling, wood transportation and infrastructure construction) at least to a basic extent. This led to the conclusion that majority of thoroughfares (except forest roads) are adopted to mechanization up to the width of 230 cm.

From this point of view, the optimal width of forest fire vehicles, that would be able to access Slovenian forests outside forest roads (and fire roads) is also up to 230 cm. It was estimated that appropriate vehicles with a width of up to 230 cm can perform all protection and rescue tasks: fighting wildfires with up to 1500 l water tanks, rescuing people in forestry or recreational accidents, removing unexploded ordnance. However larger vehicles with a width of up to 255 cm, with bigger water tanks or special equipment, are required to support smaller vehicles or to act autonomously from the forest roads.

Keywords: forestry mechanization, forest fire vehicles, protection and rescue, thoroughfares, wildfires

A NEW METHOD FOR HARVESTING HURRICANE DAMAGED TIMBER USING A REDESIGNED FELLING HEAD FOR A RUBBER-TIRED FELLER-BUNCHER

JAMES WALKER[1]*; TOM GALLAGHER[1]; TIMOTHY MCDONALD[1]; RICHARD CRISTAN[1]; DANA MITCHELL[2]

[1]Auburn University; [2]Department of Energy.

Corresponding author: 56jameswalker@gmail.com

ABSTRACT

This research project is with the Downed Timber Initiative project which is a bold yet obtainable idea which benefits areas devastated by hurricanes and tornados in environmental, economic, and social aspects. The Downed Timber Initiative proposes a new method for harvesting downed timber by implementing redesigned technology on ground based equipment that is commonly used by logging crews in the Southeastern United States. In this research project, a new kind of felling head will be designed, fabricated, tested, and analyzed. This felling head will attach to a standard rubber-tired feller-buncher and will feature a boom that can extend a felling head grapple saw eighteen feet from the base of the machine. The felling head can then grab, cut, and accumulate downed or standing timber for a grapple skidder to skid to the logging deck. The feller-buncher equipped with the Downed Timber Initiative felling head will have the capability to harvest timber anywhere inside its boom operating zone. The mechanical integrity of individual components, hydraulic system requirements, and dynamic (tipping) simulations of the machine system have been tested in engineering software, and the results of each show the machine is suitable for in-woods use. A prototype will be manufactured to confirm the tests. This prototype consists of a Barko 80 XLE boom mounted on a modified John Deere FD45 felling head that will be attached to a John Deere 843L feller-buncher. On the end of the boom will be a Waratah FL85 dangle head saw. It is expected that this machine will vastly improve the efficiency of a downed timber harvesting operation for a standard southeastern logging crew.

Keywords: Keywords: hurricanes, tornados, downed timber harvesting, rubber-tired feller-buncher, felling head

EVALUATION OF ASPEN (POPULUS TREMULA) TIMBER STRENGHT PARAMETERS OF ROUNDWOOD ASSORTMENTS INFECTED BY FUNGI (PHELLINUS TREMULAE)

ZIEDONIS MIKLAŠĒVIČS[1]*; NATALIJA BURNEVIČA[2]; JĀNIS IEJAVS[3]

[1]State Stock Company "Latvijas Valsts Meži" (Latvia's State Forests); [2]Latvia State Forest Research Institute "Silava".; [3]Forest and wood products research and Development Institute "Meka".

Corresponding author: z.miklasevics@lvm.lv

ABSTRACT

The external characteristics of aspen (Populus tremula) tree give the only clue to the quality of logs, packing case timber, pulpwood and other roundwood assortments obtained in harvesting. When the tree is bucked into roundwood assortments, the cross sections at the butt and top ends of these assortments may provide additional indicators of the quality such as heart colouring, wetwood, heartwood hard rot and heartwood soft wood. Thus, it becomes important when correlating the occurrence of these imperfections with the quality of sawn timber that is produced from the aspen logs and packing case timber. Although Populus tremula has a wide distribution throughout Europe, there are no unified quality requirements for roundwood assortments due to lack of scientifically approved information related to wood structure. To identify the fungi caused Populus tremula decay and describe the main anatomical changes generated by the fungi (Phellinus tremulae) Polymerase Chain Reaction laboratory technique were used in the investigation. The main goal of the study is to work out the Populus tremula roundwood, harvested in final felling sites timber strength parameters depending on timber quality characterized data based on the testing methods: moisture content - according to ISO13061-1:2014; density - according to ISO13061-2:2014; compression strength paralel to the grain- according to ISO 13061-17:2017; modulus of elasticity- according to ISO 13061- 4:2014; three point bending strength - according to ISO 13061- 3:2014. The results of the study might help for practical applications so that this wood specie can be processed more efficiently for the value - added products and thorough knowledge of decay patterns of Phellinus tremulae are likely to assist to establish more accurate quality requirements for roundwood assortments and provide useful information for optimizing tree management programs.

Keywords: Populus tremula, Phellinus tremulae, timber strenght parameters

SEEING THE TREES DESPITE THE FOREST: LIDAR-BASED VISION SUPPORT SYSTEM FOR HARVESTER OPERATORS

BACK TOMAS ERSSON[1]*; DAN BERGSTRÖM[2]; HÅKAN LIDESKOG[3]

[1]SLU, School of Forest Management; [2]SLU, Department of Forest Biomaterials and Technology; [3]LTU, Department of Engineering Sciences and Mathematics.

Corresponding author: back.tomas.ersson@slu.se

ABSTRACT

Waste is not good. Lean forestry entails reducing waste, and doing cost-efficiently only what is needed to fulfil the forest owner's goals. An example of wasteful forest practices is pre-clearing undergrowth trees before first thinning. Undergrowth has economic, ecological and social values. For example, in Swedish forestry, no study in the last 10-15 years has found motor-manual pre-clearance to be economically justified despite the fact that pre-clearing increases harvester productivity during thinnings. Hence, pre-clearance can arguably be viewed as unsustainable. However, undergrowth trees can hinder the operator's view during thinning. This hindrance can cause stress, and makes harvesting more difficult and time consuming. Nevertheless, new technology can probably support operator vision and eliminate the need for pre-clearance. Thus, there is a need for technical development of vision support solutions for practical implementation during first thinning. In a project during the 2022 Sirius Creative Product Development course at Luleå University of Technology, mechanical engineering students explored all kinds of options for harvester operator's vision support. After systematic analysis, the students decided upon a Lidar-based solution mounted under the windshield of the harvester cab. This Lidar solution is cost-efficient, robust, and can build up a high-resolution, three-dimensional point cloud that operators can use to see what is behind undergrowth in order to avoid obstacles and position the harvester head with precision at the trunk base. At present, technical development continues together with manufacturers. This kind of vision support solution offers a great opportunity for harvesting contractors to raise the profitability of their operations, and for Nordic forestry to become more economically, ecologically and socially sustainable. Vision support solutions are also applicable in other forest operations, e.g. during Continuous Cover Forestry management.

Keywords: Undergrowth; Pre-clearance; Cleaning; Thinning; Wood harvesting; Lean Forestry

EVALUATING THE EFFECTIVENESS AND IMPLEMENTATION BARRIERS OF LOGISTICS SOFTWARE FOR MANAGING FOREST BUSINESSES

CHAD BOLDING[1]; JOSEPH CONRAD[1]; SARAH KINZ[1]; JOSH SEGO[1]*

[1]University of Georgia

Corresponding author: bolding@uga.edu

ABSTRACT

The forest industry in the southern United States makes a $250 billion economic impact and accounts for 2% of all jobs in the region. The southern wood supply chain is under stress with an aging workforce, rising operational costs, safety concerns, and lack of innovation. The supply chain is robust and productive but very complex and fragmented. The challenges include a segmented structure where independent businesses operate in an environment of competition and minimal collaboration. TRACT, developed by Timber Apps, LLC, has established itself as a logistics software solution for timber suppliers, logging business owners, and other supply chain members. TRACT is designed to assist organizations in reducing administrative costs, increasing transparency, improving security, and enabling data-driven decisions in real time. The objectives of this project were to evaluate the effectiveness of the TRACT software solution for improving the management of forest businesses and assess barriers to greater adoption of forest logistics software within the supply chain. We conducted confidential interviews with TRACT customers and similar businesses that do not use forest logistics software. Interviews focused on how TRACT customers currently use the software, perceived benefits of its use, and the differences between TRACT customers and companies of similar size that do not use forest logistics software. In addition, we assessed administrative procedures and estimated administrative costs per unit of timber harvested for TRACT customers and non-customers of similar size and attributes. Results will be useful for businesses engaged in wood supply chain activities and provide insight into the benefits and challenges associated with using real time data from forest logistics software to make decisions.

Keywords: technology, harvesting, management, efficiency, supply chain

COUNTRY-WIDE ANALYSIS OF THE POTENTIAL USE OF HARWARDERS FOR FINAL FELLINGS IN SWEDEN

RIKARD JONSSON[1]; MIKAEL RÖNNQVIST[2]; PATRIK FLISBERG[3]; PETRUS JÖNSSON[3]; OLA LINDROOS[4]*

[1]Skogforsk; [2]Université Laval; [3]Creative Optimization; [4]Sveriges lantbruksuniversitet - Campus Umea.

Corresponding author: rikard.jonsson@skogforsk.se

ABSTRACT

There is a need to decrease the costs of cut-to-length operations. The harwarder, a one-machine system with the potential to reduce the costs, has been compared to the two-machine system (TMS) at the stand and regional levels but not at the national level, which is important as basis for decision to implement. The objective was therefore to analyze its potential on a large scale in Swedish final fellings. It was evaluated using two modeling approaches in conjunction with data representing around 30% of Sweden's yearly final fellings from five forestry organizations. The analyses revealed that total costs could be reduced by around 3% if up to 50% of the total volume was logged using harwarders rather than the TMS. This would require the introduction of up to 250 harwarders into machine fleets that currently use only the TMS. The two modeling approaches gave similar results. It was concluded that the harwarder may need to demonstrate greater potential to justify a full-scale implementation in Swedish forestry, but the machine could be improved through technological development, especially through automation.

Keywords: Cut-to-length method; optimization; strategic decision-making; machine system comparison

POTENTIAL OF BLOCKCHAIN TECHNOLOGY IN FOREST SUPPLY CHAINS

LUKAS STOPFER[1]; HANS-ULRICH DIETZ[1]; THOMAS PURFÜRST[1]*

[1]Albert-Ludwigs-Universität Freiburg

Corresponding author: lukas.stopfer@fobawi.uni-freiburg.de

ABSTRACT

Blockchain technology has the potential to revolutionize the forestry industry by providing a transparent and secure method for tracking and verifying the origin and movements of forest products. By enabling secure tracking of forest products, blockchain can improve the forestry industry. Transactions in the supply chain can be recorded in a decentralized ledger. This increases transparency and traceability, helping to combat illegal logging, deforestation and fraudulent labelling. The technology can also streamline processes and reduce errors and fraud, leading to cost savings and increased confidence in the sustainability of products. Blockchain also has the potential to track CO2. But there are challenges, including ensuring accurate data and engaging actors. However, it is important to note that the implementation of blockchain technology in the forestry industry is still in its early stages, and there are challenges that need to be overcome such as ensuring the accuracy of the data recorded on the blockchain and ensuring the participation of all relevant stakeholders in the supply chain. In the joint project "Blockchain technology as a driver for the digitalization of forestry", potentials are being specified, the technical prerequisites are being worked out and the potential and acceptance of the market participants are being determined through a large representative survey. The presentation will present the results of a feasibility study on the use of a blockchain-mapped supply chain for the entire forestry and timber industry, from forest to customer. In addition, the technical and software requirements and possible implementation options for the use of blockchain technology in forestry business processes will be discussed. Furthermore, the results of the nationwide survey among different actors in the forestry-wood chain are explained and classified. The results of the nationwide survey among the different actors in the forestry-wood chain provide valuable insights into the perspectives and needs of the different stakeholders in the industry and show the real potential, challenges, but also limitations of this relatively new technology.

Keywords: Blockchain Technology, Forest Supply Chain, Digitalization

BATTERY VS PETROL-POWERED CHAINSAW: PRODUCTIVITY ANALYSIS IN A CONIFER CLEAR-CUT

FRANCESCO NERI[1]; ANDREA LASCHI[2]; ELENA MARRA[1]; FABIO FABIANO[1]; NICCOLO' FRASSINELLI[1]; ENRICO MARCHI[1]; RICCARDO PAOLONI[1]; CRISTIANO FODERI[1]*

[1]Department of Agriculture, Food, Environment and Forestry—DAGRI, University of Florence, Florence, 50145, Italy; [2]Department of Agricultural, Food and Forest Sciences—SAAF, University of Palermo, Palermo, 90128, Italy.

Corresponding author: francesco.neri@unifi.it

ABSTRACT

In recent years the technological development of batteries has allowed the production of powerful, compact and light manual tools. The growing interest in battery-powered tools has also affected the industrial sector of chainsaws and the market has evolved not only in the hobby sector and professional green maintenance but also in the forest one. In this context, this study aimed to test and compare the performance in a conifer clear-cut of two chainsaws similar in terms of weight and power, the Stihl MSA 300 battery-powered and the MS 261C-M petrol-powered, measuring the working times and calculating the productivities. Two forest operators carried out the clear-cut, in two areas of about one 1.5 ha within a 50-year-old parcel of Scots pine. The results show that within a working day, considering a gross time of about 7.4 hours for each operator, an average of 20 trees (average tree volume of 0.64 m3) was felled in each area. In terms of net productivity, no statistically significant differences between the two chainsaws were found. Investigating the single phases productivities with chainsaw in “use”, battery chainsaw shows an average processing productivity lower than 0.26 m3h-1 of that recorded for the petrol chainsaw. Moreover, the average charge duration was 0.88 h, while the full tank duration for the petrol model was 0.97 h. With the battery chainsaw was possible to fell and process an average of two trees per charge. Finally, our research demonstrates that battery chainsaws have great potential in forest operations too, but a solution is needed to manage batteries in forest, considering the actual need of 8 charges per standard workday.

Keywords: productivity investigation; conifer clear-cut; battery; petrol; chainsaw

SYSTEMIC CHALLENGES AFFECTING LOGGING BUSINESSES IN THE US SOUTH AND LAKE STATES: ARE THESE BUSINESSES AT A KEY CROSSROAD?

CHARLES BLINN[1]; JOSEPH CONRAD[2]*

[1]University of Minnesota; [2]University of Georgia.

Corresponding author: cblinn@umn.edu

ABSTRACT

Logging businesses are a critical component within the wood supply chain. Those businesses supply wood fiber to mills that manufacture products for markets worldwide, serve as key economic engines in many rural communities, and sustain the health and vigor of forests through their harvesting practices. The long-term health and viability of those businesses is a growing concern in the US today due to issues associated with a) in-woods labor (e.g., availability, aging workforce) b) trucking (e.g., availability, costs), c) rising costs (e.g., equipment, fuel), d) loss of markets (e.g., mill closures, quotas), e) business consolidation (e.g., economies of scale, capacity utilization), and f) Covid-19 pandemic impacts (e.g., supply chain issues, short- or long-term loss of labor). Through the use of published data and recent surveys of logging business owners, the authors examined the impact of those key concerns on logging businesses in the US South and Lake States. The cost of new logging equipment increased by 10–25% in the past two years and the price of diesel fuel increased by 34% in 2022. Mill closures have resulted in losses in markets and temporary surplus logging capacity in some areas while mill openings and expansions have resulted in concerns about the adequacy of logging capacity in other areas. The COVID-19 pandemic had an uneven impact with some loggers reporting lost production because of employee illness or death and reduced mill demand. Other loggers reported production increases because of increased mill demand resulting from high lumber prices and strong demand for packaging during the second half of 2020 and much of 2021. While rates paid for logging and timber hauling have increased, they often lag input cost increases. The future of independent logging businesses is highly uncertain, with major implications for forest landowners, forest managers, forest products mills, and the rural communities that depend on these businesses.

Keywords: Wood supply chain, Logging business, Labor, Trucking, Covid-19, Markets, Costs

A US SOUTH AND LAKE STATES REGIONAL COMPARISON OF INDEPENDENT LOGGING BUSINESSES FOLLOWING A PANDEMIC AND MARKET UNCERTAINTIES

JOSEPH CONRAD[1]; CHARLES BLINN[2]*

[1]University of Georgia; [2]University of Minnesota.

Corresponding author: jlconrad@uga.edu

ABSTRACT

The US South is the leading timber producing region in the US and a major source of softwood pulpwood, lumber, and wood pellets. The US Lake States region is a leading producer of high-quality hardwood timber, flooring, and paper. In both regions, timber is harvested and delivered to mills by independent logging businesses. These businesses face many challenges following the COVID-19 pandemic, changes in forest industry structure including both mill openings and closures, and rising input costs. The University of Minnesota and other organizations have conducted regular surveys of Minnesota logging businesses dating to the 1970s and the University of Georgia has surveyed Georgia logging businesses at five-year intervals since 1987. We used data from the 2022 surveys conducted in Minnesota (Lake States) and Georgia (US South) to assess the status and challenges faced by logging businesses in these two regions. Business owner demographics were similar in both regions with average owner ages of 54 and 55 years in the South and Lake States, respectively. Logging business owners had operated their business for an average of 31 years in the Lake States and 26 years in the South. The US South utilizes full-tree feller-buncher/grapple skidder systems almost exclusively while the Lake States utilize a mix of cut-to-length and tree-length/full-tree systems. Average annual production was much higher in the South, averaging approximately 80,000 tonnes per business compared to 20,000 tonnes per business in the Lake States. Capital investment per business was also much higher in the South, averaging $2.2 million (USD) compared to $313,000 in the Lake States. Logging business consolidation has been a consistent trend in both regions with a small number of high production businesses harvesting a growing percentage of the annual harvest volume. More than 75% of businesses reported breaking even or making a profit in 2021 in both regions. Shortages of both equipment operators and truck drivers and the need for more markets were noted by survey respondents in both regions, while logging businesses in the South also emphasized the high cost of log truck insurance as a major challenge. Landowners, forest industry, and policymakers should recognize the clouded future of independent logging businesses and work towards solutions that improve the long-term viability of these essential businesses.

Keywords: Timber harvesting businesses, COVID-19, Profitability, Logger Demographics

LOGGING MACHINERY IN BULGARIA – PAST, PRESENT AND FUTURE

SOTIR GLUSHKOV[1]; ERIK FINDEISEN[2]; IVAILO MARKOFF[1]; ROSEN NOVAKOV[3]; STEFAN STOYANOV[4]; DIMITAR BUYADZHIEV[1]*

[1]Forest Research Institute, Bulgarian Academy of Sciences, Sofia; [2]University of Applied Sciences, Erfurt, Germany; [3]Gorainvest Ltd.; [4]Mina Partners Ltd..

Corresponding author: imarkoff@abv.bg

ABSTRACT

In the present study, a forecast for the market of logging machines in Bulgaria is made, based on data on Bulgarian forests and the experience of Central Europe. Against this background, the latest development of logging machines and technologies in the Republic of Bulgaria, which broke the decline associated with the economic crisis of the market transition, is examined. Data are also given for older periods, from the post-war years after the WW2 to the present day. Mechanized logging with harvesters, forwarders, yarders, etc. logging machines, incl. with multi-operational machines, began to develop rapidly in Bulgaria from 2015, mainly due to financial reasons and the situation of the labor market in the previous period. EU membership has led to an improvement in the investment climate, which is already being felt in forestry.

Keywords: tractors, yarders, harvesters, forwarders, processors, market of machinery

PERFORMANCE OF A MOUNTY 4000 CABLE YARDER WITH WOODY H FAUCET PROCESSOR

*SOTIR GLUSHKOV[1]; DIMITAR BOYADZHIEV[1]; IVAILO MARKOFF[1]**

[1]Forest Research Institute, Bulgarian Academy of Sciences, Sofia

Corresponding author: imarkoff@abv.bg

ABSTRACT

Softwood extraction with the Mounty 4000 while thinning mountain coniferous forests in the Rhodopes was studied. During the period 2017-2019, a new machine was observed operating in summer conditions, with workers with about 3 years of experience. A performance equation was fitted and a time rate proposal was prepared. The Mounty system has been found to show higher productivity (30% up to 2 times) than official logging standards based on Kohler 300 and similar.

Keywords: hydraulics, cable yarder, time standard, timber extraction.

IMPROVING SUSTAINABILITY AND RESILIENCE OF WOOD LOGISTICS BY TRANSPORT SIMULATION

CHRISTOPH KOGLER[1]; PETER RAUCH[1]*

[1]University of Natural Resources and Life Sciences, Vienna

Corresponding author: christoph.kogler@boku.ac.at

ABSTRACT

In a resource-constrained world the access to wood as renewable raw material of the future is crucial to fulfill the sustainable development goals. Climate crisis induced forest calamities lead to logistical bottlenecks challenging wood supply chain management. Wood transport is the connecting link between system components of wood supply chains and, therefore, suffers heavily under associated fluctuating demand and long queuing as well as lead-times resulting in wood value loss. Transport simulation enables the development of transport fleet strategies in risk scenarios to further improve sustainability and resilience of wood logistics. Discrete event simulation is a valuable methodology for wood transport simulation, because it focuses on business processes for a digital representation of wood supply chains and provides an intuitive approach for facilitating stakeholder participation. Furthermore, it has major strengths in integrating stochastic elements, complex interactions, time dynamics and bottleneck-related queuing systems to implement realistic quantitative decision support for researchers, students and stakeholders of wood supply chains. Consequently, discrete event simulation models for unimodal, multimodal and multi-echelon unimodal wood transport are presented, which enable multicriteria-based strategy development, optimal fleet configuration and wood quality preservation: Multimodal wood transport strategies reduce negative environmental impacts (e.g., CO2, noise) and increase resilience (e.g., additional transport capacity after calamities, storage capacity at the terminal) through short self-loading truck transportation to train terminals and subsequent rail transport. However, multimodal supply chain management is more challenging compared to unimodal transportation, making the developed model a needed quantitative decision support tool for developing transport fleet strategies based on multi-criteria metrics developed with practice experts. Multi-echelon unimodal wood transport strategies are based on short self-loading truck transportation to transshipment terminals, there semitrailers are provided for the subsequent transport with semitrailer trucks. The lower tare weight of semitrailers compared to self-loading trucks increases transport efficiently as well as alleviates the drastic self-loading truck driver bottleneck. The multi-echelon unimodal model allows the simultaneous optimization of the fleet as well as handling infrastructure (i.e., number of transshipment slots, self-loading trucks, semitrailers). Quality-preserving wood transport strategies are based on the significant correlation between lead-time and quality loss of spruce logs during storage and transport (mainly caused by fungal and insect infestation). The discrete event simulation model demonstrates the potential of vegetation zone-based risk forecast to develop unimodal and multimodal transport strategies that prioritize wood at risk of devaluation and thus avoid wood value loss. The presented wood transport models demonstrate the high suitability of the discrete event

simulation method for contingency planning, risk management and strategy development to improve sustainability and resilience of wood logistics. Further development opportunities for wood transport simulation include the integration of real-time data and artificial intelligence.

Keywords: wood supply chain management, forest logistics, discrete event simulation, lead-time

A GOOD NIGHT'S SLEEP SUPPORTS OPERATIONAL PERFORMANCE AND WORKABILITY - A LONGITUDINAL STUDY WITH CONTINUOUS DATA COLLECTION OF CTL MACHINE OPERATORS

HELI KYMÄLÄINEN[1]; JUKKA MALINEN[2]; TEPPO HUJALA[1]; CAROLA HÄGGSTRÖM[3]*

[1]University of Eastern Finland; [2]Metsäteho Ltd; [3]Swedish University of Agricultural Sciences.

Corresponding author: heli.kymalainen@uef.fi

ABSTRACT

The fully mechanized cut-to-length (CTL) harvesting method plays a crucial role in the forest industry. Operational performance on CTL harvesting varies greatly due to the machine operator i.e. the human factor. Operators execute intensive decision-making processes and complex visual-motor tasks in a limited time, and in the Nordic countries, operating CTL machine is strongly independent and demanding work requiring heavy machinery-, forest management-, raw material-, IT-, and communication skills. Earlier research has shown that good workability supports and enhances work quality and productivity, whilst the balance of workability is constantly sought through one's personal resources and work demands. Thus, workability is affected by personal attitudes and lifestyle choices, as well as work management, organizational arrangements, and work circumstances. This study aimed for a long-term longitudinal study with continuous data collection to investigate how CTL machine operators' workability index (WAI), personal lifestyle choices, seasons, and shift work affected operational performance. Research compiled a group of 14 volunteer CTL machine operators across Finland and participants were given smartwatches (Polar Ignite) for data collection of sleep, and activity level, and follow-up on a workability index questionnaire and fitness test every three months over a year. Participants operated machines from John Deere (3 harvesters), Ponsse (7 harvesters, 1 forwarder), and Komatsu (3 harvesters), and the machines were under 5 years old. The productivity data from John Deere and Komatsu harvesters was collected in .pdf and .xml formats, and Ponsse data were collected in .drf and .prd formats, and further converted/processed in excel-spreadsheets. All the data from smartwatches as well as productivity data from CTL machines were collected remotely, the smartwatch data via software server, and productivity data via email. Eventually, the study analyzed the production of 152 745.5 m3 of timber combined with self-tracking data. WAI seems to work well also for forest operations thus operators' relative productivity (Pr) had an increasing trend while WAI increased. Furthermore, participants with higher sleep value (SV) had also higher Pr, and SV and Pr were affected by shift work and seasons. Overall, it's important to understand the human factor and its contribution to operational performance as well as the operational work demands on the human being. Supporting employees' workability ensures good operational performance which is reliant on motivated and healthy operators. This paper contributes to understanding the productivity of forest harvesting by acknowledging workability and well-being as key factors.

Keywords: CTL harvesting, productivity, workability, sleep, human factor

MODELLING FOREST ROAD TRAFFICABILITY WITH SATELLITE RADAR

DAG FJELD[1]; MAGNUS PERSSON[2]; JOHAN FRANSSON[2]; JAN BJERKETVEDT[1]; MARTIN BRÅTHEN[3]*

[1]Norwegian Institute for Bioeconomy Research, Swedish University of Agricultural Sciences, SLU; [2]Linnaeus University; [3]Skogforsk.

Corresponding author: dag.fjeld@slu.se

ABSTRACT

Wood supply in the boreal zone works requires planning for seasonal freeze-, thaw- and drying cycles to secure year-round supply to forest industries. Reduced winter frost and increased precipitation requires new approaches for exploiting the varying trafficability of forest roads throughout the year. The bearing capacity of non-industrial forest roads is often unclassified, and in these cases transport planning relies on the local knowledge of transport managers and haulers. More readily available measures are needed to guide transport planning through spring, summer and fall. This study examined two approaches; monitoring weekly road use from digital transport messaging and measuring bearing capacity in field studies. PapiNet Digital messaging used landing coordinates, transport dates and volumes to join individual loads to road network data, DTM-variables, quaternary surface deposit types and weekly weather (temperature, precipitation and snow depth). The field study used road cross-section data to join measured bearing capacity (E-module, MPa) to road construction materials, surface deposit types as well as static and dynamic soil moisture indexes where available. Both road use and bearing capacity were related to the main surface deposit types: glacio-fluvial deposits (code 20, 50), moraine deposits (codes 11, 12) and marine/fjord sediments (code 41). All analyses were limited to frost-free periods. Delivery messaging showed how weekly truck transport volumes shifted between sites with changing weather. Transport over roads of cohesion soils (code 41; marine deposits of silt, clay) was highest during warm and dry periods, while transport over frictional soils (codes 20, 11, 12; glacio-fluvial or moraine deposits) was highest during periods of high precipitation. The field study data correlated measured bearing capacity (e-module in MPa) with road compaction and deformation. For the whole data set, 27-36 % of the variation in e-module (R2) could be explained by surface deposit type, bearing layer materials and season (4 equinox-based classes). Further analysis of e-module was done for road sections of local surface deposits where digital data was available for static and dynamic soil moisture. Depth-to-water (DTW) was used to represent the static soil moisture state for each sections. Weekly soil moisture variables from two alternative satellite programs (Copernicus SWI, NASA SMAP) were used to represent the temporal variation in their sub-surface moisture status. DTW (n=38), together with surface deposit type (20, 11, 41) and wearing course materials explained 37 % of variation in e-module. Replacing DTW with the weekly soil moisture index at 15 cm (Copernicus SWI_015, n=38) explained 39 % of variation. Replacing DTW with weekly subsurface soil moisture active/passive (NASA SMAP, n=41) explained 60% of variation in e-module. For forest roads built of local surface deposits, satellite-sourced sub-surface soil moisture improved predictability of bearing capacity. Further work with integrating transport messaging with both static and dynamic soil moisture measures should enable real-time tracking of road use and availability during changing weather conditions.

Keywords: e-module, subsurface soil moisture

CTL TRANSPORT MANAGEMENT – A NORDIC CASE STUDY OF WORK PROCESSES AND ORGANIZATIONAL PERFORMANCE

*KARL STERNER[1]; TORBJÖRN EDMAN[2]; DAG FJELD[1]**

[1]Swedish University of Agricultural Sciences; [2]SCA.

Corresponding author: dag.fjeld@slu.se

ABSTRACT

The goal of this study was to provide a generic process map for state-of-the-art transport management in CTL systems and quantify the effect of varying planning and control cycles on organization performance. The KPI for organizational performance was weekly delivery fulfilment and the study was limited to the non-winter months when there is greatest variation in road trafficability. The process map documents operational planning and control activities at monthly, weekly and daily levels. Two main variants of planning activities were found. These had diverging effects on average delivery fulfilment as transport distances increased but could also facilitate varying degrees of responsiveness in core supply areas. Regarding the control cycle, the number of follow-up activities used by managers increased with the number of mills/terminals served and their total weekly transport volume.

Keywords: hauling operations, planning, control, delivery fulfilment

RAIL TRANSPORT IN SWEDISH WOOD SUPPLY – SEASONAL VARIATION, SYSTEM RISKS AND MITIGATION COSTS

*IDA SJÖLLING[1]; ERIK RÖNNQVIST[2]; DAG FJELD[1]**

[1]Swedish University of Agricultural Sciences; [2]Creative Optimization.

Corresponding author: dag.fjeld@slu.se

ABSTRACT

This study examines the potential for reduced risks in roundwood transport by rail. The study quantifies seasonal variation and system risks under boreal conditions, as well as practical routines for managerial response to these. The study case is based on an integrated forest company with 11 supply terminals supplying coastal mills in mid-Sweden. The terminals were distributed from south to north Sweden, with six core terminals located in the interior- and mid- supply zones for coastal mills. The monthly flows ranged from 75 to 118% of the annual average and the monthly variability of terminal inflows was 67% higher for the interior than the mid-zone terminals. Comparing inflows between assortments, the lowest variability was for coniferous pulpwood (8%) and pine sawlogs (18%), increasing thereafter to deciduous pulpwood (28%) and spruce sawlogs (53%). Regarding rail system disturbances, the frequency of deviations from scheduled routes for the core terminals was 16-17%, resulting in cancelled routes for 53-65% of deviations. Two mitigation scenarios were tested to reduce supply risks (scenario1) and a combination of supply and system risks (scenario 2). These risk mitigation scenarios had only marginal effects on system costs (< 1%). The optimal solutions, however, involved a 4-5 % reduction of truck transport output (m3km per period) and 7-8% increase in rail output. From the perspective of rail operations, interview with service buyers and providers showed that the mitigation scenarios were fully feasible on an annual planning horizon. Further options are provided for quarterly, monthly and weekly horizons.

Keywords: roundwood, multimodal transport, terminals, contingencies, resilience

ACCURACY OF THE CALCULATING RUT DEPTH IN LOWLAND FOREST USING THREE DIFFERENT MEASURING METHODS

MIHAEL LOVRINČEVIĆ[1]*; DAVID JANEŠ[1]; ANDREJA ĐUKA[1]; MAJA POPOVIĆ[1]; TIBOR PENTEK[1]; TOMISLAV PORŠINSKY[1]; ZORAN BUMBER[2]; IVICA PAPA[1]

[1]Faculty of Forestry and Wood Technology, University of Zagreb; [2]Hrvatske šume d.o.o. (Croatian forests Ltd).

Corresponding author: mlovrin@sumfak.hr

ABSTRACT

The continuous passage of forest machines on the forest floor leads to a disturbance of the soil properties. When the loading induced by the vehicle exceeds the bearing capacity of the soil, the soil begins to compact and deform. The result of this phenomenon is the formation of ruts. Soil damaged in this way has a reduced amount of macro and micropores, a higher density, and there is a loss or mixing of the organic layer. All of the above negatively affects the growth and development of young trees. In the literature, although the occurrence of ruts is often investigated, the method of measuring the rut depth is usually poorly described or not described at all. This paper describes the method of measuring and calculating the depth of ruts using three methods: using a meter (classical method), workstation and Real-Time Kinematic positioning (RTK) device. Field studies were conducted in winter time, on a terrain with a specific microrelief caused by the water and flood regime in narrow-leaved ash (Fraxinus angustifolia Vahl) lowland forests of the Republic of Croatia. The ruts were caused by the movement of the forwarder on the forest floor with mounted half-tracks, half-tracks and chains, or without half-tracks and chains. On 4 skid trails, with a length of 100 meters each, every 50 meters one door was placed, total of 12 doors . Doors were 4 meters wide and they served as fixed points for measuring the rut depths. A total of 156 ruts were recorded using the classic method and workstation, and 66 using the RTK device in order to established rut depth. Data processing was done using software Microsoft Excel.

Keywords: rutting, forwarder, RTK, workstation, soil damage

DEVELOPMENT OF HYBRID DRIVE OF SKIDDER

MARIJAN ŠUŠNJAR[1]*; ZDRAVKO PANDUR[1]; MARIN BAČIĆ[1]; HRVOJE NEVEČEREL[1]; MIHAEL CIPEK[2]; JURAJ BENIĆ[2]; KRUNO LEPOGLAVEC[1]

[1]Faculty of Forestry and wood technology University of Zagreb; [2]Faculty of Mechanical Engineering and Naval Architecture University of Zagreb.

Corresponding author: susnjar@sumfak.hr

ABSTRACT

The paper presents a conceptual innovation solution of a hybrid skidder. The innovation refers to a hybrid skidder with a diesel engine coupled with a separate electric motor with two clutches, which enables multi-mode work modes and the replacement of a winch drive based on a hydraulic drive with a drive based on an electric motor. During the work of winching the role of the pump drive is taken over by the electric motor, so that during such activities the diesel engine can be turned off or idling in order to save fuel. In addition to the listed components, a battery for energy storage has been added. For the development of the hybrid drive, it was a necessary prerequisite to precisely determine the skidder's energy consumption when timber skidding in different field conditions. For this purpose, it was necessary to perform field measurements on existing vehicles. When analyzing energy consumption for the purposes of modeling the drive of a hybrid skidder, the key values are extreme - maximum values. The future hybrid drive must satisfy the need for energy in all operating conditions, including the most demanding situations that may occur when the skidder is operating in extreme conditions. For this reason, long-term monitoring and measurement of energy consumption was necessary in order to observe extreme situations and measure the highest energy consumption per working day, work cycle and individual work operation. The research was carried out on 2 skidders Ecotrac 140 V under real working conditions. WIGO-E (Telematic Data collector) measuring equipment with integrated GPS system and fuel flow meter (accuracy in milliliters) is installed on both skidders. Data on fuel consumption, position and direction of skidder movement, winch activity, engine speed, drive motor torque, gas pedal position and temperature were collected by connecting the CANBUS bus from the vehicle's computer to the WIGO-E gateway. WIGO-E transmitted all data via GSM communication to Web platforms (Cloud). In doing so, the data collection frequency from the skidder was achieved in the range of 3 to 5 seconds. In addition to remote data collection, the amount of wood extracted during each work cycle was also recorded in the field. In total, measurement data were collected for 272 working days of skidders. The conceptual solution of the hybrid skidder drive is based on the measurement data bases collected from two Ecotrac 140 V skidders, mechanical drive parameters (engine speed characteristics, transmission ratios, etc.), hydraulic and electrical system schematics. Mathematical and simulation models of hybrid skidder drive components and computer algorithms for data processing were developed and the structure of the elements of the hybrid drive (electric motor, batteries, control unit) were determined and presented in the paper. Research was carried out within the project "Development of a hybrid skidder - HiSkid from the Operational Program "Competitiveness and

Cohesion" 2014 - 2020 within the call "Investment in Science and Innovation“ and it was co-financed from the European Fund for Regional Development.

Keywords: hybrid drive, skidder, energy consumption, electromotor, simulation model

NAVIGATING FORESTS WITH MACHINE LEARNING-BASED PATH PLANNING FOR THE PORTAL ADVANCING MECHANISM

SEBASTIAN BEISER[1]*; BENJAMIN KAZENWADEL[1]; MARCUS GEIMER[1]

[1]Karlsruhe Intitute of Technology - Institute of Mobile Machines

Corresponding author: sebastian.beiser@kit.edu

ABSTRACT

The ongoing mechanization of forest machinery caused by performance and cost pressure leads to an increase in size and weight of the equipment. However, the interaction between the heavy machines and soft and wet forest soils can cause issues in regard of sustainability. The portal-advancing mechanism was researched and developed to tackle the environmental issues related with the ruts of wheel-driven machinery caused by wheel-slip in flat and wet forest environments. Since the movement cycle of this new machine is not limited to skid tracks and due to the specific kinematics of the machine, new navigation algorithms have to be researched. Data-driven algorithms propose new chances to tackle these complex optimization problems. The field of reinforcement learning does hereby allow algorithms to learn a movement policy solely by interacting with their environment. Therefore, different reward functions can be defined such as the maximization of the performance of the machine or the optimization of the fuel efficiency. For training and evaluation purposes of the algorithm a simplified forest environment was developed. This environment is based on randomly generated forest maps with a high level of abstraction. The simulations show that the policy learned by the algorithm is able to choose an optimized path in regard to the selected reward function. The use of machine learning methods offers a promising solution to the challenge of path planning for forestry machines and has the potential to improve the efficiency and sustainability of forest operations.

Keywords: path planning, machine learning, harvesting, portal advancing mechanism

EVALUATION OF SOIL EROSION RATES AND IMPLEMENTATION OF BEST MANAGEMENT PRACTICES IN CONVENTIONAL AND BIOMASS HARVEST SITES ACROSS THE SOUTHEASTERN REGION OF THE UNITED STATES

MANISHA PARAJULI[1]*; TOM GALLAGHER[1]; RICHARD CRISTAN[1]; DANA MITCHELL[2]; MARISSA JO DANIEL[3]; TIMOTHY MCDONALD[1]; ARJUN RIJAL[1]

[1]Auburn University; [2]U.S Department of Energy; [3]International Paper.

Corresponding author: mzp0131@auburn.edu

ABSTRACT

Biomass for energy production is becoming an increasingly popular option that could lead to greater use of forest residues. However, the use of logging residues could result in soil erosion if not managed properly. This study evaluated 30 operational harvests in the Coastal Plains of Alabama, Florida, and Georgia, comparing erosion rates and best management practices (BMPs) implementation status between biomass and conventional harvest sites. The study used the universal soil loss equation forest method (USLE-Forest) to estimate the potential erosion within six operational categories: harvest areas, roads, skid-trails, streamside management zones (SMZs), decks, and stream-crossings. BMP audits were conducted following state implementation guidelines. The results showed that although there was a slightly higher weighted average erosion rate from biomass harvests, there were no significant differences when compared to conventional harvest sites (p-value = 0.111). Similarly, there were no significant differences between biomass and conventional harvest sites for each operational category. Regardless of the harvest type, the construction of roads and skid-trails resulted in significantly higher erosion rates (with a p-value < 0.05) than other operational categories. The overall BMP implementation rate was more than 90% in both harvest sites, and a negative correlation between BMPs and weighted average erosion was observed (-0.376). These results suggest that increased utilization of logging residues for energy production does not necessarily lead to higher erosion rates compared to the conventional method when BMPs are implemented correctly. Therefore, proper implementation of BMPs is crucial at all harvest sites, regardless of the type of harvest.

Keywords: Logging residues, bioenergy, soil erosion, USLE, BMPs

EXOSKELETONS IN PRUNING OPERATIONS – RESULTS OF A PILOT STUDY

MARIUS KOPETZKY[1]*; HENRIK BROKMEIER[1]; DIRK JAEGER[1]

[1]Department of Forest Work Science and Engineering, University of Göttingen

Corresponding author: Marius.kopetzky@uni-goettingen.de

ABSTRACT

Manual forest work is known to be physically demanding and causing risks for musculoskeletal diseases. Early invalidity of experienced forest workers on one side and the lack of junior staff on the other make it increasingly harder to cope with the demand in human resources for forestry in the future, especially planting, tending, pruning and felling operations. To solve this problem the proliferating technology of yet industry focused passive exoskeletons is under review at the University of Göttingen concerning their adaptability for forest tasks. Passive exoskeletons are rigid structures, worn by users, to support certain movements through rubber expanders. They showed potential to reduce muscle strain during several tasks in laboratory and industrial environments. Therefore, a pilot study was conducted to investigate the potential of a shoulder supporting passive exoskeletons to reduce muscle strain and cardiovascular strain in a pruning operation of Douglas fir (Pseudotsuga menziesii Franco) in Germany. Three forest workers conducted a pruning operation up to reach height with an electric pruning shear, F3015 from INFACO, in a 20 years old stand of previously marked Douglas fir trees, mixed with Norway spruce (Picea Abies L.) and Beech (Fagus sylvatica L.). The forest workers were equipped in alternating order with or without a shoulder supporting passive exoskeleton. To investigate the effect of the exoskeleton on the participants a time study was conducted to calculate the number of pruned trees per hour, the time demand per tree and the walking time. Additionally, ergospirometry was conducted, including heart rate measurement with a Polar chest belt, as well as breathing rate, respiratory volume and oxygen consumption per breath to determine the cardiovascular strain level during work. In addition, the electromyographic (EMG) signals of four muscles (biceps brachii (BB), anterior deltoideus (AD), mid deltoideus (MD) and upper trapezius (UT)) were collected. Time demand per tree ranged between 1.4 to 3.6 minutes for all three participants. Comparing the sessions with and without the exoskeleton for each participant there were no significant differences. Therefore, passive exoskeletons seem not to have any effect on pruning productivity with an electric shear. Also, cardiovascular strain seemed to have been unaffected by using the passive shoulder exoskeleton. Though differences were found in heart rate and oxygen consumption of each participant, there were no significant differences between the sessions with and without the support of the exoskeleton. EMG signals of AD, MD and UT showed significant differences using the exoskeleton compared to the reference, though not all indicated reductions in muscle strain. For AD and MD reduced muscle activations could be found ranging over all participants between 3 to 42% for AD and 12 to 32% for MD. For two participants there also was reduced muscle strain in UT (9% and 16%). However, one forest worker seemed to have experienced an additional load on the UT due to the use of the passive exoskeleton. This pilot study

indicated that application of passive exoskeletons did not increase productivity but has a relieving effect on the supported muscles during a pruning operation.

Keywords: Passive Exoskeleton, Pruning, Douglas fir, Ergospirometry, EMG, Pruning Shear

IMPLEMENTING AN OPERATOR PROTECTIVE DEVICE ON QUAD-BIKES - USER EXPERIENCES

TOMAS NORDFJELL[1]*; THOMAS KRONHOLM[1]; BJÖRN EDLUND[1]; CAROLA HÄGGSTRÖM[1]; PETER LUNDQVIST[2]

[1]Swedish university of agricultural sciences, department of forest biomaterials and technology; [2]Swedish university of agricultural sciences, Department of People and Society.

Corresponding author: tomas.nordfjell@slu.se

ABSTRACT

A quad bike (QB) is a 200-300 kg all-wheel driven vehicle that's proven useful in forest work like e.g. silviculture and inspections. In 2021 alone, 12,000 new QBs were registered in Sweden. The number of serious QB-related accidents and deaths increases. A safety-enhancing measure repeatedly highlighted in the research is to equip QBs with an operator protective device (OPD) that prevents the vehicle from rolling around completely in rollover accidents. QBs in e.g. Australia must be equipped with an OPD, but the interest in Sweden has been limited. Some studies have pointed out resistance to OPDs due to concerns that it might interfere with normal use. The objective was to map and describe the experiences of a large group of users of QBs with an OPD. The OPD Quadbar was distributed to 50 people who had an interest in fitting it to their QB. Views were collected before the study, after a shorter period of use and after a year. A large majority of the participants used their QB for transport in forestry or on the farm. The most common types of terrain were woodland, private road, tractor road and agricultural land. It was common to drive with a coupled trailer. Common concerns before installation were that the OPD would affect driving or that it could be stuck in low-hanging branches. Other concerns were that it would hinder the use e.g. a winch or trailer. During the test period, about 20% of the participants were involved in a QB-related accident or incident. In occurred rollover accidents, the Quadbar had worked as intended. In some of the less serious incidents, the drivers had misjudged the new height, resulting in hitting objects when driving under low passages. No injuries were reported in connection with the incidents. Participants were generally satisfied with the tested Quadbar, as shown by a large proportion expressing that they were likely to recommend Quadbar to their acquaintances. The results also show that the participants' feeling of safety increased with the OPD mounted on the QB and that this feeling increased over time. The most common concerns experienced were that the Quadbar's attachment impaired the ability to connect a trailer to the QB, and that it made it difficult to use the winch. Some participants had made modifications to be able to use the QB according to their needs. The OPD made the QB higher making it difficult to transport it on a trailer with a cover. Several participants, therefore, called for a more flexible solution to be able to temporarily remove or fold down the Quadbar. To conclude, the tested OPD worked well for most of the participants and it increase both the perceived and actual safety of QB use. The project visualized improvements needed for the Quadbar to become better suited for QB use in forestry. We hope that this work can accelerate the development of safety and lead to large-scale implementation of OPDs, similar to the development in Australia.

Keywords: ATV, forestry, rollover protection, ROPS, safety

SILVER BIRCH GRADING MODEL BASED ON REGENERATION HARVEST DATA

JIŘÍ DVOŘÁK[1]*; MARTIN JANKOVSKÝ[1]; PETR MORAVEC[1]; PAVEL NATOV[1]

[1]Czech University of Life Sciences Prague, Faculty of Forestry and Wood Sciences

Corresponding author: dvorakj@fld.czu.cz

ABSTRACT

In 2021, the share of salvage logging in the Czech Republic was 87 % of total harvests. The reason for that was the still intensive outbreaks of bark beetles, namely Ips typhographus, which resulted in the harvest of 86 million m3 (60 % of the total harvests), between 2017 and 2021. Along with the harvests, the area of regenerated forest stands also increases, with an increasing share of hardwoods mixed in, including the so-called pioneer species. One such tree species is Silver birch, the share of which is expected to increase in the upcoming years. Therefore, we need to consider its use, so it is not used just for fuelwood. This study aimed at completing of the percentage assortment tables for birch from regeneration harvests. During measurements, felling samples of the birch were prepared from forest district Trutnov, in the north of Czech Republic. The sample logs were graded, and their length, diameter at breast height, diameter per 50 cm of log length, and other parameters were measured. Measurements were carried out by a digital calliper or data gathering from *.STM files of harvester forest machine systems. All data were transferred to a database, in which logs were scaled and graded according to Recommended rules for measuring and grading of wood in the Czech Republic. A scheme and model of two percentage assortment tables were made for logs in 4 cm diameter intervals in various quality grades as well as a division of trees into two groups: (i) healthy no damage, straight stems, (ii) stems damaged in the upper part by breakage and in the bottom part by decay up to two metres of height. For group (i), up to 96.1 % of log volume related to higher quality grades, depending on diameter interval; for group (ii), up to 78.4 % of log volume related to higher quality grades. The results showed that if proper sorting methods are applied, birch can be used for industrial processing to a large extent.

Keywords: birch, assortment percentage tables, bucking, quality grade, timber scaling

ANALYSIS OF DECISION-MAKING PROCESSES FOR STRATEGIC TECHNOLOGY INVESTMENTS IN SWEDISH LARGE-SCALE FORESTRY

RIKARD JONSSON[1]*; LOTTA WOXBLOM[1]; ROLF BJÖRHEDEN[1]; EVA-MARIA NORDSTRÖM[2]; BOSKO BLAGOJEVIC[3]; OLA LINDROOS[2]

[1]Skogforsk; [2]Swedish University of Agricultural Sciences; [3]University of Novi Sad.

Corresponding author: rikard.jonsson@skogforsk.se

ABSTRACT

Technological development gives forest companies opportunities to maintain competitiveness in the highly cost-sensitive market for forest products. However, no previous studies have examined the technological development decisions made by forest companies or the support tools used when making them. We therefore aimed to describe and analyze 1) the processes used when making such decisions, 2) the associated decision situations, and 3) the use of and need for decision sup port tools in these processes, with a harwarder concept as case. Semi-structured interviews were conducted with respondents from six forestry organizations. Two theoretical frameworks were used to analyze the interviews, one for unstructured decision processes and one for decision situations. The respondents' descriptions of their decision processes were consistent with those observed in other industries, and it was shown that decision-making could potentially be improved by invest ing more resources into diagnosing the problem at hand. The main objective in decision-making was to maximize economic criteria while satisfying threshold requirements relating to criteria such as operator well-being, soil rutting, and wood value. When facing large uncertainties, inter viewees preferred to gather data through operational trials and/or scientific studies. If confronted with large uncertainties that could not be reduced, they proceeded with development only if the potential gains exceeded the estimated uncertainties, and implemented innovations in a stepwise manner. These results indicate a need for greater use of existing decision-support tools such as problem-structuring methods to enable more precise diagnoses, simulations to better understand new innovations, and optimization to better evaluate their theoretical large-scale potential.

Keywords: forest technology development, harwarder, information needs, qualitative analysis, semi-structured interviews

PORTABLE SOIL PROTECTION SYSTEMS – A TECHNIQUE FOR MITIGATING SOIL DISTURBANCE AND IMPROVING ACCESS IN GROUND-BASED LOGGING OPERATIONS?

INGO SIEBERT[1]*; RAIMUND SCHNEIDER[2]; GEBHARD SCHÜLER[1]

[1]Research Institute for Forest Ecology and Forestry Rhineland-Palatinate, forest agency Rhineland-Palatinate; [2]Department of Soil Science, University of Trier.

Corresponding author: ingo.siebert@wald-rlp.de

ABSTRACT

Economic constraints and technical progress lead to the increasing mechanization of wood supply chains and thus to the use of more powerful and heavier machines in forest management. Particularly, for reasons of soil protection, wheeling is concentrated on permanent skid trails. For maintaining forest technical trafficability on skid trails and thus providing soil protection, existing techniques, such as wide tires, twin tires, or supporting bogie tracks have been used. Although those techniques can reduce detrimental impacts on soils there is still a need for improving ecosystem services, especially ecologically and economically relevant soil functions. As an improvement, temporarily installable, portable soil protection systems could be used that are well established, e.g. in civil engineering. Particular advantages over conventional techniques are the load distribution on a significantly larger surface area, machine independent usage and no additional weight increasing the net weight of the machines. However, studies on portable soil protection systems in forests are scarce and especially the mechanical soil strength and induced soil stresses have not been investigated so far. Hence, we examined the effects of heavy duty HDPE plastic plates in several field studies that were conducted in the Rhenish Slate Mountains of South-West Germany. The aim was to compare selected soil mechanical and soil physical properties between unprotected and protected ruts at different soil depths. The trials were conducted with a loaded eight wheel forwarder. In all study sites, the rut depths of the protected patches were shallower compared to the unprotected ones. The results of the Bolling pressure probe measurements predominantly showed lower maximum pressures and consequently less induced soil stress under the portable soil protection system than for the unprotected soil. Likewise, dry bulk densities were lower and the final steady-state infiltration rate was significantly higher. In conclusion, the investigated portable soil protection system represents an additional alternative for mitigating soil disturbance, improving access to forests and thus contributes to sustainable forest operations.

Keywords: environmental impact, skid trail, soil stress, precompression stress, soil properties

THE VOLUME OF LOGGING RESIDUES AND WOOD CHIPS PRODUCED FROM NORWAY SPRUCE REGENERATION FELLINGS

MARTIN JANKOVSKÝ[1]*; JIŘÍ DVOŘÁK[1]; JOSEF MICHNA[1]; PAVEL NATOV[1]

[1]Czech University of Life Sciences Prague

Corresponding author: jankovskym@fld.czu.cz

ABSTRACT

The study was focused on measuring the amount of logging residues and the volume of wood chips produced within regeneration fellings in the Czech Republic and determining the conversion factor between mean felled stem volume and the volume of logging residues and wood chips produced. The amount of logging residues extracted from particular forest stands, was measured on forwarder bunks. Subsequently, the relationships between the mean felled stem volume in the particular forest stands and logging residues and wood chips were observed. The measurements took place in 52 stands, with a total volume of harvested timber reaching 32,789 m3 , a total volume of logging residues of 30,173 loose m3 and a total wood chips volume of 18,531 m3. The volume of mean felled stem ranged from 0.38 to 1.36 m3. Both logging residue pile volume and woodchip volume showed a strong linear correlation with mean felled stem volume. The conversion factor between mean felled stem volume (in the range between 0.50 and 0.99 m3) and the loose volume of logging residues reached 0.58 for Norway spruce trees.

Keywords: logging residues; wood chips; mean felled stem volume; Southern Bohemia

THE SOLUTION IS IN EXPERTISE – WOOD SUPPLY VISION 2030 FOR THE FINNISH FORESTRY

JUKKA MALINEN[1]*

[1]Metsäteho

Corresponding author: jukka.malinen@metsateho.fi

ABSTRACT

Metsäteho, as a Finnish forest industries mutually owned research and development organizations, has produced over the years vision papers for the future wood supply R&D work. Previous vision, "Efficient Wood Supply 2025", made 2015 and updated 2018, focused on digitalization. New vision work begun at the beginning of the 2022 with a fresh start without any presumptions. The first perception was that the speed and scale of global changes and the crises of the 2020s have proven the rate of change in the operating environment and target state. The importance of the green transition and ensuring the security of supply have been emphasized. In wood production and nature management a ten-year period is short. However, there is an immediate need for the measures, and the impacts will be there for decades. The vision work aimed to review the future development over acute crises and respond to the identified megatrends concerning the forest sector. The development path was reviewed based on other parties' megatrend descriptions and interviews with stakeholders. The vision includes three focal points: 1) the vitality of nature and wood production capability of forests are taken care of with the help of diverse forestry and nature management, seeing to the property of forest owners, 2) wood supply operations are cost-, energy- and environmentally efficient and 3) the use of technology is being enhanced, technology is being embedded in everything and the data economy shares information efficiently. The R&D actions derived from the focal points were formulated under five topics, 1) nature management and social responsibility, 2) people, 3) climate change and availability of wood raw material, 4) resource-efficient wood procurement, and 5) information. Although the vision work was coordinated by Metsäteho, it is intended to be a vision for development in all Finnish wood supply sector. R&D is carried out in extensive cooperation with different research sectors in Finnish as well as international joint projects. Metsäteho will implement the vision for its part in accordance with its resources and expertise.

Keywords: wood supply, wood procurement, harvesting, logistics, vision

INFLUENCE OF TWO TYPES OF FLOTATION BOGIE TRACKS ON CONTACT PRESSURE DISTRIBUTION

LORENZ BREINIG[1]*; HENRIK BROKMEIER[1]; DIRK JAEGER[1]

[1]University of Göttingen

Corresponding author: lorenz.breinig@uni-goettingen.de

ABSTRACT

Flotation bogie tracks are widely used to mitigate soil deformation and retain machine mobility when operating wheeled forest machines on soils with low bearing capacity. While all of these tracks have flat and wide track pads in common, there is considerable variety in actual track-pad shape among available track types. Two types of flotation bogie tracks from manufacturer Olofsfors AB were assessed in a test facility for measuring static contact pressure distribution via foil sensors installed under a homogenous sand layer. Rasterized images of contact pressure distribution were obtained for both track types as well as for bare tires as a reference. Applied wheel loads of 30, 45 and 60 kN were tested in combination with tire inflation pressures set to 250, 350 and 450 kPa for each track type and the reference. Both track types were found to significantly reduce mean contact pressure by significantly increasing contact area, but the track type with completely flat track pads had a markedly greater effect than the type having track pads with recessed lateral ends, especially with the highest wheel load tested. Furthermore, the track type with completely flat track pads was particularly effective in reducing peak mean contact pressure, defined as the highest mean contact pressure of a square area of approximately 160 cm2, or 25 sq.in, by achieving a more uniform pressure distribution over the entire contact area. While these observations under standardized and static conditions cannot be directly transferred to field conditions and the dynamic load transfer of a moving forest machine, they suggest that the efficacy of bogie tracks to reduce soil deformation during forest operations strongly depends on the proper choice of track type.

Keywords: Soil protection, off-road traffic, machine mobility, terramechanics, mechanized forest operations

INDUSTRIALISATION AND FORESTRY 5.0 – DIGITALISATION AND AUTOMATION

CAROLA HÄGGSTRÖM[1]*; ERIK ANERUD[1]; CAMILLA WIDMARK[1]

[1]Swedish University of Agricultural Sciences

Corresponding author: carola.haggstrom@slu.se

ABSTRACT

Forestry and the export-oriented forest industry play a vital role in the Swedish economy. The highly mechanized forestry industry is highly dependent on rapidly changing digital technologies; remote sensing technologies are standard in forest management and planning, most forest machines are partly automated, GPS systems help drivers navigate the site, and an information system store data on almost every action the driver or the machine performs. Cloud technologies support the sharing of production data from the forest machines to the customers and the road transport fleet. However, the potential of digital technologies is unutilized within the Swedish forestry industry. Large-scale organisations dominate forest management services in Sweden, whose core business model focuses on timber production and trading. The industry is working according to a traditional value chain, hence omitting the digital transformation. The digital transformation can be understood as the industrial revolution processes, where the aim of the most recent Industry 5.0 is to support industries in bringing together digital and green transitions with a sustainable, human-centric and resilient European industry. Industry 5.0 moves from pure profit-driven activities and acknowledges societal needs in which innovation should also add value to all involved, from owners to workers, consumers, society, and the environment. Hence, digital and new technologies are essential enablers of the changes needed to deliver the European green deal. Together with the Industry 5.0 vision, it will play a key role in fulfilling the sustainability goals and the bioeconomy transformation. However, when adding the challenge of industries' green transition to the challenge of embracing digital technologies in contemporary firms, it is critical to explore the level of digitalisation in the Swedish forest industry and what bottlenecks there are in further digital transformation efforts. This study aimed to evaluate how the Industry 5.0 framework contributes to forest management processes in developing digital ecosystems and automation and establish perceived barriers. The current state of digitalisation, potential and obstacles of further digitalisation and autonomous operations were derived from stakeholders within the Swedish forest sector on three separate occasions in 2019 and 2020. Digital processes were studied based on qualitative data from interviews. After that, forest companies, forest owners' associations, contractors, manufacturers, and researchers were approached with a web-based survey followed by a subsequent workshop about future expectations, needs and obstacles of future autonomous forestry work. To conclude, the results showed that individual processes might be highly digitalised, but links between processes are underdeveloped or not digitalised, which means that digitalisation's full potential cannot be utilised. The Swedish forest sector is pushing towards further automation and system developments while stressing cost-effectiveness and the ability to increase sustainable forest management, i.e. Industry 5.0 solutions. Thus, the challenge is to connect those automated and digital processes into digital ecosystems to

make the forest management process even more efficient. Due to the many barriers and the significant push towards industry 5.0 solutions in forestry, this study identified a need for a forestry automation community that drives the automation issue and the forest sector's priorities through collaboration.

Keywords: Digitalisation, Forest management, mechanisation, digitalisation

TOOL OF TIME AND SPACE EXPANSION IN FORESTRY FOR DIGITAL TRANSFORMATION AND DESIGN

TOSHIO NITAMI[1]*; SYUNSUKE KANEKO[1]

[1]Foralgo, University of Tokyo

Corresponding author: toshio.nitami@gmail.com

ABSTRACT

The authors have constructed a regional forestry management system by creating a mathematical model that expresses a regional forestry design and business scenario and using tools in cooperation with each other. This system consists of three tools: GIS, 3D model design tool, and SD tool. A regional operation scenario is designed and constructed as a System Dynamics (SD) model, allowing for free time simulation studies of operating income and changes in forest conditions according to the scenario. The authors call the system that enables practical forestry DX, its structure, functions, and the services it provides the "Regional Forestry Design System." By linking with GIS data, the size and density of standing trees in a forest stand can be displayed in a 3D virtual space with a model corresponding to the tree species, allowing the model to be displayed in any forest at any time in the scenario. You can easily and efficiently grasp and understand the results of design through changes due to growth and maintenance.

Keywords: Forest Management, Scinario, System Dynamics, Harvest, 3D CG

AUTOMATIC DETECTION OF FOREST MANAGEMENT UNITS AS A BASIS TO OPTIMALLY COORDINATE PLANNING, FOREST OPERATIONS AND CONTROLLING IN FOREST ENTERPRISES

LEO GALLUS BONT[1]*; LIOBA RATH[1]; JANINE SCHWEIER[1]

[1]Swiss Federal Institute for Forest, Snow and Landscape Research WSL

Corresponding author: leo.bont@wsl.ch

ABSTRACT

Forest management, especially in Central Europe, provides numerous ecosystem services in addition to the provision of wood as a raw material. To manage these forests efficiently and in a target-oriented manner, both good forest management planning and efficient operational execution (harvesting operations) are required. Both are interdependent. To link both (planning with controlling and forest operations), it is essential to divide the forest into smaller areas, so-called forest management units (FMU). The goal is that FMUs can be managed and planned independently of each other. This means that each FMU should have a self-contained fine access and should be as homogeneous as possible with regard to other characteristics. We will present a spatial optimization model that automatically identifies FMUs. The optimization pursues three goals: FMUs should be as compact, spatially contiguous areas as possible (objective 1), within which forest management should be technically and operationally coordinated (objective 2), and the area should have as homogeneous properties as possible, such as the harvesting method used, the ecosystem service provided, or the administrative affiliation (objective 3). The model was developed and successfully tested in close cooperation with the Forest Service of Grisons in the Swiss Alps.

Keywords: Forest Management Planning, DSS, Spatial Optimization, Cable Yarding, Forest Operations

SIMULATING TIMBER LOGISTICS BASED ON A TRUCK TERMINAL – CASE NORTHERN FINLAND

PERTTU ANTTILA[1]*; KARI VÄÄTÄINEN[1]

[1]Natural Resources Institute Finland

Corresponding author: perttu.anttila@luke.fi

ABSTRACT

The majority of timber harvested in Finland is transported directly from forest road-side to forest industries. With increasing needs to reduce emissions from transport sector and to secure even timber supply with limited number of truck drivers, truck-terminal-based logistics could offer several benefits. Even if diesel trucks and skilled drivers were necessary in inbound logistics, outbound logistics could be handled with HCT and/or alternative power sources and less experienced drivers. Furthermore, truck-terminals would enable collecting single-assortment loads and 24/7 timber supply to large biorefineries. A trucking entrepreneur is willing to invest in a terminal, but would like to know, e.g., which location and size is optimal, what is the best alternative for outbound logistics, and whether a separate loader is needed in the terminal. To assess the effect of various parameters on the transport costs and CO2 emissions a discrete-event-simulation model is being developed. The procurement region covers approximately 2.5 mill. ha in the northern part of North Ostrobothnia province from coast to the eastern border of Finland. The data on road-side storages consist of 4083 storage points from a large forest company. A number of terminal-based scenarios will be formulated and compared to the business-as-usual scenario, i.e., direct truck transport. Finally, the unit costs, resource needs and emissions of the scenarios will be reported.

Keywords: discrete-event simulation, log truck, pulpwood supply, timber terminal

MULTISPECTRAL SATELLITE TIME SERIES FOR OPERATIONAL MONITORING OF OAK FOREST DIEBACK

FLORIAN MOURET[1]; CÉCILE VINCENT-BARBAROUX[2]; EMMANUEL CACOT[1]*

[1]UNISYLVA; [2]University of Orléans.

Corresponding author: florian.mouret@univ-orleans.fr

ABSTRACT

This study focuses on the analysis of oak dieback in forests of the Centre-Val de Loire region, France. The main objective is to evaluate the interest of multispectral satellite time series for operational monitoring of forest dieback. Thanks to the in-situ data collected from 2017 to 2022 on about 2700 oak plots, a multi-tile and multi-year mapping of the analyzed area was performed using a supervised classification approach. Our results show that it is possible to map forest dieback at a large scale (overall accuracy = 80% and balanced accuracy = 79%). More importantly, this study highlights the importance of training sample selection, which is done using data augmentation techniques to have a better generalization over years. The learned model can also be used for operational mapping of forest condition in the coming years, for which the accuracy is slightly reduced and varies in the range of 70-80%. Overall, both in situ data and model predictions showed evidence of forest decline in many areas of the study region. Furthermore, our results show that large areas of forest can decline over short periods of time, highlighting the interest of satellite data in providing timely and accurate information on forest status at large scales. This encourages the use and improvement of such approaches in the future, especially in the context of climate change.

Keywords: dieback, oak, climate change, multispectral satellite data

HIGHLY MECHANIZED AND MOTOR-MANUAL HARVESTING TECHNOLOGY IN SRC

FRANK BURGER[1]*; BETTINA WIDMANN[1]

[1]Bavarian State Institute of Forestry

Corresponding author: frank.burger@lwf.bayern.de

ABSTRACT

The Bavarian State Institute of Forestry has been involved in the experimental cultivation of fast-growing tree species on agricultural land, so-called short rotation coppice (SRC), for thirty years. In addition to yield and ecological studies, the main focus is on the harvesting of SRC. The main goal ist the production of energy chips as climate neutrally as possible and of course with low cost. Some of the experimental plots have resprouted for six times; the plantations are already in the sixth rotation period. A whole range of harvesting chains - from motor-manual to highly mechanized could be tested so far. The poster presents the result of orienting working time studies carried out on the harvests. The harvesting chains are analyzed in terms of their costs and technical labor productivity, and the results are presented.

Keywords: SRC, Energy Chips, Resprouting, Harvest

AGILE FUELBREAK MAINTENANCE WITH MULTIPURPOSE EXCAVATORS EQUIPPED WITH MINI-WINCH

MARTINO ROGAI[1]*; CARLA NATI[1]; GIANNI PICCHI[1]

[1]CNR - Italian National Research Council

Corresponding author: martino.rogai@ibe.cnr.it

ABSTRACT

Wildfires are an increasing threat to the Mediterranean forests. Among the preventive measures adopted, the establishment of a network of firebreaks, fuelbreaks and shaded fuelbreaks has been considered strategic to reduce the risk of wildfire occurrence and enhance the efficiency and safety of the firefighting actions. Yet, in order to maintain the effectiveness of such infrastructure, a timely and cost-effective maintenance is required. In fact, without a proper management a fire- or fuelbreak may quickly be invaded by vegetation, reduce its accessibility and the capacity to reduce the wildfire intensity. In some cases, this dynamic may even lead to an increased speed of wildfire spread compared to the absence of firebreak . Given the above scenario, agile and effective work systems for the management of wildfire preventive infrastructures are crucial to maintain their value and function over time. At present, a plethora of solutions are used, depending on the local equipment and expertise. The availability of public funding is also a critical factor, as these forest works are typically non self-sustainable from the economic point of view. The present research tests the possibility to deploy an agile semi-mechanized work system based on mini-excavator to perform the tasks of biomass removal from unattended fuelbreaks, featuring a mixture of trees and invasive shrubs. As an additional challenge, the areas involved featured several environmental restrictions to forest operations, requiring low-impact systems. For the purpose, a common mini-excavator had been equipped with a mini-winch for the extraction of trees and, where possible, shrubs. Shear, grapple and mulcher attachments had been used to remove the remaining vegetation and slash, converting the prime mover in a multi-purpose equipment. This system has been compared with a semi-mechanized solution where manual work is supported by farm tractors equipped with winch and/or mulcher. In both cases, the resulting products and by-products had been segregated and piled in order to maximize their value for local production of energy and added-value manufacts, enhancing the overall economic balance of the operations.

Keywords: wildfires, preventive silviculture, forest operations, excavator, fuelbreak, wildfire prevention, mini-winch

INNOVATIVE SYSTEM TO ENHANCE SYNTHETIC ROPE IN FOREST OPERATIONS

GERARD ALCOVERRO POCH[1]*; ADRIANO RADDI[1]; GIANNI PICCHI[2]

[1]Forest Science and Tachnology Center of Catalonia; [2]CNR-IBE.

Corresponding author: gerard.alcoverro@ctfc.cat

ABSTRACT

In the Mediterranean forestry sector, most companies are still working with low degree of mechanization (e.g. farm tractors) to decrease logging costs, the missing adoption of synthetic rope (Ultra-high-molecular-weight polyethylene) is one of the consequences. Yet, synthetic rope allows to improve winching productivity and operations ergonomics (Ottaviani, G. et al., 2011 and Magagnotti, N. and Spinelli, R., 2011). The main aim of this study is to adapt the synthetic rope to the specific requirements of winching hauling. Namely, it addresses the demand of the local forest companies to create an effective splice between synthetic and wire ropes. This is based on the observation that the main wear of the synthetic rope was concentrated in its last few meters due to the high friction induced by sliding against the choker chain or the timber (when the cable is used directly as choker). The hypothesis is that a hybrid system, connecting both cable with a splice, provides the comfort of the synthetic rope and the robustness of the steel cable (deployed just in the last few meters). The present study aims at assessing the reliability, utility and economic benefit of the synthetic and wire rope splice compared to pure synthetic rope. To compare the two cable systems, these were installed in different forest machinery (winch on farm tractor or skidder) and installing terminal steel chockers or chains. Data was collected by means of records filled out by the same operator, noting work conditions, production and damages. The results confirms that the wear of the synthetic rope is concentrated in its last few meters. However, the wear intensity (expressed as meters of cable lost) varies significantly depending on the surface involved in friction: an average of 30 m of cable were lost after hauling 1.000 t sliding mainly against wood, reduced to 15 m of cable lost per 1.000 t of timber hauled with choker chain. In our test the splice proved too bulky to get out from inside of farm tractors winches, while it could be easily integrated in the skidders. Nevertheless, the hybrid cable lasted about 450-500 t of extracted roundwood. Results show that it is necessary improve the splice between synthetic and wire ropes, providing better reliability and a narrower hybrid cable suitable for farm tractors and choker chains. Currently, a heat shrink cover has been studied to increase resistance of splice protecting it again steel cable.

Keywords: synthetic cable, steel cable, splice, forest operations, safety, winch, hauling

INTENSIFY WOOD HARVESTING TO SUPPLY THE BIOECONOMY: IMPACTS ON SITE REGENERATION AND COST-EFFECTIVENESS

CLAUDIE-MAUDE CANUEL[1]*; EVELYNE THIFFAULT[1]; NELSON THIFFAULT[2]

[1]Université Laval; [2]Canadian Wood Fibre Centre (Natural Resources Canada).

Corresponding author: claudie-maude.canuel.1@ulaval.ca

ABSTRACT

Climate change mitigation requires worldwide modifications in energy consumption and production to replace fossil energies. Biomass from forests is an important feedstock for the energy transition, but high supply costs impede the profitability of forest bioenergy. Moreover, the high variability in stand characteristics of Canadian forests represents an operational challenge for biomass procurement. Integrating forest biomass procurement into the process of wood procurement, which involves harvesting operations for conventional products, and incorporating it into silvicultural operations for site renewal, has the potential to reduce bioenergy system supply costs. This approach can be implemented in accordance with sustainable forest management principles. In that context, we aimed to identify stand characteristics that would favour biomass supply in the form of trees and tree sections in temperate and boreal forests of eastern Canada. We hypothesized that increasing harvesting intensity in response to a diversifying wood market that includes biomass procurement would decrease the volume of post-harvest woody debris across sites, then favour regeneration. We also hypothesized that the additional costs incurred to procure forest biomass for bioenergy would be negligible relative to overall harvest costs, and partly offset by silvicultural savings for site renewal. We compared four wood procurement treatments of increasing intensity (from harvesting only sawtimber to harvesting sawtimber, pulpwood and biomass for bioenergy) using a randomized block design at different sites, which presented a gradient of stand characteristics. We assessed regeneration success and silvicultural needs for site renewal by using data from field surveys to perform model selections and principal component analyses. We performed a financial analysis by using on-board computer data as inputs. Increasing harvesting intensity significantly impacted the volume of post-harvest woody debris across six sites. However, the effects of woody debris volume on regeneration were inconsistent and varied as a function of pre-harvest stand characteristics. We observed an inverse relationship between woody debris cover and the presence of planting microsite of good quality, but woody debris had little influence on natural regeneration. Procuring biomass for bioenergy did not affect feedstock unit costs (CAD m^-3) at three sites and had limited impact on average harvest costs (CAD ha^-1) for low-density mixedwood stands with large trees. High-density coniferous stands with small trees generated more feedstock for bioenergy (up to 50 m^3 ha^-1) than other stand types, but biomass procurement increased average harvest costs. The cost-effectiveness of the wood supply chain did not vary significantly along the wood procurement intensity gradient we studied when silvicultural savings were considered. Our study supports that conifer-dominated stands were more responsive than other stand types to harvest intensity in terms of regeneration success and cost-effectiveness of forest operations. The relationship between market needs and regeneration should be addressed as a site-specific issue in forest management and

silviculture practices. The intensity of biomass harvesting, stand characteristics and market conditions proved to be important factors influencing wood procurement profitability. Our findings contribute to the development of effective strategies for climate change mitigation and sustainable forest management in Canada and other forested regions facing similar challenges.

Keywords: biomass, harvest costs, silviculture, cut-to-length harvesting, climate change mitigation

THE QUANTIFICATION OF PINUS PATULA RECOVERY AND PRODUCTIVITY OF MANUALLY ORIENTATED BIOMASS COLLECTION IN POST MECHANISED FULL TREE AND SEMI MECHANISED TREE LENGTH HARVESTING OPERATIONS

THANDEKILE NCONGWANE[1]; MUEDANYI RAMANTSWANA[1]*; RAFFAELE SPINELLI[2]; ANDREW MCEWAN[1]

[1]Nelson Mandela University; [2]CNR IVALSA.

Corresponding author: muedanyi.ramantswana@mandela.ac.za

ABSTRACT

The use of biomass as an alternate source of energy has grown in popularity. Globally, plantation forest biomass harvesting has mainly been achieved through semi and fully mechanised systems because of their high yields. However, the use of manual systems has been neglected due to technical limitations and financial viability. Thus, in South Africa, there is no scientific research looking at manual systems of collecting biomass from plantations. This research examines the productivity of the manual biomass collection and the quantification of recovered and unrecovered residues after mechanised full tree (FT) and semi mechanised tree length (TL) harvesting operations in Pinus patula compartments. A total number of 8 plots with +/-200 standing trees were marked in each system. The diameter and height of all marked trees were measured to determine tree volume. Moreover, the quantification of recoverable woody biomass was determined, where after, a residues assessment method using plots and line transects was used to determine the amount of unrecovered residues. The time taken for each operation including motor manual processing, manual extraction, and manual loading was assessed to determine the productivity (hours per ha and oven dry tons). In the FT system, the results showed that the mean standing volume and log recovery was 91.5 m3/ha and 73.6 m3/ha respectively. In this system, the woody biomass recovered after conventional harvesting was 5.2 odt/ha. The productivity results revealed that motor-manual processing took 2.7 h/ha, manual extraction 9.9 h/ha and manual loading 5.6 h/ha. Manual extraction was the least productive operation as it took 2 h/odt whilst motor manual processing and manual loading took 0.6 h/odt and 1.1 h/odt respectively. For the TL system, the results revealed that the mean standing tree volume and log volume was 61.5 m3/ha and 50.2 m3/ha, respectively. In this system, the woody biomass recovered after conventional harvesting was 9.1 odt/ha. The productivity results revealed that motor-manual processing took 7.2 h/ha, manual extraction 23.8 h/ha and manual loading 9.9 h/ha. Manual extraction was the least productive operation as it took 2.8 h/odt whilst motor manual processing and manual loading took 0.8 h/odt and 1.1 h/odt respectively. For the unrecovered residues, the results showed that the FT system yielded 17.1 odt/ha whilst the TL system produced 12.7 odt/ha. The stemwood and branches were the largest parts remaining after harvest in both systems. The TL system had more woody biomass left on site while FT had less woody biomass left on site after harvesting. The TL harvesting system cost was ZAR/ha (827.9) and ZAR/ODT (95.9) whilst the FT system cost was ZAR/ha (378.3) and ZAR/ODT (75.6). The quantification of woody biomass recovery, manual collection productivity and cost

estimates provided in this research will serve as important baseline information for forestry companies and contractors involved in this field.

Keywords: woody biomass, unrecovered residues, productivity, FT and TL harvesting system

INDIVIDUAL LOG IDENTIFICATION TO IMPROVE SUPPLY CHAIN EFFICIENCY

KEITH RAYMOND[1]*; ANDY DICK[2]

[1]Forest Growers Research Limited; [2]Logjiztix Limited.

Corresponding author: keith.raymond@fgr.nz

ABSTRACT

Forestry in New Zealand uses load delivery dockets to track logging production and delivery of log products to customers. For export logs, a separate system of individual log tagging is used whereby paper tags are manually attached at log scaling stations and ports. Log tracking and traceability through individual log identification (LogID) using Radio Frequency Identification (RFID) was exhaustively studied in Europe in the early 2000s (Indisputable Key project) but no alternative system to manual application of tags has been widely implemented. Forest Growers Research Ltd (FGR), New Zealand forestry's research and development company, reviewed the benefits and costs of RFID for individual log tracking and traceability, along with other technologies, such as ink-jet printing. The review found that systems that attach tags, with plastic or metal components, were not desirable, from both a labour point of view attaching tags and reloading tag applicators, and from a contaminants point of view further down the supply chain. An alternative system, using unique LogID punched into the log end, has been developed by Otmetka AB of Uppsala, Sweden. Benefits include: providing a standardized solution for log product tracking and traceability for the whole log supply chain; potential cost efficiency compared to current paper tag or RFID systems; and opportunities for further efficiencies to be introduced in the downstream supply chain. A project in the 'Forest Work in the Modern Age' Primary Growth Partnership managed by FGR and co-funded by the Ministry for Primary Industries, was commenced in 2019, in collaboration with Otmetka AB, to develop a punch code individual log marking system. Rather than pursuing RFID technology, FGR decided that the Otmetka Log Marker could provide a lower-cost log tagging solution. Otmetka AB signed an agreement with FGR in March 2020 and a New Zealand-based subsidiary of Otmetka AB, Otmetka New Zealand Ltd (ONZ), was formed. A collaboration has been developed between ONZ and two New Zealand manufacturing partners, Engineering Services (Rotorua) Ltd, manufacturer of Woodsman brand processors, harvesters, and feller-bunchers and Pocket Solutions Ltd, a mobile communications technology company. FGR has collaborated with ONZ and Engineering Services (Rotorua) Ltd to install and field test the Log Marker on a Woodsman log processor. Otmetka and Pocket Solutions Ltd (PSL) have also collaborated to develop a solution for an individual log mark reading system. PSL is developing a mobile reader, under NZ logging conditions. To date, design, and development of a first prototype of the Otmetka Log Marker has been completed. Early testing of the workshop-based prototype indicated log stamping time of 300ms (0.3 sec) which is well within the time taken between saw cuts in logging operations. The first prototype Otmetka Log Marker has been installed on a Woodsman 750 model processor. Until the Otmetka Log Marker is tested in an operational harvesting situation we will not know if it is going to be a

commercial success. Testing and verification of the original business case is ongoing and further results will be presented.

Keywords: individual log identification, log punch code, log tracking and traceability

AUTOMATIC LOAD SECURING SYSTEM FOR IMPROVED LOG TRANSPORT

KEITH RAYMOND[1]*; JARED SILVESTER[2]

[1]Forest Growers Research Limited; [2]Trinder Engineers Limited.

Corresponding author: keith.raymond@fgr.nz

ABSTRACT

The forest industry in New Zealand, like many other forest industries around the world, is experiencing labour shortages, as a result of changing demographics, and generational preferences for work. Currently, there is a major research and development programme underway in New Zealand, called Forestry Work in the Modern Age, managed by Forest Growers Research Ltd (FGR), the New Zealand forest industry's research and development company, and co-funded by the Ministry for Primary Industries. It is aimed at development of further mechanisation, automation and robotics in the harvesting and log logistics part of the forestry value chain. One project in this programme is Automated Log Load Securing. This project commenced in 2021, in collaboration with the Trinder Group, comprising Trinder Engineers Limited, a general engineering company and Waimea Engineering, a transport development and certification company operating in the primary and construction sectors in New Zealand. The project has developed an automated log truck load securing system that eliminates manual chain throwing and manual chain tensioning; maintains the required load restraint tension automatically throughout the trip; and enables in-cab monitoring of load restraint status to alert the driver of any issues. Other developments in log load securing, such as the ExTe Com90 automatic load restraint, and the ExTe TU automatic tensioners are available but have limitations such as high cost. The Waimea Load Securing System, WASP, comprises Chain Throwers (CT) fitted internally to each stanchion to place the chains over the load mechanically, Auto-Tensioner (AT) winches mounted adjacent to each stanchion/bolster to tension the chains and maintain the required load restraint tension automatically; and a Load Monitoring System (LMS) via load pins (strain gauges) fitted into each chain's anchoring shackle. The tension on the chain is transmitted to an in-cab monitoring system via Bluetooth to give an audible alarm if there is a change in tension status. The WASP system aims to be cost competitive with these other commercial products but also offering the New Zealand log trucking industry a local solution designed for New Zealand conditions; higher tensions achieved with AT (than ExTe TU tensioner); plus load monitoring capability with communication through to the In-Cab Display; and the option of an integrated AT/LMS. The prototype system was launched at the TMC Trailers Trucking Show in Christchurch in November 2022. The key benefits of the system to date have been reduced workload of truck drivers in securing chains over the load and tensioning those chains, reduced risk of injuries thus helping to meet the industry's zero injury goal, and opening log transport job opportunities to a wider demographic, including people who are less physically strong. The only negative impact identified so far has been increased cost of log transport. Field testing of the prototype system continues, and results will be presented.

Keywords: Log transport, load securing, log logistics, worker safety, ergonomics

GROUTED ROCK ANCHORS FOR CABLE YARDERS: A NEW ZEALAND CASE STUDY

PATRICK HUMPHREY[1]*

[1]University of Canterbury

Corresponding author: patrick.humphrey@pg.canterbury.ac.nz

ABSTRACT

In forestry operations, finding suitable guyline anchors can be challenging, especially when deadmen or mobile anchors are not viable options. Grouted rock anchors are commonly used in mining and civil infrastructure industries to stabilize slopes or tie-down transmission towers. This study evaluated three key processes required for using grouted anchors in cable logging operations: anchor design, installation, and testing. It was based on three grouted rock anchors where installed in the Central North Island of New Zealand installed on a landing where the topography resulted in minimised landing size. Anchor design involves considering five design components, including tendon type, diameter, embedded length, shape, and grout properties. These components when modified correctly can increase holding capacity, reduce the risk of certain failure modes but often increase costs. The correct installation of the anchor is critical and requires careful attention to the anchor's orientation, centralization, and grouting process. Lastly, two testing protocols, sacrificial and acceptance testing, are relevant to guyline anchoring. For this research an acceptance test was used to ensure that the design load was appropriate for the operating conditions and that the ACOP (Approved Code of Practice) requirements were met. Each of the three anchors was loaded to 36 tons using a hydraulic jack, totalling 108 tons when rigged in tandem. The total maximum displacement of the anchor was 46 mm, which was due to the deformation of the thimble and stretching of the tendon. This displacement had negligible effects on the holding capacity. The findings of this study have implications for forestry operations, particularly in steep terrain where conventional anchor options may be limited. Grouted rock anchors can potentially provide an environmentally friendly and efficient option for guyline anchoring. However, it is important to note that the successful use of grouted anchors in forestry operations requires careful consideration of the anchor design, installation, and testing processes. Future research could investigate the long-term performance of grouted anchors in forestry operations and evaluate their economic feasibility. Overall, this study provides valuable insights into the use of grouted rock anchors as an alternative to conventional anchors in forestry operations. Further research and implementation of this technology could potentially improve the efficiency and safety of forestry operations, particularly in challenging terrain.

Keywords: Anchoring systems; steep terrain; safety; installation testing design

INTEGRATION OF INDUSTRY 4.0 CONCEPTS FOR OPTIMISING CABLE YARDER OPERATIONS

PATRICK HUMPHREY[1]*; RIEN VISSER[1]; RAFFAELE SPINELLI[2]

[1]University of Canterbury; [2]IBE, CNR.

Corresponding author: patrick.humphrey@pg.canterbury.ac.nz

ABSTRACT

Industry 4.0 represents the coming of the fourth industrial revolution. Industry 4.0 covers emerging technologies that are likely to create a paradigm shift in the way industrial operations are conducted and significantly boost productivity. These technologies include the Internet of Things/Services (IoT/S), Cyber-Physical Systems (CPS), Augmented Reality, Automation and Big data. The cable yarder manufacturing industry has the opportunity to improve its operations by incorporating several of these technologies. Key steps in integrating Industry 4.0 include developing current technologies around automation and the technology to predict and take corrective action based on a live data feed. Those at the forefront of Industry 4.0 technology in forestry have achieved live data collection from machinery. For example, live data feed can be used to determine real-time productivity statistics of machines, reengineering the way productivity/time studies are conducted. This fall short in terms of using the data to improve operations and or manufacture. The next logical step is to establish a functioning 'Internet of Things' system where there is machine-to-machine and machine-to-cloud data transfer of all machines in an operation. This technological advancement sets the basis for using Big Data and Artificial Intelligence to analyse and make decisions based on parameters and patterns within the dataset. Working with three cable yarder manufacturers in both Italy and New Zealand, this research uses live data feeds and 'machine learning' to establish preventive and predictive maintenance of machinery. The goal is to develop programs can alert operators that their actions are increasing the rate of failure of parts, that parts are becoming to warn or broken or that oil/lubricant needs to be replaced. This project is being completed within the scope of a Masters with data collection starting in March, and analyses starting in July.

Keywords: Technology, automation, manufacture, maintenance, machine learning, big data

FORESTRY DIGITIZATION USING BUSINESS DESIGN OPTIMIZATION TOOL AND 3D DISPLAY TECHNOLOGY

SHUNSUKE KANEKO[1]*; TOSHIO NITAMI[1]; TAKUYUKI YOSHIOKA[1]; HYUN BAE KIM[1]

[1]University of Tokyo

Corresponding author: dpedr01a@g.ecc.u-tokyo.ac.jp

ABSTRACT

System dynamics (SD) is a simulation method that predicts the behavior of a system by describing the change of an object for a time step Δt using a mathematical formula. SD is applied in various fields including natural science, because it can represent systems with complex nonlinear changes. The authors constructed an SD model to understand changes in forest conditions due to forest operations, enabling business design in regional forestry. This model incorporates an optimization tool that adjusts parameters by grid search, which is mainly used to adjust hyperparameters in machine learning models, making it possible to optimize the feasible amount of forestry business. The objective function and the parameters in the model can be arbitrarily arranged, making it possible to design business projects according to the intentions of forest owners and forestry entities. In addition, income and costs can be calculated by estimating the amount of harvested timber and working hours for each operation. The governmentally published data and previous studies were used as a reference for required values. These results make it possible to select favorable management scenarios from various criteria such as labor input, changes in forest carbon accumulation, and profitability. Lastly, changes in the forest based on the scenario can be visualized in 3D space, in which the forest condition reflects tree density and standard tree height for age. The attributes of the forest are georeferenced with GIS, and the coordinates of the stands can be matched to the terrain mesh by using the game engine Unity extension package. In the future, it would be possible to identify the coordinates of each single tree using point cloud data (PCD) and create an accurate digital twin. Though processing using high-performance GPUs is required when reproducing images over a wide area, these digital technologies are expected to promote the utilization of forest resources.

Keywords: System Dynamics, Mathematical simulation, Optimization, 3D model, GIS

CARBON FOOTPRINT OF NEW ZEALAND'S LOGGING OPERATIONS

SIMON SMITH[1]*; DOUGAL SHEPHERD[1]; RIEN VISSER[1]

[1]University of Canterbury

Corresponding author: simon.smith@pg.canterbury.ac.nz

ABSTRACT

As many sectors within New Zealand and around the globe race to decarbonise, the forest industry is beginning to experience some of this early pressure. This process begins with identifying a current carbon footprint. Currently, there is little research on the emissions produced by harvesting operations, especially the comparisons between different extraction methods. This report focuses on capturing the carbon footprint estimates for harvesting crews in New Zealand. It demonstrates a simplified methodology for emissions reporting and outlines the potential advantages and disadvantages for forest managers and harvest crews to measure emissions. In order to estimate carbon footprint, a crucial first step is to set the 'scope'. The Scope defines the extent that carbon is included or excluded in the analyses. 'Scope 1' has been used and specifically focuses on 'direct GHG emissions and removals'. For logging operations, fuel use is expected to contribute to over 90% of the total carbon footprint under Scope 1. Hence the focus was on the collection of fuel use data primarily through a survey of forest managers and crews. Overall, 55 crews across multiple harvesting sites were recorded. This included 30 ground-based, 13 swing yarder and 12 tower yarder crews with an average number of machines of 4.8, 8.1 and 7.4. Fuel use (diesel) ranged from 1.2 - 11.2 L/m3 (average of 3.67) for ground based, 2.8 - 9.1 L/m3 (4.3) for swing yarder, and 2.0 - 11.3 L/m3 (5.0) for tower yarder crews. Carbon footprint is reported in tonnes of CO2 equivalent (tCO2e), and published fuel to CO2e conversion factors provided from the New Zealand government are used. Overall, a similar trend in both total and per m3 logged carbon footprint was observed. The tower yarder (hauler) crews proved to have the highest, with an average of 920 tCO2e /annum and 14.5 kgCO2e /m3 respectively. Swing yarder crews averaged the next highest (770 tCO2e/annum and 12.4 kgCO2e /m3) with ground based resulting in the least (685 tCO2e/annum and 10.5 kgCO2e /m3). The current key benefits of GHG reporting in New Zealand were to prepare for potential disclosure requirements, potentially reduce costs long term, have better investment/financing opportunities and help reach the nation's net-zero targets. Drawbacks included costs, time, and reporting not necessarily making reduction action occur.

Keywords: carbon emissions fuel burn climate change greenhouse gas

DEVELOPMENT OF AN AUTOMATIC DRIVING FORWARDER USING IN COMBINATION WITH LIDAR-SLAM AND GNSS

MASAHIKO NAKAZAWA[1]*; DAI OTSUKA[1]; SEISHIRO TAKI[1]; CHIKASHI YOSHIDA[1]; HIROKO MUNEOKA[1]; MASAHIRO IWAOKA[2]; YASUO NAKASHIMA[3]; ATSUSHI MATSUI[4]

[1]Forest Research and Management Organization Forestry and Forest Products Research Institute; [2]Tokyo University of Agriculture and Technology; [3]Morooka Co., Ltd.; [4]Panasonic Advanced Technology Development Co., Ltd..

Corresponding author: naka1978@ffpri.affrc.go.jp

ABSTRACT

There are problems of ensuring safety and decreasing number of forestry workers and so on in forestry section. For this reason, automation and remote control of forestry machine operations are required. In Japan, a large part of the forest is steep terrain and out of mobile phone range, it is difficult to estimate accurate self-position using RTK-GNSS (Ntrip). SLAM (Simultaneous Localization and Mapping) is useful in these conditions, but it has only relative coordinates. For example, it could not cooperate with existing GIS because it is not absolute coordinates. Japanese popular forwarder is rubber crawler type, and one of the bottlenecks for Japanese harvesting system is forwarding due to its lower labor productivity. Therefore, an automatic driving forwarder was developed using in combination with LiDAR-SLAM and GNSS. As a result, we succeeded in automatically driving a long uphill strip road with steep gradient, complex shape and soft ground. These developed techniques could be applied to other forests around the world.

Keywords: forwarder, automatic driving

MEASURING THE WORKLOAD OF RUNNING FORWARDER VEHICLES FOCUSING ON MACHINE MOVEMENT

CHISA NAKATA[1]*; HIROKAZU YAMAGUCHI[1]; YUTA INOMATA[1]

[1]National Research and Development Agency Forest Research and Management Organization

Corresponding author: nakatac27@ffpri.affrc.go.jp

ABSTRACT

Workload of wood transportation using forwarder is a heavy burden because of running on unpaved roads, especially in Japan with steep terrain. However, the effect of working conditions during running forwarder is not clear. Therefore, to assess the workload of forwarder running, we measured heart rate changes of operators due to individual working conditions. The running tests on forest roads was conducted in July 2022 using forwarder (MST-650 VDLⅢ, Morooka Co., Ltd.) at Forestry Mechanization Center, Ministry of Agriculture, Forestry and Fisheries. Heart rate was measured using a wearable heart rate sensor (WHS-1, Union Tool Co.). As working conditions, the movement of forwarder was measured using inertial measurement unit (NGIMU, x-io Technologies Ltd.). From the aircraft attitude angle and sprocket rotation speed, travel distance, travel speed, tilting vehicle, and turning angular velocity were calculated. Based on the results, the heart rate increased at low speeds during reverse travel by the forwarder. In addition, the aircraft tilted greatly in the vertical direction with sudden operation. Therefore, there was a possibility that it was difficult to operate in reverse due to poor visibility conditions.

Keywords: Running vehicles, Labor burden, heart rate, inertial measurement unit

COMPARISON OF FOREST ROAD PRISM MEASUREMENTS BY VARIOUS 3D MEASUREMENT TECHNIQUES

MSASASHI SAITO[1]*; MASARU WATANABE[1]; KENICHIRO TODA[2]; YUKIO SENGOKU[3]

[1]Iwate University; [2]Geo・Forest Co., Ltd.; [3]Nagano Prefecture Forestry Consultants Association.

Corresponding author: msaito@iwate-u.ac.jp

ABSTRACT

Proper maintenance of forest roads requires that changes in their geometry are regularly identified and acted upon. Regular measurement is particularly important because cracking and subsidence of the road surface can often lead to large-scale forest road collapse. Until now, the measurement of fine forest road prisms (road surfaces, slopes, ditches, etc.) has been carried out using total stations. This measurement method can measure fixed cross-sectional and longitudinal sections, but requires a great deal of effort to measure the three-dimensional shape. In recent years, aircraft LiDAR measurements have made it possible to measure the 3D shape of terrain and forest roads, but the resolution is only about 1 m grid and detailed changes in forest road prisms cannot be deciphered. In this study, therefore, UAV LiDAR(DJI L1), video-based SfM(DJI osmo), iPhone-LiDAR(iPhone 13 Pro), TLS(FARO S150) and conventional total station surveying of forest road and operational road were used to compare cross-section, longitudinal and the resolution of 3D data. The forest road to be measured is 3.5 m wide and gravel paved, while the working road is 3.0 m wide and unpaved. Both measured sections of about 200 m. First, transects were surveyed using a total station at intervals of approximately 20 m. Other 3D measurements were taken while leaving targets on the side lines to compare the transects. Next, UAV measurements were carried out. The point density was about 400 points/m2 and the DSM resolution was about 5 cm. TLS measurements showed a point density of 650 points/m2 around the forest road surface. SfM and iPhone LiDAR were measured while the operator was walking. All measurements provided more detailed forest roads prism than the total station. Challenges arose with each measurement method: the UAV measurements showed different geometries depending on how the noise from the shrub-layer vegetations was filtered out, and there were relative errors with the absolute coordinates. iPhone LiDAR measurements showed that the IMU errors accumulated as the distance increased and the 3D geometry became more twisted. increased. Video-based SfM required adjustments for noise etc. in the captured photographs; TLS measurements were easy to process data, but depending on the installation position, it was sometimes not possible to measure to the shoulder or the end of the slope.

Keywords: Forest roads prismP,3D measurement,LiDAR,TLS,UAV,SfM

OVERVIEW OF THE INTEGRITY CONDITIONS OF STEEL CABLES DEPLOYED IN TIMBER HAULING WITH MAGNETO-INDUCTIVE SENSOR: A CASE STUDY IN TUSCANY REGION (ITALY).

FABIO DE FRANCESCO[1]*; GIANNI PICCHI[1]

[1]CNR IBE

Corresponding author: fabio.defrancesco@cnr.it

ABSTRACT

Steel cables are among of the key components of forest operation, particularly in mountain and hilly areas were winches and yarders are the main equipment deployed for timber hauling. In spite of being proved to be heavy duty tools, the forest environment represents for steel cables an extreme condition, causing intense mechanical wear, thus reducing the tensile strength. Such damages may represent a significant treat for the safety of forest operators and the integrity of the equipment deployed. Yet, in the Italian forestry sector there is no specific regulation imposing periodic controls and relative protocols on the steel cables installed on forestry machinery. Such control is performed on a voluntary basis and by means of visual inspection by the operators themselves. These controls, when timely performed, have the additional drawback to focus just on externally visible damages of the cable: internal wire breaks are difficult or impossible to detect. In sectors involving transportation of persons, such elevators and cableways, dedicated standards impose periodical maintenance and inspections. In this case, the whole structure of the cables (external and internal) is assessed by means of magneto-inductive sensors which allow a fast and reliable check of wires integrity. Their application in the forest sector may represent a substantial increase in the prevention of accidents and damages due to cable failure. In the present paper we present a case study of magneto-inductive sensor inspection conducted in a pool of Italian forestry firms in Tuscany Region. The research will provide an overview of the data provided by the sensor on cables with different characteristics and functions (winches and cable yarders) and the wear conditions of the cables presently deployed by the local operators.

Keywords: Magneto-inductive, steel cable, mechanical wear, winching, yarding, safety and ergonomics

POTENTIAL OF THE GREEN REVERSE LOGISTICS IN THE PULP MILL SUPPLY CHAIN

ANGELO MOURA[1]*; SAULO GUERRA[2]; YOHANES NUWARA[3]; HUMBERTO EUFRADE[1]

[1]Sinarmas Forestry; [2]Sao Paulo State University; [3]Asia Pulp and Paper Sinarmas.

Corresponding author: angelo.c.moura@sinarmasforestry.com

ABSTRACT

The primary power source for the pulp industry comes from the planted forest. This industry passed for many technical improvements in the last decades, with its cycle almost closed, turned into an energy self-sufficient, and also selling the surplus energy to the market. The planted forest supplies the primary raw material not just for the pulp, as fiber, but also for energy, through biomass (residues, branches, and bark) and the lignin as the primary source that is burnt in the recovery boiler (in black liquor format). All the improvements and parameters that impact this well-developed industrial process are explored mainly in many existing studies in the literature. So, the purpose of this research is to analyze the potential to return the surplus energy to the pulp supply chain in a different way, specifically in logging transportation. With new energy, source trucks are being developed by different players, and demand to reduce gas emissions all over the globe, it may become a great opportunity, as a new technology breakthrough to the sector. Diesel consumption in log transportation has the highest utilization in the pulp production chain. This research intends to analyze the main steps of this chain in a specific pulp plant mill, looking at logistics real data, the energy balance in the mill, and its costs, to finally understand how feasible it is to change surplus energy destination, and potential for power losses uses as well. This study, we believe, will draw attention to this integration opportunity, to implement it in the current ones and also to be considered in the new pulp plant designs.

Keywords: hauling, energy matrix, alternative fuels

COMPARISON OF EUCALYPTUS STEM DIAMETER ESTIMATION FROM TERRESTRIAL LASER SCANNING POINT CLOUD DATA AND GROUND-BASED MEASUREMENTS

LADDAWAN RIANTHAKOOL[1]*; JIRAWAT YINGDEE[1]; THEERAPONG CHUMSANGSRI[1]; DETRIT SITTIBAL[1]

[1]Kasetsart University

Corresponding author: fforlwr@ku.ac.th

ABSTRACT

Stem diameter is an important variable in forest mensuration, with applications in growth assessment, stand density estimation, wood production, and carbon sequestration. Stem diameter is normally measure with diameter tape or calipers through ground-based methos. Terrestrial laser scanning is a technology of 3D model that can be used to measure the objects and environments via non-destructive method. The objective of this study is to compare the accuracy and precision of eucalyptus stem diameter estimation from terrestrial laser scanning (TLS) point cloud data and ground-based diameter tape measurements under light air wind conditions, in order to evaluate the potential of TLS for improving forest mensuration. The sample for this study consisted of 15 eucalyptus trees with an average diameter at breast height (dbh) of 13.51 cm and an average height of 18.54 m. Stem curves of standing eucalyptus trees were evaluated automatically from 3D forest program. The analysis of the data showed that the root mean square error (RMSE) of the estimated stem diameter using the TLS was less than 5 cm, with the best performance for position of trees that were lower than 7 m in height about 37.7% of the tree height. Under light air wind conditions, the results of this research demonstrated a high level of accuracy in the estimation of stem diameters for the lower portion of the tree.

Keywords: Stem curves, 3D model, LIDAR, wind, stem parameter, Eucalyptus

DOES BIOMASS HARVEST AND UTILISATION FOR INDUSTRIAL PURPOSES REDUCES GHG EMISSIONS BEYOND THE FOREST LANDSCAPE BOUNDARIES?

DIMITRIS ATHANASSIADIS[1]; ERIK ANERUD[1]; CARMEN CRISTESCU[1]*

[1]Swedish university of agricultural sciences

Corresponding author: carmen.cristescu@slu.se

ABSTRACT

Harvest of forest biomass results in a lateral C export flux and is associated with emissions from harvest machinery and transport trucks which altogether reduce the climate benefit of a managed forest landscape. Beyond the system boundaries of a forest landscape, however, biomass use can help achieving negative emissions through C storage in long-lived wood products, substitution of fossil fuels in the transport sector as well as substitution of energy intensive materials (e.g. concrete) in constructions. We have estimated and will present results on the biomass export from a forest landscape and per 1000 m3 of wood harvested. We evaluated the GHG emissions associated with three alternative biomass utilization cases: 1) Business as usual case in which timber and pulpwood are used for wood products and pulp production, respectively, while logging residues are used for energy production in a combined heat and power (CHP) plant. In this scenario, an increased biomass use in the construction sector was also accounted for. 2) Pyrolysis substitution case in which sawmill by-products are used for the production of pyrolysis oil at a CHP plant. In this case we further differentiate whether the pyrolysis oil is subsequently used to a) substitute fossil oil in the CHP or b) to produce methanol which is added to diesel fuel and thereby substituting some of its fossil fuel component. 3) Lignin substitution case in which lignin extracted from by-products in pulp mills is used for substituting fossil feedstock in the chemistry industry. The highest substitution effect (660 tonnes CO2 eq./1000 m3solid over bark) was noticed when 60% of the roundwood volume was used in the construction sector and sawmill by-products are used to produce pyrolysis oil which is used in the CHP plants instead of oil (Pyrolysis substitution case). The highest CO2 budget was observed in the lignin substitution case where the production of 25 tonnes of bioadhesive would result in an emission of 208 tonnes CO2 eq. These results will be used in order to obtain a complete GHG budget associated with forest biomass production by integrating forest landscape GHG fluxes with emissions and mitigation potentials of biomass extraction for energy and construction sectors.

Keywords: climate impact carbon flux harvest transport biomass-use scenarios substitution

IS IT POSSIBLE TO USE THE MACHINE MANAGEMENT DATA TO ESTIMATE THE EFFECTS OF SOIL AND TERRAIN ON THE FOREST MACHINE PERFORMANCE?

FILIPPO GUERRA[1]*; ALBERTO UDALI[1]; THILO WAGNER[2]; FRANCESCO MARINELLO[1]; STEFANO GRIGOLATO[1]

[1]Forest Education Center, Department V—Center for Forest and Timber Industry, State Enterprise for Forestry and Timber, Northrhine-Westphalia; [2]Department of Land, Environment, Agriculture and Forestry, Università degli Studi di Padova.

Corresponding author: filippo.guerra@wald-und-holz.nrw.de

ABSTRACT

The Cut-to-Length harvesting system is nowadays predominant in the field of mechanized forest operations, consisting in harvesters and forwarders forestry machines. These machines are equipped with an on-board computer (OBC) that collects a large amount of information concerning either machine parameters and harvested timber. Stream machine data are sent to the data management system of the machine on cloud. Data are stored and automatically summarized on hourly, daily, weekly or monthly basis. The present work aims at verifying whether the machine data summarized on an hourly basis by the machine management system can be used to evaluate the effects of terrain morphology, soil parameters, DTW map, weather-climatic conditions etc. (acquired at macro level through the geographic data portals) on the machine´s performance such as the fuel consumption and the related travelled traveled distance. This work should identify eventual additional improvements in machine data collection and in data machine management post-processing analysis, which could provide a solution to support harvesting strategies, managing calamities-outbreak and gaining competitiveness. Moreover, it aims at being an active support to the operator to understand at macro level the effects ground condition and environments - with focus on machine and soil interactions - on the machine performance based on long observation period.

Keywords: precision forestry; industry 4.0; harvesting; forwarding; long-term monitoring; forest operations

PRODUCTIVITY ANALYSIS OF SKIDDING OPERATIONS USING UAV VIDEO CAPTURES INTEGRATE WITH WEIBULL DISTRIBUTION METHOD

HALIT BÜYÜKSAKALLI[1]; EBRU BILICI[2]*; ABDULLAH E. AKAY[3]

[1]Mugla Univesity; [2]University of Idaho; [3]Bursa Technical University.

Corresponding author: ebilici@uidaho.edu

ABSTRACT

The timber extraction activities, considered as one of the costly stages of production of wood-based products, should be planned effectively to ensure high production rate. The time study analysis, which is widely preferred in the productivity analysis, is usually carried out by monitoring the work stages at the study site by using time recording devices. Since the production of forest products often takes place in steep and difficult terrain conditions, it is difficult to apply the time study analysis at every work sites. With advancing technology in forestry, many opportunities have been emerging in terms of using new data acquisition, processing, and re-estimation techniques in evaluation of forest operation. In this study, high resolution digital video capture of the tractor skidding operation was obtained with an Unmanned Aerial Vehicle (UAV) and productivity analysis was performed. The study generated a model of theoretical volume distributions using the Weibull probability density function. The average total skidding cycle time obtained from the videos was 5.60 min. The average productivity of skidding operations was found to be 4.01m3/hour. In analysis, the c value (the shape parameter) was 3.1 and the b value (the scale parameter) was 0.41. This showed that the shape parameter provides preliminary information about the distribution of the volume frequency. It was found that the frequency of the volume data moved away from 0 as the shape parameter of the Weibull distribution increased. Thus, the shape parameter provided preliminary information about the distribution of the volume frequency. The compatibility of the measured volume of timber with the estimated volume of timber is conceivable that the approach can be used by decision-makers as a tool for predicting the productivity of skidder.

Keywords: Skidding, UAV, productivity, Weibull distribution

FOREST ROAD SURFACE MONITORING USING GNSS-AIDED DASHCAMS AND COMPUTER VISION

STEPHAN HOFFMANN[1]*; MOSTAFA HOSEINI[1]; STEFANO PULITI[1]; RASMUS ASTRUP[1]

[1]Norwegian Institute of Bioeconomy Research (NIBIO)

Corresponding author: stephan.hoffmann@nibio.no

ABSTRACT

Sustainable forest management systems require purpose orientated road networks. with operational measures to preserve the functional design to avoid cost intensive repairs. But roads are subject to wear, and in particular the deterioration of water bound surfaces of forest roads need to be detected in time to schedule maintenance operations to ensure traffic safety, avoid cost intensive repairs and mitigate environmental impacts. For target oriented and preventative maintenance, frequent data collection and analysis is required to schedule operations efficiently. Since such data collection commonly involved labours manual assessments, this study demonstrates an automated solution for monitoring forest road surface deterioration using consumer grade optical sensors. A YOLOv5 model coupled with a strongSORT tracking was adapted and trained to detect and track potholes in the videos captured by a GNSS (global navigation satellite systems) enabled dashcam, mounted in the windshield of a passenger car. Dashcam footage for training was collected on forest roads in Norway and Germany, and augmented with similar recordings form an iPad, as well as publicly available dashcam dataset from urban roads of South Africa. This allowed training based on several datasets recorded in diverse geographical regions under different weather conditions. The trained model shows a detection and tracking performance of up to a precision and recall level of 0.79 and 0.58, respectively, with 0.70 mean average precision at an intersection over union (IoU) of at least 0.5, and Higher Order Tracking Accuracy (HOTA) of 31.4. We applied the trained model on a forest road in southern Norway, which was recorded under different lighting and weather conditions with the popular GNSS fitted dashcam Nextbase GW622. The instantaneous geographical coordinates delivered by the GNSS module at the rate of 10-Hz is used to geolocate the video frames and correspondingly model-detected potholes. The geolocated video frames over an exemplary stretch of forest road with a length of about 1-km exhibit a root mean square deviation of about 9.7m with respect to the coordinates retrieved from OpenStreetMap. The geolocated potholes are finally compiled into a heat map, which is translated into a road deterioration map. For the experiment, we considered four classes of road deterioration, based on pothole frequency per defined road segment to classify road maintenance needs. The number of classes, pothole frequency and segment length can be customized according to individual needs. Thus, the developed approach is highly flexible and can be used for scheduling road maintenance operations based on the data collected by any standard forest vehicles. Being part of the Norwegian SmartForest project activities, the system is currently incorporated into the ForestSense cloud solution to provide another tool to users. It is aimed to further augment the system to detect other maintenance related features such as washboards, wheel-ruts, vegetation or uprising stones of the base layer.

Keywords: forest roads, pothole detection, YOLOv5, deterioration map, GNSS, road maintenance

PREDICTING RUT DEPTH WITH SOIL MOISTURE ESTIMATES FROM ERA5-LAND AND IN-SITU MEASUREMENTS

MARIAN SCHÖNAUER[1]*; THILO WAGNER[2]; DIRK JAEGER[1]

[1]University of Göttingen; [2]Landesbetrieb Wald und Holz NRW.

Corresponding author: marian.schoenauer@uni-goettingen.de

ABSTRACT

Spatiotemporal modelling is an innovative way of predicting soil moisture and has promising applications in supporting sustainable forest operations. One such application is the prediction of rutting, which can cause severe damage to forest soils and ecological functions. In this work, we used ERA5-Land soil moisture retrievals and several topographic indices to model the response variable, in-situ soil moisture measurements, by means of a random forest model. We then correlated the predicted soil moisture with terrestrial recorded rut depth from different trials. Our spatiotemporal modelling approach successfully predicted soil moisture with an R-squared of approximately 65%. The final model included the topographic Depth-To-Water index, terrain slope, as well as ERA5-Land soil moisture retrievals. These retrievals showed to be the most important predictor in the model, indicating a large temporal variation. The prediction of rut depth was also successful, resulting in an R-squared of 0.40. Our results demonstrate that by using data from several sources, including ERA5-Land retrievals, topographic indices and in-situ soil moisture measurements, we can accurately predict soil moisture and use this information to predict rut depth. This has practical applications in reducing the impact of off-road traffic of heavy machinery on forest soils and avoiding wet areas during forest operations.

Keywords: spatiotemporal modelling, rut depth, soil moisture, ERA5-Land, predictive systems

DEVELOPING THE FOREST TRAFFICABILITY PREDICTION THROUGH ROLLING RESISTANCE MEASURED BY FOREST VEHICLE

AURA SALMIVAARA[1]*; JARI ALA-ILOMÄKI[1]; SAMPO KULJU[1]; EERO HOLMSTRÖM[1]; PETRA VIRJONEN[2]; PAAVO NEVALAINEN[2]; JUKKA HEIKKONEN[2]; SAMULI LAUNIAINEN[1]

[1]Natural Resources Institute Finland; [2]University of Turku.

Corresponding author: aura.salmivaara@luke.fi

ABSTRACT

Mechanized forest operations put pressure on forest soils. Reliable knowledge on soil strength influenced by soil texture, soil moisture, organic matter content, clay content, bulk density, stoniness, root system, is required for efficient and environmentally acceptable forest operations. However, current data available on forest soil properties are coarse and collecting such data with traditional methods is laborious and expensive. Forest vehicles performing operations in forests can be harnessed to provide data on rolling resistance, which further can be used as one key factor in trafficability prediction. The CAN-bus channel of a harvester offers temporally high-resolution data on the power used and the speed traveled, and by considering the terrain slope measured by an inclinometer, the calculation of the rolling resistance is possible to areas where the vehicle has operated. In our Academy of Finland funded project ("TRAM"), we have collected an extensive data on rolling resistance from Southern Finland covering 11 different locations extending a 4-month period in the spring and summer of 2021. The results enable us to characterize the rolling resistance variation in boreal forests and link it to available spatial data and modeled hydrological state to study the predictability of rolling resistance and further trafficability. We were able to remove some of the previous restrictions on calculating the rolling resistance on steeper slopes and currently we can use calculated rolling resistance values within [-10 to 10] degree slopes. Our calculations limit to speed range 0.6-1.2 m/s with an assumption there is no wheel slippage. While rolling resistance cannot be calculated to spots where wheels do slip, we are able to detect these by comparing speed of wheels measured by CAN-bus channel and GPS-measured speed. These areas with wheel slippage are also very important for trafficability prediction. While there are already several mapping approaches available serving forest trafficability assessment, the accuracy and particularly the temporal aspects require more development. More detailed understanding of the temporal variation in trafficability is crucial particularly due to climate change that might change the duration and timing of frost periods when trafficability is on sufficient level. Harnessing forest vehicles for informing us on the temporal and spatial variation in rolling resistance offers an important resource for improving trafficability prediction.

Keywords: trafficability, rolling resistance, soil properties, CAN-bus channel data, spatial analysis

PROJECT INTELLIWAY – INTELLIGENT ROAD CONDITION MONITORING AND PREDICTIVE MAINTENANCE FOR FOREST ROADS

MARIAN SCHÖNAUER[1]*; THILO WAGNER[1]

[1]Landesbetrieb Wald und Holz NRW

Corresponding author: marian.schoenauer@uni-goettingen.de

ABSTRACT

The maintenance of forest roads is becoming increasingly challenging and expensive, particularly in the face of changing weather conditions and high usage due to calamities in recent years. Accurate knowledge of the status of forest road systems can improve routing, planning, and maintenance, and the development of predictive maintenance strategies could be beneficial. In the project “IntelliWay”, we installed a sensor beam, including ultrasonic sensors and a motion sensor, on multiple vehicles to capture data of the surface of forest roads. The data were analyzed using different machine learning algorithms, which were trained using expert appraisals of the road conditions. Our preliminary results indicate that the classification of road conditions can be facilitated through the use of the sensor beams used and subsequent post-processing and analysis. The machine learning algorithms were able to accurately classify the road conditions based on the sensor data, demonstrating the potential for this approach to support the maintenance plannings of forest roads. The development of a geoinformation system that integrates the data from the sensors could enable the visualization of the status of forest roads, allowing for improved planning, routing, and scheduling of maintenance measures.

Keywords: forest roads, predictive maintenance, condition monitoring, classification

THE CONTRIBUTION OF SINTETIC PROJECT IN THE FRAME OF THE FORTHCOMING EUDR TIMBER TRADE REGULATION

GIANNI PICCHI[1]*; CARLA NATI[1]

[1]CNR-IBE

Corresponding author: gianni.picchi@cnr.it

ABSTRACT

The European Union Deforestation Regulation (EUDR) will enter in force by the end of 2024. It will substitute the present EU Timber Regulation (EUTR), entered into force on 3 March 2013, introducing several innovations to counter deforestation and forest degradation. Among the measures adopted, it will require industrial consumers and traders to demonstrate the georeferenced origin of all timber products. This poses a considerable challenge to the EU sawmill industry and in general to the forest sector as it implies an additional burden, both economic and organizational. The effort to provide trustworthy georeferenced data may be particularly relevant for small to medium enterprises all along the value chain, which will be forced to adopt in a relatively short time and adequate system to fulfill the EUDR requirements. To support and facilitate the adaptation of the EU forest and timber sector, the Horizon Europe program opened a competitive call to select proposals addressing the digitalization of the forest value chains. The project “Single Item Identification for Forest Production, Protection and Management (SINTETIC)” was recently funded under this call thanks to its innovative approach based on the self-sustainability of a traceability system centered on product quality optimization. The presentation will describe the technology advances foreseen in SINTETIC. These are designed to be adaptable to forest value chains with any level of starting digital development, supporting them in the fulfillment of the EUDR. Additionally, it will detail the unique tree-to-board tracking system, which will be used to disclose the full potential of a multisource data integration spanning from the digital forest inventory to the X-ray analysis of logs in the sawmill.

Keywords: traceability, timber products, due diligence, value chain, precision forestry, digitalization

CHARACTERIZATION AND SPATIAL DISTRIBUTION OF LOGGING RESIDUES AS INDICATORS FOR THE SUCCESSFUL OF NATURAL AND ASSISTED FOREST REGENERATION

ALBERTO UDALI[1]*; GUNTA GRUBE[1]; SARA CUCCHIARO[1]; EMANUELE LINGUA[1]; STEFANO GRIGOLATO[1]

[1]Department TESAF, Università degli Studi di Padova

Corresponding author: alberto.udali@unipd.it

ABSTRACT

After extensive disturbance events, the main focus is typically given to the presence of large quantities of deadwood and subsequent salvage logging operations to prevent further disturbances to occur or generate additional damage, such as forest fire or bark beetle outbreaks. These kinds of operations are aimed to recover most of the value of the fallen trees, with less or no consideration on the key role that deadwood and coarse woody debris (CWD) have in succession dynamics inside a forest. The adoption of harvesting configuration, whether relies on ground-based machines or aerial-based systems, and cutting techniques, usually cut-to-length (CTL) or full-tree (FT), influences the quantity, type, and distribution of woody material. Moreover, the adoption of such systems and configurations in salvage logging conditions creates more uncertainty in the creation of deadwood and its location. The presence of woody material, especially CWD, helps microsites favorable for forest regeneration by retaining moisture at ground level, and lowering soil surface temperature, as well as protecting seedlings from browsing. The aim of the work is to assess the effect of salvage logging on CWD and logging residues spatial distribution based on the adopted harvesting configuration.

Keywords: logging residues; forest dynamics; harvesting system; coarse woody debris

DO RARE SAPROXYLIC BEETLE SPECIES INTERFERE WITH HARVESTING OPERATIONS AFTER BARK BEETLE OUTBRAKES?

IVAN ŽARKOVIĆ[1]*; MILIVOJ FRANJEVIĆ[1]; KRISTIJAN TOMLJANOVIĆ[1]; IVICA PAPA[1]; DAVID JANEŠ[1]; ANDREJA ĐUKA[1]; DINKO VUSIĆ[1]

[1]Faculty of Forestry and Wood Technology University of Zagreb

Corresponding author: izarkovi@sumfak.unizg.hr

ABSTRACT

In conditions of extreme weather such as droughts, windstorms and freezing rain, bark beetle outbreaks have been common in the last decade for Croatian forestry. According to data from Croatian Forests Ltd., a state-owned company, in cooperation with the Faculty of Forestry and Wood Technology, University of Zagreb and the Croatian Forestry Institute, assessed that, following freezing rain in Gorski Kotar County in February 2014, an icebreaker caused damage to an area of 38,341 ha. The gross volume of wood damaged during the storm was 1,640,771 m3 of mostly broadleaved species. Uneven-aged stands of silver fir Abies alba (Mill.) and European spruce Picea abies (L./Karst.), covering an area of 8225 ha, and wood stock of 93,204 m3 and 14,525 m3 of silver fir and European spruce, respectively, were severely damaged. Furthermore, in December 2017, a windstorm in Gorski Kotar County caused damage to approximately 500,000 m3 of wood stock and even more in silver fir and European spruce stands. Because of the large amount of damaged and downed trees and rugged terrain conditions (the pre-mountainous part with terrain slope above 33%), and despite higher road density of 21.5 km/1000 ha (compared to the Croatian average of 15.43 km/1000 ha forest roads), not all damaged timber was removed from the forest stands. Such conditions are suitable for the development of sproxylic beetles because there is a proportional relationship between diameter at breast height (DBH) and degree of damage after demanding weather conditions that are excellent niches for saproxylic insects. Younger and thinner trees and branches bend, unlike older and thicker ones that break due to increasing stiffness. The wood quality adequate for saproxylic beetles varies significantly according to tree species exposure, decaying stage, stem diameter, bark thickness, position (laying or standing), moisture level, and the presence of associated micro-habitats. In such conditions in Croatian, managed uneven-aged stands rear saproxylic beetle Treptoplatypus oxyurus (Dufour, 1843) was found, and its preference for host and relationship between diameter at breast height is explained. Thirty-three silver fir trees infested with T. oxyurus were recorded in 2021 with a total volume of 171.644 m3, an average DBH at 65.27 cm and in the area of 108.95 ha of Dinaric beech and silver fir forest. The presence of T. oxyurus showed that windfall disturbance can be an important agent that creates habitat heterogeneity, thus being a driving force of forest succession and a source of regional biodiversity in forest ecosystems without interfering with harvesting operations.

Keywords: extreme-weather, bark beetle, Treptoplatypus, biodiversity, managed forests, European silver fir

ESTIMATING THE NON-UTILIZED MERCHANTABLE VOLUME OF CONIFEROUS TREES WITH THE USE OF HARVESTER DATA

MYRIAM DELMAIRE[1]; ERIC R. LABELLE[1]*

[1]Université Laval

Corresponding author: eric.labelle@sbf.ulaval.ca

ABSTRACT

It is common to have non-utilized wood material (NUWM) remaining in the stand after mechanized cut-to-length operations. An agreement between the provincial government of Québec, Canada and the forest industry executing forest management activities on public lands has been established regarding a threshold of NUWM that can be left on the cut over. Problems linked to this agreement are compounded by labour shortages, which have an impact on the precision of the mandatory field inventories. In an attempt to alleviate some of these challenges, the objectives of this study were to: (1) reconstruct and estimate the merchantable NUWM volume beyond the last processed log of balsam fir and white spruce with the use of harvester on-board computer (OBC) data, (2) design a software tool to estimate and spatialize merchantable NUWM, and (3) perform an explorative comparison between the OBC method and conventional field inventory. The work was carried out at five test sites in the Gaspésie region of Québec, Canada. Each site was harvested by a single-grip harvester operating a different OBC system (OPTI4G, Log Mate 500, and Log Mate 510). The reconstruction of 970 study trees (460 white spruce and 510 balsam fir) was carried out to first develop the volume algorithms necessary to evaluate the merchantable section of the treetop at 9.1 cm in diameter. By combining the Varjo model and a linear regression, it was possible to estimate the length of the top section per tree. A prediction bias of 0.0245 m and 0.1748 m was evaluated for the merchantable top section for white spruce and balsam fir, respectively. A spatialization tool using production reports from StanForD (.pri) and StanForD 2010 (.hpr), GPS data, as well as the perimeter of the harvest area, was developed to localize the volumes of NUWM by harvest sector. Finally, an exploratory comparison of the traditional NUWM inventory method and the method with OBC data highlighted a possible cost reduction of approx. 35 $/ha and an increase of precision for the OBC method. The new method should also allow faster response time to make corrections by targeting problem areas.

Keywords: harvester; stem reconstruction; merchantable volume; StanForD 2010; Boreal Forest

ASSESSMENT OF THE IMPACTS ON SOIL DURING WOOD EXTRACTION OPERATIONS IN THE SHORT-MEDIUM TERM.

RICCARDO PAOLONI[1]*; ELENA MARRA[1]; CRISTIANO FODERI[1]; FRANCESCO NERI[1]; STEFANO GRIGOLATO[2]

[1]Dipartimento di Scienze e Tecnologie,Agrarie,Alimentari,Ambientali e Forestali - Università di Firenze; [2]Department TESAF, Università degli Studi di Padova

Corresponding author: riccardo.paoloni@unifi.it

ABSTRACT

In the Italian Apennines, the use of tractor with a winch is still one of the most common systems adopted for wood extraction on steep terrain. Skidding operations can potentially cause impacts on soil resulting in increased compaction, decreased of porosity and displacement of organic matter. The aim of this study was to assess the soil impacts caused by the use of tractor with a winch in two different forest sites with different soil textures in central Italy. On both sites, the soil impact was measured, after a different number of tractor passages, on a slope gradients of 20 %. The soil samples were collected at three different times: before, after machine passages and one year after the passages, considering the wheel position on soil (inside-between the ruts) and the wood extraction direction. The study revealed that bulk density increase of 22 %, and soil porosity decreased of 8 % after the machine passages. However, after one year, the impacts varied between the sites. In the first site, there was a decrease of 7 % in bulk density and an increase of 3 % in porosity, while in the second site, the impacts didn't change. Organic matter did not show significant variations in all the tracks in the short-medium period. The study revealed that as the number of tractor passes increased, there was an increase in soil compaction and a reduction in soil porosity. These impacts were more evident for uphill passages and inside the ruts. The impacts decrease in the following year depending on soil texture, slope extraction direction and wheel passage point. The results highlight the need for appropriate management practices, such as: i) reducing the number of passages, ii) implementing post-extraction soil restoration techniques, iii) mitigating the negative impacts of tractor winch wood extraction.

Keywords: steep terrain, winch, bulk density, porosity

DEVELOPMENT OF DATA-DRIVEN DIGITAL BUSINESS MODELS FOR FOREST ROAD MAINTENANCE IN GERMANY

FELIPE DE MIGUEL-DÍEZ[1]*; FERRÉOL BERENDT[1]; INA EHRHARDT[2]; TOBIAS CREMER[1]

[1]Eberswalde University for Sustainable Development; [2]Fraunhofer Institute for Factory Operation and Automation IFF.

Corresponding author: felipe.diez@hnee.de

ABSTRACT

The optimal maintenance of forest roads is crucial to ensure efficient forest operations and wood logistics, but also for socio economic purposes, such as recreation of the local population, which are gaining more and more importance. It is well known that poorly and erratically maintained forest roads can have severe financial consequences for forest enterprises. In Germany, the assessment of the forest roads condition is, so far, carried out visually by forest owners. In the best case, such as in some few larger forest enterprises, this visually assessed forest road condition is reported manually in a digital system. However, the visual assessment is a subjective approach. That is why efforts are put into the implementation of new technologies, i.e., sensor technology-based devices. Using an automated process has additional advantages, as the forest roads and their current maintenance state can be visualized in a digital map, which provides a valuable tool to a broad spectrum of stakeholders for diverse purposes (e.g., efficient maintenance planning, navigation or wildfire management). In this novel digital data-based system of assessment, many stakeholders can and should be involved: forest owners, foresters, haulage companies, IT service providers, hunters, hikers, nature conservation organizations, fire departments etc. However, the knowledge from stakeholders about both 1) the needs of such digital forest road condition data and 2) the capabilities and desires to get involved in subprocesses (e.g., data collection) is very scarce. Therefore, a qualitative social study was conducted in Germany. For this qualitative social study, 30 semi-structured interviews with a wide range of stakeholders were conducted. The interviewees shared valuable information about 1) their requirements to forest road and forest road maintenance, 2) digital forest road condition data and 3) possible applications of such data. In particular, they stated their expectations on the forest road condition data, the up-to-dateness of the data, the type of desired visualization platform. Of high interest for the development of a data-driven business model (DDBM) was the the interviewee's answers related to their willingness to acquire and/or collect such data as well as the suitable acquisition framework. Finally, both constraints and shortcomings, which could lead a DDMB to fail, were compiled within the framework of the interviews. Moreover, this study showed that forest road users which are not yet involved in the forest road maintenance management, such as hikers, fire departments or nature conservation organizations, should be fully included in the process. The strong interest in digital forest road condition data of most of the stakeholders showed that such DDBM can help generating new financial sources for the forest owners, if properly marketed. In conclusion, the analyses from the interviewee's statements showed that a viable and sustainable DDMB can successfully be developed in order to

establish such an assessment system, which will improve considerably the management of forest road maintenance.

Keywords: forest road maintenance; forest logistics; data-driven busines models; digitalization

A SYSTEM INTEGRATOR FOR BETTER WOOD SUPPLY COORDINATION: FROM OR TO AI

PEDRO EBOLI[1]*; LUC LEBEL[1]; LUIS ANTONIO DE SANTA-EULALIA[2]

[1]Université Laval; [2]Université de Sherbrooke.

Corresponding author: pedro.eboli-ribeiro-pecanha.1@ulaval.ca

ABSTRACT

Natural and extensively managed forests allow for the supply of raw materials to a diversified forest industry, capable of processing several tree species in several locations. In this context, where mills must share the same procurement areas while having different supply needs, coordination of activities becomes a necessity. The alignment between forest management planning and wood supply activities is complex in itself. When several independent business units must develop common alignment, the task may seem overwhelming. One approach to promote coordination is through using a system-integrator, a third-party organization responsible for achieving collaborative, fair, and neutral planning. The supply planning process in the forestry sector is often done manually, based mostly on the planners' experiences and intuition. However, this method limits the number of variables, objectives, and constraints that can be considered. The diversity of origin-destination pairs and products, the fragmentation of the procurement area, and the non-synchronized temporal constraints suggest that Operations Research (OR) methods would allow performance gains. The full potential of the system-integrator concept remains poorly explored in the scientific literature, particularly in the context of forestry and natural resources. Moreover, the use of advanced planning tools remains under-explored in an industrial context. The objectives of this study are twofold: 1) to identify the functions that can be performed by a system-integrator during wood supply planning for a multi-actor and multi-product forestry network, and 2) to quantify the benefits of the implementation of advanced mathematical optimization methods to support the system integrator's decision-making process. We performed a case study where a forest management company, acting as a system-integrator, carries out the annual supply plan for a set of nine mills with different needs in volume and quality of raw material. The system-integrator selects and synchronize the harvest blocks while proportionally balancing the volume of all species, the average distance between harvest areas and mills, and the type of silvicultural treatments (thinning, final harvest). As many as 915 harvest blocks must be considered by the integrator. The manual selection of harvest blocks takes about four months to complete. The implementation of mathematical optimization decision support tool to perform this selection reduced by more than half the time required for this operation. Furthermore, it allowed for the testing of different operational scenarios. The approach allowed to identify plans that lowered operational costs. Compared to manual selection, the optimized solution reduced the average distance from harvest areas to mills by approximately 9%, resulting in a $1.09/m³ reduction in transportation costs. In addition to the improvements in the agility of the planning process and the reduction of operational costs, the application of mathematical optimization contribute to the impartiality and transparency of the planning performed by a system-integrator. Building on the strategic position of system-integrator within an industrial network and its trusted data gathering

capacities, we foresee the possibility of developing AI-supported decision-making for even faster wood-flow adjustments. The integrator also offers forecasting and analytics capabilities to its beneficiaries.

Keywords: system integrator, collaborative planning, forest supply chain, operations research

HARVESTER SEASONS – A SERVICE SUPPORTING CLIMATE SMART AND SUSTAINABLE FOREST OPERATION PLANNING

MIRIAM KOSMALE[1]*; MIKKO STRAHLENDORFF[1]; ASKO POIKELA[1]; HEIKKI OVASKAINEN[1]; ANNI KRÖGER[1]; MIKKO MOISANDER[1]; TUOMO SMOLANDER[1]; JAAKKO IKONEN[1]

[1]Finnish Meteorological Institute

Corresponding author: miriam.kosmale@fmi.fi

ABSTRACT

Finland has the highest proportional share of forest land in Europe and the forestry sector plays traditionally a significant role for its countries economy. Finnish Meteorological Institute has developed Harvester Seasons, a service supporting the forestry sector for sustainable operation planning accounting for weather as well as seasonal predictions and its influence on forest trafficability. Poor terrain and forest road trafficability conditions caused by changing climatological and weather conditions can lead to significant production shortfalls due to the need of rescheduling forest operations. Especially wet conditions with low soil bearing capacity increase the risk of damaging the soil ecosystem. On the contrary snow covered, dry or frozen soil offers best condition for the forest trafficability with heavy machinery. The challenge in timber harvesting is optimized operation planning according to actual carrying capacity of the ground. Harvester Seasons https://harvesterseasons.com is a service offering weather and seasonal forecast range prediction of forestry operations conditions. The service combines soil wetness, soil temperature and snow depth information to predict forest soil bearing in relation to 20–40-ton harvesters and haulers traveling in individual forest parcels to be cut. It includes short-term weather and seasonal ensemble forecasts and downscales its information to a spatial resolution suitable for forest operation planning. The service leverages especially the European efforts on climate monitoring by linkage of Copernicus DIAS, the Copernicus Climate Data Store and data records to the needs of the forestry sector. This service is developed in collaboration with Metsäteho and co-designed with users from the Finnish forestry sector. We will present the latest updates on the service, its datasets and how Harvester Seasons can support forest operation planning in Europe.

Keywords: seasonal forecast, climate model, forest trafficability, weather forecast

HARVESTING FRAGMENTED FOREST: SYSTEM SELECTION USING A SIMULATION-OPTIMIZATION APPROACH

LEO PAINCHAUD[1]; LUC LEBEL[2]*; DANIEL BEAUDOIN[2]

[1]Groupe Lebel; [2]FORAC - U. Laval.

Corresponding author: luc.lebel@sbf.ulaval.ca

ABSTRACT

Nordic forests, such as those found in Canada used to offer opportunities for large and relatively homogeneous harvesting blocks. Increased fragmentation of forests makes operation planning more difficult and affects costs of road building and machinery relocation. Currently, the diversity of systems used for forest operations in eastern Canada is limited and represents only a fraction of existing alternatives. It is a possibility that at least one alternative could outperform the systems currently used in fragmented boreal forest. To this end, a subset of potential systems was identified in a preliminary evaluation of harvest systems in fragmented operations. From this sample, the objective is to identify the harvest system resulting in the lowest wood procurement cost in fragmented forest landscape. The candidate systems were modelled using a static deterministic approach. The results present systems that can lead to a potential decrease in wood procurement costs in fragmented forest areas. It appears from the results that the best systems in fragmented forests are those involving fewer machines, hence the lowest relocation costs. Two CTL systems outperformed all others. The system using removable crane self-loading trucks for transport and the one using the forwarder for loading both resulted in a 4 C$/m3 advantage over the third least expensive system in the most fragmented harvest sites. The provided numerical results and the mathematical models should prove useful to wood supply managers and academics interested in a broader perspective on available harvesting systems.

Keywords: harvesting, simulation, optimization, logistics, system selection

BRUSHCUTTER MOUNTED DEBARKER AS SMALL SCALE TECHNOLOGY FOR IN-STAND DEBARKING

MEHMET EKER[1]*; RAFFAELE SPINELLI[2]

[1]Isparta University of Applied Sciences, Faculty of Forestry; [2]Italian National Research Council, Institute of Bioeconomy.

Corresponding author: mehmeteker@isparta.edu.tr

ABSTRACT

In the harvesting process of wood raw materials, the debarking of conifer roundwood is often carried out at the stump site, in the stand. When performed manually, that task is time-consuming and expensive – even when labor cost is moderate. When mechanized debarking is not an option, intermediate technology can be deployed in order to increase the efficiency of in-stand debarking and alleviate the task of the workers engaging with it. That is especially the case of steep mountain sites, where suitable implements can be fitted to conventional chainsaws for motor-manual in-stand debarking. This study addresses a small-scale motor-manual debarker obtained by fitting a debarking head to a portable brush-cutter. The aim of the study was to introduce this new tool and to evaluate its effectiveness through a comprehensive set of indicators covering both productivity and ergonomics. The new portable debarker was manufactured as a prototype by mounting the Baseh debarking head on a Orac BG 520 brushcutter. The complete machine has power of 1.4 kW and weighs 8.2 kg. A similar design was already developed in Italy in the early 2000s, but the new Turkish version integrates the additional features of the modern equipment available today. Time studies were conducted in Turkey at several sites and under varying conditions. When debarking brutian pine (Pinus brutia Ten.) logs, productivity averaged 2-4 m3/h , which was significantly higher than the productivity achieved with traditional manual tools such as axes or debarking knives, but still lower than recorded for the original chainsaw-mounted version. However, the brush-cutter mounted debarker allows for a better work posture, since operators can maintain an upright, neutral stance, without bending or twisting their backs – and that is an important advantage of the new tool.

Keywords: Brushcutter mounted debarker, In-Stand debarking, Debarkers, Log debarker, Debarking

ETN SKILL-FOR.ACTIONS PROJECT, FACING THE FOREST CARBON BALANCE UNDER THE UNCERTAIN OF THE CLIMATE CHANGE

NARCIS MIHAIL BACESCU[1]*; FILIPPO GUERRA[2]; ABHAY BHARADWAJ[3]; FRANCESCO SFORZA[4]; GUNTA GRUBE[1]; LOGAN BINGHAM[5]; DANIEL MINKLAEV[6]; OTTO PIENAAR[7]; PRZEMYSLAW JANKOWSKI[8]; BOHDAN KOLISNYK[9]; SHAMIN AHMED[10]; FREDERICO SIMÕES[11]

[1]University of Padova - UNIPD; [2]Ministerium für Klimaschutz, Umwelt, Landwirtschaft, Natur- und Verbraucherschutz des Landes Nordrhein-Westfalen - FBZ; [3]RWTH Aachen University - RWTH; [4]Berner Fachhochschule - BFH; [5]Technische Universitaet Muenchen - TUM; [6]Libera Università di Bolzano- UNIBZ; [7]Stellenbosch University-Su; [8]Institution Nacional de Investigacion Y Tecnologia Agraria y Alimentaria – INIA; [9]Warsaw University of Life Sciences – SGGW; [10]Technische Universitaet Muenchen – TUM; [11]Universidad de Valladolid- UVA.

Corresponding author: narcismihail.bacescu@phd.unipd.it

ABSTRACT

The ETN Skill-For.Action project is founded on the frame of H2020 MSCA-ETN program. The project consists on founding and training twelve Early Stage Researchers (ESRs) thematically focussing on understanding the carbon fluxes in managed forest systems. The project networking is based on academic and non-academic partners. The network-wide training activities are structured in order to prepare a new generation of ESRs able to innovate forest management in the EU towards a carbon-smart forest management based on multidisciplinary expertise. Along a wide spectrum of climate zones and a gradient of forest management intensities, the general objectives and challenges of the project, are to generate a deepen knowledge about on one side, the dynamics of carbon sequestration and forest resilience against biotic and abiotic stressors, acknowledging site and stand characteristics. On the other side, the project also aims to increase the knowledge regarding the potential to reduce carbon emissions generated from forest operations, in order to provide stakeholders with innovative models for optimised and smart forest management. More specifically, the contribution will present the activity of the ESRs linked to the reduction of carbon emissions of forest operation and focusing the research activities on machine fuel consumption rates, machine-soil interactions, machine simulations and performance optimization.

Keywords: H2020; MSCA-ETN; Early Stage Researcher; efficiency; carbon cycle

USING UNMANNED AERIAL VEHICLES TO MONITOR IMPLEMENTATION OF FORESTRY BEST MANAGEMENT PRACTICES

ARJUN RIJAL[1]; RICHARD CRISTAN[1]*; TOM GALLAGHER[1]; LANA NARINE[1]

[1]Auburn University

Corresponding author: rzc0067@auburn.edu

ABSTRACT

Timber harvest activities such as the construction of roads, skid trails, and stream crossings have the greatest potential for erosion and sedimentation problems. Forestry best management practices (BMPs) monitoring serves as a tool to evaluate the status of implementation and determine the effectiveness of BMP guidelines. The use of BMP implementation rates as an indicator of water quality protection is logical since properly applied BMPs have been shown to reduce erosion and sedimentation. Conventional BMP monitoring has contributed substantially to assessing BMP implementation. However, conventional on-the-ground surveys can be time consuming. Unmanned aerial vehicles (UAVs) have been rapidly emerging as a new tool for local-scale monitoring. In this study, we evaluated the feasibility and potential of UAVs for monitoring forestry BMPs. By utilizing BMP guidelines and survey questions from Alabama, Georgia, and Florida, this study compared the performance of UAV live feed surveys and UAV-created map surveys with conventional surveys across major BMP categories on 30 study sites utilizing the BMP survey for that state. We found that using a UAV for monitoring BMPs was efficient for providing a general overview of an area from above. UAV live feed surveys were as effective as conventional surveys across all major BMP categories. The correlation coefficient (r) for all BMP categories combined (UAV live feed vs conventional) was 0.98 for detecting when BMPs were implemented and 0.94 for detecting when BMPs were not implemented and needed to be. However, UAV-created map survey results (UAV map vs conventional) were not as effective (r of 0.87 for detecting implemented BMPs and 0.49 for detecting not implemented BMPs). Stream crossing BMP questions were the main issue impacting map surveys which was not an issue with the live feed surveys due to being able to lower the UAV and evaluate the crossing at different angles. While UAV-created map surveys may be less effective, they provide a permanent observation record. This project also developed a standardized framework for using UAVs to monitor forestry BMPs. In conclusion, the usage of a UAV using live feed data in the field is a capable option to monitor forestry BMPs.

Keywords: Forestry BMPs; drones, UAVs, timber harvesting, remote sensing

DEVELOPMENT OF A PHOTOGRAMMETRY-BASED METHOD TO ESTIMATE THE GROSS VOLUME OF ENERGY WOOD STACKS

FELIPE DE MIGUEL-DÍEZ[1]*; BENJAMIN ENGLER[1]; THOMAS PURFÜRST[1]

[1]Albert-Ludwigs University of Freiburg

Corresponding author: felipe.demiguel@foresteng.uni-freiburg.de

ABSTRACT

In the energy wood assortment is included chipped fuel, fuelwood and bark. Likewise, this category encompasses manufactured products such as pellets. This wood assortment, which is explicitly intended for an energetic use, can be measured both in solid m³ or loose m³ (bulk m³). After conducting harvest processes, both crown and branches materials are stacked together with the small-sized roundwood. Thus, the resulting shape and composition of those stacks are quite heterogeneous. Consequently, volume estimations of those stacks (also known as heaps due to that heterogeneity) used to be inaccurate when applying the traditional measurement methods. To overcome this shortcoming, a novel method derived from implementing new technologies, photogrammetry, was tested for estimating the gross volume of energy wood stacks more accurately. Specifically, 53 energy wood stacks were scanned using two different devices: 1) a camera installed in a UAV and 2) an iPad Pro equipped with LiDAR technology. To generate the 3D models, the software pix4D (as well as pix4D capture to scan the stacks) was used. The energy wood stacks properties were also manually measured and the results recorded. Furthermore, it was also possible to estimate the conversion factors (from m³ (st) to loose m³) since the energy wood stacks were chipped after being scanned and calculated and the woodchips volume was subsequently measured as well. The conversion factors were then estimated based on the resulting volumes using pix4D (m³ (st)) and the wood chips volume (loose m³). In addition, those factors or variables, which could have some influence on the conversion factors, were identified as well. The gross volume of each stack was estimated in this trial five times. The individual results differed from each other, as did the volumes estimated depending on which device was used. In particular, the volumes estimated based on the samples taken with the iPad were higher than those estimated based on the samples using the camera installed in the UAV. Moreover, a specific correlation was determined between the stack volume and the relative deviation of each of 5 estimations per stack: the lower the stack volume, the lower the relative deviation. Concerning the conversion factors (from m³ (st) to loose m³), the figures resulted in 1.2 for predominantly energy roundwood and in 0.5 for stacks made up of crown and branch materials. These conversion factors were in line with those used in practice. Notwithstanding this fact confirms that the methodology used in the present study is appropriate for estimating the volumes of energy wood stacks, further research is needed in order to improve its accuracy.

Keywords: Photogrammetry, energy wood, wood stacks, measurement

LIDAR-BASED AUTOMATED METHODS FOR ESTIMATING THE GROSS VOLUME OF INDUSTRIAL ROUNDWOOD STACKS

FELIPE DE MIGUEL-DÍEZ[1]*; MAURICO ACUNA[2]; NIKOLAI KNAPP[3]; TOBIAS CREMER[4]; THOMAS PURFÜRST[1]

[1]Albert-Ludwigs University of Freiburg; [2]Natural Resources Institute Finland (Luke); [3]Thünen Institute of Forest Ecosystems; [4]Eberswalde University for Sustainable Development.

Corresponding author: felipe.demiguel@foresteng.uni-freiburg.de

ABSTRACT

The roundwood measurement is an essential phase when acquiring that raw material. The accuracy requirements for the measurement process are very high, since small deviations in the measurement process when acquiring such high volumes of roundwood can lead to dramatical economic losses for the purchasing companies. Over the last decades in several European countries, both traditional and photo-optical methods have been used to estimate the gross stack volumes, being this value fundamental for billing. However, these methods, which are based on measuring the surfaces of the front and rear sides of the stack and multiplying their mean value by the order length of the logs, imply certain inaccuracies making them prone to deviations in the gross stack volumes estimations, e.g., assuming that all stacked logs have the same length or rounding the measurement results. A further limitation lies in the occasional inaccessibility of the rear side of the stack, being only considered this side of the stack for estimating the gross volume. Moreover, higher overestimations can be expected, if only the front side of the stack is considered for the volume estimation and every log is stacked with its butt end to that side. On the contrary, these shortcomings can be avoided by using LiDAR data, i.e., scanning the complete stack with devices equipped with this technology at high range, e.g., GeoSLAM ZEB HORIZON. In this study, two automatized line processes are developed to estimate the gross stack volume based on LiDAR data. The reliability of the obtained results was evaluated by comparing them with measurements conducted according to traditional methods and using photo-optical methods. The evaluation results showed that the successfully developed line processes provide reliable results. However, the accuracy of the results provided by the developed line processes could not be analyzed, since there is no method so far which can be deemed as ground truth data when measuring the gross stack volumes. Based on the findings of this study, the users (e.g., roundwood purchasers, forest practitioners, forest owners, etc.) could benefit from the advantages provided by these developed line processes such as their simplicity, transparency and capability to be reproduced for verification purposes by each stakeholder involved in the wood supply chain.

Keywords: Roundwood measurement, stacks, LiDAR, Python, Digitalization

ASSESSING THE ACCURACY OF HOLOLENS 2 APPLIED TO GEOGRAPHICAL INFORMATION SYSTEMS (GIS) FOR FOREST OPERATIONS

FELIPE DE MIGUEL-DÍEZ[1]*; THOMAS PURFÜRST[1]

[1]Albert-Ludwigs University of Freiburg

Corresponding author: felipe.demiguel@foresteng.uni-freiburg.de

ABSTRACT

The Augmented Reality (AR)-technology has contributed to increase the efficiency and quality of the works in the field in a broad spectrum of areas, specially, architecture engineering construction (AEC) and industry (regarding safety and maintenance). In contrast, the implementation of this technology in the forest sector is still in the initial stages. The main application areas in the forestry have been focused so far on navigation, wildfires management and roundwood measurement. Recent developments have combined AR and geographical information systems (GIS) in the forestry so that the users can virtually visualize the borders of relevant areas in the forests, e.g., plots, roads, etc. In this sense, the use of HoloLens 2 allows a broad spectrum of users, e.g., forest practitioners, harvester and forwarder operators or forest road builders, to recognize the forest area in which the operations are conducted. At the same time, relevant attributes related to the area are virtually displayed. The virtual visualization of those attributes provides users important information, including the type of forest ownership or if the area is contaminated with ammunition, radioactivity, forest pests and diseases, etc. This information is to be considered when performing the forest operations in those areas in order to prevent misuses or work accidents and ensure that the forest operations are being conducted in the planned forest areas, e.g., the harvest processes are conducted in the corresponding forest plot and only affect the selected trees. In this regard, the reliability and the accuracy of the virtual visualization of the borders are of utmost importance. Thus, this study aims to evaluate the accuracy of a recently developed device, through which the AR-technology and GIS can simultaneously be used, HoloLens 2 by comparing the virtually visualized borders with test areas georeferenced, whose surface was also measured using a total station. The findings of this analysis confirm the reliability of this device for being used in forest operations. This capability together with the other services provided by this device such as measuring roundwood, navigating in the forest or signalizing dangers in order to avoid work accidents make HoloLens 2´ capabilities very promising for their application in the forestry in the near future.

Keywords: Augmented Reality, GIS, HoloLens 2, Forest operations

MACHINE LEARNING-BASED FOREST BIOMASS SUPPLY CHAIN MANAGEMENT FOR BIOENERGY

JINGHAN ZHAO[1]; JINGXIN WANG[1]*

[1]Center for Sustainable Biomaterials & Bioenergy, West Virginia University

Corresponding author: jingxin.wang@mail.wvu.edu

ABSTRACT

Forest biomass is a renewable energy source with great potential to address the increasing energy demand and mitigate greenhouse gas emissions. However, there are challenges for the efficient management of forest biomass supply chains, specifically the optimization of harvesting, transportation, storage, and processing operations. Machine learning (ML) has emerged as a promising tool for solving these challenges by extracting valuable insights from large and complex datasets of forest biomass operations. This study concentrates on biomass supply chain, logistics, and performance of the chain components through ML-based analytics. The ML algorithms and data definition are also discussed. Data on biomass, harvest, and machines, as well as seasonal, geographic, and market factors, are analyzed to develop the models that can be used to assist in decision-making of logistics planning and resource allocation, optimize the supply chain, and improve the overall performance and profitability.

Keywords: forest biomass; supply chain optimization; machine learning; logistics; artificial intelligence

THINNING AS A TOOL TO INCREASE RESISTANCE TO STRESSORS IN THE INTERIOR OF BRITISH COLUMBIA

SERGIO ALONSO[1]*; DOMINIK ROESER[1]

[1]University of British Columbia

Corresponding author: sergioas@student.ubc.ca

ABSTRACT

Commercial thinning (CT) is a versatile and widely implemented mid-rotation silvicultural treatment. Despite the multiple benefits associated, foresters find challenges in implementing CT for multiple reasons, mostly related to the profitability of the operations. In the interior of British Columbia, Canada, fibre supply shortages and unprecedented wildfires and insect outbreaks are a current reality and the interest in CT is high, but at the same time, there is a lack of sufficient scientific knowledge of CT operations. In this research, we study the productivity and cost of common approaches to CT operations in mixed conifer stands and residual stand damage. Following, we will study cutting-edge CT technologies and harvesting layout by transferring know-how from other jurisdictions and compare the results and evaluate the implications again on productivity and residual stand damage. A combination of direct observations with machine on-board-computer data, LiDAR and forest inventories to precisely measure the productivity of the operations and identify the main factors that influence productivity. The final result will be a cost-benefit analysis of CT operations to quantify and help inform how CT can be used as a tool to increase resistance to fires, drought, eruptive insects and windthrow while providing multiple values in British Columbia.

Keywords: commercial thinning operations harvesting fibre shortage

ACCURACY AND TIME CONSUMPTION OF LOGSTACKLIDAR AND IFOVEA PRO FOR VOLUME CALCULATION OF STACKED TIMBER

KAROL TOMCZAK[1]*; MACIEJ PIOTROWSKI[2]; MARTA PĘDZIK[1]; PATRYCJA HOCHMAŃSKA-KANIEWSKA[1]; RYSZARD GĄSIOROWSKI[1]; PIOTR MEDERSKI[3]; ARKADIUSZ TOMCZAK[3]

[1]Łukasiewicz Research Network - Poznań Institute of Technology, Center of Wood Technology, Winiarska 1, 60-654 Poznan, Poland; [2]Forest Experimental Station in Murowana Goślina, Poznań University of Life Sciences, Rogozińska 38, 62-095 Murowana Goślina, Poland; [3]Department of Forest Utilisation, Faculty of Forestry and Wood Technology, Poznań University of Life Sciences, Wojska Polskiego 71A, 60-625 Poznań, Po.

Corresponding author: karol.tomczak@pit.lukasiewicz.gov.pl

ABSTRACT

The manual measurement of stacked wood is one of the most time consuming activities for a forestry worker. In Poland, in 2022, roundwood timber and logs accounted for more than 60% of harvested wood, mainly prepared by cut-to-length technology. Harvested timber requires efficient and accurate measurement for the timber trade. As technology advances, the devices and applications used in forestry can provide us with increasingly accurate measurement data. Indeed, the methods for digitally measuring stacked industrial timber are under constant development. Some of these solutions use length references marked on the stack front, for example, a 1m stick, but those based on LIDAR or stereoscopic cameras can work without length reference. Although systems are similar, they differ in accuracy of final volume calculation and the time needed to perform the measurements. The main objective of this study was to evaluate the differences in the accuracy and time consumption, of wood measurement by means of two digital devices, one without length references and one with length reference. Accuracy was also understood as repeatability – exactness in more than one measurement by the same device. Volumes obtained from digital equipment were compared with figures collected from manual measurements. The study was performed on stacked industrial pine timber. Every stack was measured by two people, five times each stack, using two digital applications: LogStackLIDAR (without length reference) and iFovea Pro (with length reference), both installed on iPad Pro. In total, ten digital measurements of each stack were made. Manual measurements were also taken by two people, one measurement each person. During data collection, the time consumption of the whole measuring process was gauged using a digital stopwatch. The final results of every measurement were calculated without any conversion factor and were estimated as cubic meter stacked (CMS) volume, m3. The project is in progress. Final results will consist of data from 30 stacks, and will be presented at the Formec 2023 conference. It is expected that the most accurate and the fastest measurements will be obtained when using the LogStackLIDAR application (without a length reference), based on laser technology. The proportions in accuracy as well as proportions in time consumption between the measurement methods will be the subject of the final presentation at the conference.

Keywords: forestry digitalisation; roundwood; photo-optical wood measurement; work efficiency; iOS

USING LIDAR AND ROADENG10 TO EVALUATE THE CONCEPT OF BENCHED FOREST ROAD DESIGN IN MODERATELY STEEP TERRAIN.

CAMPBELL HARVEY[1]*; RIEN VISSER[1]

[1]University of Canterbury

Corresponding author: campbell.harvey@canterbury.ac.nz

ABSTRACT

New Zealand is currently harvesting many first rotation plantation forests that require new infrastructure. Much of the terrain being harvested is regarded as erosion-prone and steep due to underlying geology, tectonic uplift and local climate. Erosion susceptibility and steep slopes can be serious infrastructure planning issues at harvest with safety, environmental risk and cost effectiveness being significant motivators for practitioners. To meet these challenges, first rotation forest infrastructure is designed and constructed with a 'fit-for-purpose' philosophy. This philosophy aims to ensure safety, environmental and cost expectations are met without excess. While side-cast construction for rolling terrain and full-bench construction for steep terrain are familiar to forest infrastructure specialists in most parts of the world, New Zealand practitioners also use a 'benching' technique to stabilise earth fill on moderate-to-steep side slopes. Benching refers to the installation of a second narrower track below the final road template, to provide a footing for the over-steepened fill slope. New Zealand law requires the use of the benched construction technique (or better) on side slopes from 25 to 35 degrees (40 – 55%). Some constructive debate over the effectiveness of the construction technique has led to this research into the stages of construction, the movement, compaction and security of the fill. Three new build sites were scanned with a DJI Zenmuse L1 LiDAR sensor on board a DJI Matrice 300 UAV platform to capture high resolution terrain datasets. These new road segments ranged from 300 to 800 m in length. The sites were revisited later in the construction sequence to capture further LiDAR data. Using ArcGIS, CloudCompare and RoadEng10, mapping the temporal terrain changes sheds light on how the fill is shifted, and key measures such as bulking factors, which play an important role in the final template shape but are rarely incorporated into design. Capturing changes as construction progresses also provides insight into the loading of the lower bench by fill from the road template above. This presentation will step through the concept of benching as an advanced concept for forest road construction in moderately steep terrain. It will establish the actual design and construction process using RoadEng10, supported by the three LiDAR case studies. This research is an important first step to understand whether New Zealand forest practitioners are getting value for money from constructing with this ubiquitous, yet unstudied, construction method.

Keywords: forest roads, construction, remote sensing, forest engineering

ESTIMATING SLASH PILE BURN OCCURENCE IN BRITISH COLUMBIA USING VERY HIGH-RESOLUTION VIRTUAL GLOBE IMAGERY

ANDREA NESDOLY[1]; ZEXI LIU[2]*; BEN HUDSON[1]; DOMINIK ROESER[2]; WERNER KURZ[1]

[1]Natural Resources Canada, Canadian Forest Service; [2]Department of Forest Resources Management, University of British Columbia.

Corresponding author: zexiliu@student.ubc.ca

ABSTRACT

Slash pile burning (SPB) is one of the significant sources of Canada's carbon emissions, in British Columbia (BC), the deficiency of explicit records for the SPB occurrence rate due to the imperfect policy regulations and anthropogenic norms leads to the inaccuracy of SPB carbon emission accounting. The current burning occurrence rate regarding to clear-cut harvested areas is based on experts' opinions, which are 15% and 50% for the coast and interior of the province. Fine-tuning the estimated slash pile burning occurrence rate and assessing how they change over time is a practical assignment for accurate SPB carbon emission accounting in BC. Very-high-resolution aerial imagery with time series is conducted in the study to manually detect burning conditions for the 489 randomly sampled cutblocks of the total area of 9,119 ha within BC from 2012 to 2020. The study outputs the SPB occurrence rate as 15% of the sampled harvest area on the coast (1,084 ha) and 59% of the interior (6,797 ha) for all years, which can contribute to more robust and precise SPB occurrence model estimates. The further comparison may be required due to uncertainties from the non-ideal temporal and spatial resolutions and observer bias.

Keywords: Slash pile burning occurrence rate, VHR imagery detection

ASSESSING THE CURRENT STATE OF FOREST ROAD NETWORK DEVELOPMENT BASED ON THE CONCEPT OF ACCESSIBILITY

MASARU WATANABE[1]*; MASASHI SAITO[2]

[1]The United Graduate School of Agricultural Sciences-Iwate University; [2]Faculty of Agriculture - Iwate University, and Agri-Innovation Center.

Corresponding author: u3322008@iwate-u.ac.jp

ABSTRACT

In the forest area, there are access roads (prefectural roads, municipal roads, and high-standard forest roads) that connect urban areas to forest areas, forest roads that ensure reachability for operations to each forest management unit, and low-standard operation roads that branch off from these roads to reach stumpage. In Japan, strategic development plan targets for forest roads and operation roads have been set since 2001 on the basis of the road network density theory, which is based on the maximum appropriate distance for logging machinery, but the current strategy does not fully reflect actual geospatial information because it is not an estimate in a geometric model. Therefore, there is a lack of basic evaluation of the current situation, such as what kind of forests are reachable and to what extent they are ensured by what road standards, and as a result, plans for advanced use of forest space may not have been adequately developed. In order to incorporate geospatial information into road network development planning, the concept of accessibility could be used. Accessibility is a concept that considers the attractiveness of opportunities (supply and demand) at different points in space and the diseconomies of moving between points. It has been used in transportation planning, urban planning, and geography to evaluate the interactions (flows) and frictions between the two systems, transportation and land use, but there are few examples of studies in the field of forest road studies. In this study, we developed a forest location-based accessibility (;FLA [ha/T, L, R]) incorporating three parameters: road type T (access road, forest road, operation road), land use type L (forest condition, forestry suitability, etc.), and reachability R (Euclidean distance, collectability, etc.). And we conducted an assessment of the current status of forest road network development based on the concept of accessibility. The tree movement process can be divided into (1) the landing process from individual forest management units to the operation road or forest road, (2) the transportation process by forwarders or skidders from the landing point to the truck transshipment point, and (3) the transportation process by truck from the truck transshipment point to the timber demand area. For the sake of simplicity, only process (1) is covered in this study. The analysis will be conducted in Gifu Prefecture, which has one of the largest forested divisions in Japan. FLA is calculated for individual forest management units and aggregated for administrative area unit (e.g., municipality). By examining the differences between the analysis results and existing evaluate indices (road network density, Backmund's development rate, etc.), the significance of considering road type, land use type, and reachability in evaluating the current status of road network development is discussed. In addition, regional differences in accessibility status and structure will be analyzed through comparison the results of the evaluation of each

administrative area. This study attempts to construct a new road network development evaluation index with high information resolution and interpretability.

Keywords: forest road network, accessibility, road type, land use type, reachability

VIRTUAL REALITY FORESTRY TRAINING (VR-FT)

MARK-FABIAN FRANZ[1]*; ELENA FRÜCHTENICHT[1]; ANDREA TEUTENBERG[1]

[1]Kuratorium für Waldarbeit und Forsttechnik (KWF)

Corresponding author: mark-fabian.franz@kwf-online.de

ABSTRACT

Forest owners are the first step in the forestry value chain. To reach all available resources, in a resource-constrained world, all stakeholder should be involved. But a significant part of the European forest is privately owned. In Germany almost a quarter of the total forest area belong to privat owners with small areas under 20 ha. In order to reach this target group and create the possibility to access the resources, new ways must be pursued. The project Virtual Reality Forestry Training (VR-FT), founded by FNR, presents an approach to reach these forest owners with little or no previous knowledge via virtual reality. Caused by an upcoming generation change these group will increase and there will be more urban forest owners. Digitalization is a key factor for future forestry and has a lot of potential to monitoring, management and certification but also in education. The VR-FT project based on 360° panorama views with teaching material in varying levels of difficulty. Audio files, videos and quiz give an overview to the work that is carried out in the forest over the year. Through the use of virtual reality, the inhabitation should be reduced and gamification allowed a bigger fun factor. Besides general information to forest-related issues (e.g. tree species) the increased complexity in forestry is focused. Many and sometimes conflicting objectives should be considered and observed, such as economic and ecologic interests. In addition to the provided 360°- learning environment, a web-based tool for teachers will be developed in the project. With this application it will be possible to upload own 360° views and fill them with individual teaching material. Thus, the project will be continued, with a practical orientation for a big potential user group. With VR-FT the value chain can be improved, the percentage of managed forest areas could be increased and the stakeholders getting prepared to sustainable forestry challenges.

Keywords: virtual reality, education, urban owners, generation change, forestry training

BENEFITS OF MODELLING FUEL CONSUMPTION AND ENGINE PARAMETERS OF FORESTRY MACHINES THROUGH HIGH-FREQUENCY DATA ACQUISITION FROM CAN BUS SYSTEM

NARCIS MIHAIL BACESCU[1]*; CADEI ALBERTO[1]; IÑIGO ESCAMOCHERO[2]; RAFFAELE CAVALLI[1]; STEFANO GRIGOLATO[1]

[1]University of Padova - UNIPD; [2]Agresta.

Corresponding author: narcismihail.bacescu@phd.unipd.it

ABSTRACT

Most of the modern forestry machines use a CAN Bus network to interconnect the Electronic Control Units (ECUs) which control and manage various components and systems of the machine. Communication over the CAN Bus is done via CAN frames and specific protocols as the J1939 for heavy-duty vehicles, including also built-purpose forest machines and excavators. With the use of a CAN-Bus data logger it is possible to acquire engine parameters such as rpm, torque, fuel consumption, etc. This information, when coupled with machine positions and data coming from additional sensors, such as accelerometers or IMU, can be useful for monitoring machine behaviour and providing specific and detailed information on fuel consumption. The present work reports an example of application on a skidder equipped with grapple-crane and top-opening hydraulic jaw, operating mainly for full-tree or whole-tree extraction in moderate steep and rough terrain. The aim of the work is to verify if the data acquisition can estimate the effects of variables such as terrain slope, travelled distances and load, on the engine parameters and on fuel consumption. The data will be then used to create a model to predict the GHG emission at cycle level.

Keywords: Precision Forestry; Industry 4.0; Harvesting; Mechanisation; Italy

WHY ROBOTS ARE NEEDED IN FORESTS?

FLORIAN SOMMER[1]*; CHRISTOPH GOLLOB[1]; ARNE NOTHDURFT[1]; KARL STAMPFER[1]; ANDREAS HOLZINGER[1]

[1]University of Natural Resources and Life Sciences,Vienna

Corresponding author: florian.sommer@boku.ac.at

ABSTRACT

Artificial Intelligence (AI) is playing an increasingly important role in transforming a wide range of industries. The forestry sector is no exception, and there is a growing interest in leveraging digital technologies and AI to improve forest operations. Enabling off-grid digital transformation involves deploying technologies that can operate in remote areas without access to traditional power grids and internet connectivity. Autonomous mobile Robots (AMRs) are a technology that can bring AI to the forest for a multitude of different applications. For example surveillance of forest roads, to collect data for a preventative maintenance approach, to keep them in pristine condition. Another possibility is the recording of a digital twin of the forest. With that a fully digital forest inventory could be possible. The technologies to collect the required data are available and tested already, but the bottleneck is actually collecting the data. This is the point where an autonomous robotic system can come into play. Fulfilling long lasting laborious tasks that require an enormous amount of human time or threatening health and safety of the operator. Today robotic systems are not fit for purpose when it comes to forest environments. Systems that have been in existence for years already in other industries, strongly rely on close power grid access. Many robotic systems evolved around this limitations, close access to energy and relatively simple environments. Therefore AMRs for forest operations are not really in existence right now and by no means are they really “autonomous”. We want to focus on making these robots autonomous and allowing them to become an auxiliary system to the forest industry. To achieve this there is a need to bring power for those systems into the forest by a simple and effective method, and as those systems are still relatively small, there is room to test potential future power systems that could be used also in large machinery. The power then needs to be stored on the robot to allow maximum operation time. This can only be achieved by using a hybrid approach that combines different technologies into one superior system. This includes for example the use of batteries, capacitors and fuel cells. All this needs to be connected to a robot that is capable of maneuvering challenging and everchanging terrains, while collecting various types of data. Finally the most important part is the ability of the system to navigate without human interaction. The completion of such a system will help to further bring digital technology into the forest industry.

Keywords: Digital Transformation, Robotics, Energy, off-grid, AI autonomy, forest inventory,

THE EFFECT OF PROCESSOR DEBARKING AT THE FOREST ROAD ON WOOD QUALITY DETERIORATION DURING THE INTERIM STORAGE OF LOGS UNDER ALPINE CONDITIONS

STEPHAN BÖHM[1]*; FRANZ HOLZLEITNER[1]; ELIAS AMERHAUSER[1]; PETER BAIER[1]; CHRISTIAN KANZIAN[1]

[1]Universitat fur Bodenkultur Department fur Wald- und Bodenwissenschaften

Corresponding author: stephan.boehm@boku.ac.at

ABSTRACT

The timber industry faces significant loss due to deterioration of wood quality during storage of roundwood. Bark beetles and blue-stain fungi, which cause a blue-gray discoloration as their dark-colored hyphae colonize the sapwood, are considered major contributors to this degradation. The sawmill industry has developed effective practices to mitigate wood quality loss during off-site storage, such as wet storage or wrapping logs in plastic. These practices are not suitable for the in-forest storage along the forest roads due to regulatory requirements and practicality. The increasing frequency of extreme weather events, such as droughts or storms, and the resulting frequent disturbances and calamities cause large fluctuations in the amount of wood available, with punctual peaks. As a result, the logistical capacity to transport timber is exceeded and the timber cannot be immediately transported out of the forest, but must be stored on site. Debarking of logs during harvesting could be an effective and feasible method to face quality loss under these circumstances. Two field trials were conducted in the Austrian Alps in 2022 to investigate the effect of debarking on the drying behavior of logs, the habitat quality for bark and wood breeders and the growth of blue-stain fungi. Two sets of freshly harvested spruce logs were stored for 10 weeks from late May to mid-August next to a weather station. The first set of logs contained 24 logs that were debarked during harvest. The second set of 24 logs, from the same stand and cut during the same harvest operation, but not debarked, served as a control group. Log slices were cut on a weekly basis to monitor the development of sap-stain during the critical postharvest period. Therefore, the log slices were photographed, and the percentage of discolored area was determined. Furthermore, the number and species of bark- and wood breeding insects found on the logs was recorded. For a second field trial, two piles of freshly cut logs were stored in stanchion baskets, each resting on load cells, which delivered data-records in 10 minutes intervals. One pile contained debarked logs; the other pile contained logs in bark, which served as a control group. The logs were stored from late May to mid-November to study the effect of debarking on natural drying behavior. Therefore, the moisture content was determined at the beginning and at the end of the experiment. Changes in moisture content were calculated from changes in weight. Analysis of the data collected shows that the debarked logs dried slightly faster than the logs in bark. There were significantly fewer wood and bark breeders, and there was significantly less discoloration caused by blue stain fungi on the debarked logs than on the logs in bark.

Keywords: debarking, wood quality, sap stain, blue stain, moisture content

IDENTIFICATION, GEOLOCATION AND ACCURATE HARVEST OF DYING OAK TREES IN CLIMATE CHANGE CONTEXT

EMMANUEL CACOT[1]*; MARIE BASTIEN[1]

[1]UNISYLVA

Corresponding author: emmanuel.cacot@unisylva.com

ABSTRACT

In the context of climate change and particularly following in the successive droughts of 2018, 2019 and 2020 and then 2022, the oak forests of the Centre-Val de Loire region (France) are beginning to show abnormally rapid signs of dieback. UNISYLVA, the second-largest forestry cooperative in France, manages more than 60,000 ha of oak groves over the region, on which the most stressed forest plots which contain valuable oaks must be identified. How to identify those high-valued oaks thanks to remote sensing then confirm the diagnostic, the need to harvest them with on field survey? Thanks to the annual monitoring of the evolution of the NDVI (Normalized Difference Vegetation Index), it is possible to identify the most affected areas. In those stressed plots, the identification of ones with high economic stakes completed to on-field identification of the level of trees stress with decision support tools have enabled UNISYLVA to target the harvest and to mobilize nearly 15,000 m3 in 2022. However, the remote sensing method used (unsupervised approach) remains to be improved (overall accuracy = 60%) to better identify the stressed areas and highlight the importance of field data collection in order to evaluate the results of the model over the entire region and over the years.

Keywords: remote sensing, oak, dieback, climate change, harvest

FORWARDING DAMAGES TO RESIDUAL STAND IN BEECH EVEN-AGED HIGH FORESTS

FRANCESCO LATTERINI[1]*; RODOLFO PICCHIO[2]; RACHELE VENANZI[2]; DAMIANO TOCCI[2]; NICOLÒ DI MARZIO[2]; PAWEŁ HORODECKI[1]; ANDRZEJ M. JAGODZIŃSKI[1]

[1]Institute of Dendrology, Polish Academy of Sciences; [2]Tuscia University.

Corresponding author: latterini@man.poznan.pl

ABSTRACT

The most applied harvesting approach in Mediterranean beech high forests is skidding, while the use of forwarding has been implemented only in recent times but it is taking more and more interest. This study analysed the damages to the residual stands occurred after late thinning interventions carried out in three cutting blocks located in Italy. In all the three cutting blocks timber extraction was performed by forwarding, while felling was motor-manual in two cutting blocks and mechanised in the third one. Percentage of damaged trees ranged between 7.3 and 18.8%, with damage severity from mild to severe. The study was carried out in the framework of the the project AIMSUSFOR, a Marie Curie fellowship financed by the Horizon 2020 programme and The Polish Ministry of Education and Science.

Keywords: forwarder; sustainable forest operations; reduced-impact logging; operator training

ON TRACK OF TRACELESSNESS - STRATEGIES TO REDUCE SOIL IMPACT OF MECHANIZED LOGGING

ROLF BJÖRHEDEN[1]*

[1]Skogforsk

Corresponding author: rolf.bjorheden@skogforsk.se

ABSTRACT

Mechanization has improved the working conditions, supply chain functionality and overall economy of the forest sector. But the use of heavy machinery also raises serious concerns for detrimental impacts on forest soils. Lasting negative effects on productivity and vitality of the forest, erosion, silting of water courses and risk of methylation of mercury are some of the noted concerns. The avoidance of excessive soil impact of mechanized forest operations is a key problem for forestry. If soil damage cannot be decreased, restrictions reducing the competitiveness of the sector may entail, limiting the access to sustainable forest materials. Reducing soil impact of machines is an important part of the continuing efforts of forestry to develop gentler technologies and methods. For this purpose, several strategies are available: • Reducing the ground pressure and the dynamic forces through machine design and/or weight. • Using brash, corduroy, log mats and similar to temporarily reinforce striproads. • Optimizing strip road placement based on detailed mapping of soil sensitivity. • Training machine operators in methods and procedures for 'soft logging'. • Logging the more sensitive sites only in periods when the risk of damage is reduced e. g. after a dry period or in winter when the soil is thoroughly frozen. The above strategies have been subject to trials and tests by Skogforsk in recent years. The results of this research are reviewed, and the pros and cons of the respective strategy are discussed. Technologically oriented projects include tests of tracked and rubber-tracked forwarders compared to wheeled machines, pendulum-arms compared to bogies and small machines compared to larger. Light machines may reduce compaction, shearing and rutting of soil, but at a considerable extra cost. Using high-flotation bogie tracks or rubber-tracks will effectively reduce average rut depth but may increase shearing and damage when a machine turns. Also, the tracks add weight to the construction and will increase fuel consumption except on very soft ground or in deep snow. Reinforcing (soft spots of) strip roads is a common procedure and works well. The reinforcement measures may vary with sensitivity and volume to be transported on the particular road segment. It has proven important to reinforce before signs of soil damage are appearing. Mapping soil properties of the stand and locating strip roads in such a way that most traffic will occur on the least sensitive parts of the stands has been successful. The stand is pixelated and each pixel is given a difficulty index, based on bearing capacity as well as on other factors influencing the effectiveness of transport work. Segments that need reinforcement can be identified. Foremen using this technique state that it reduces the risk of soil damage, and also makes their planning more efficient. In conclusion, all the strategies may contribute to reducing soil damage, but a combination of strategies supported by ongoing educational initiatives of machine operators,

planners and foremen is probably needed to reach a significant, general and lasting reduction of soil damage levels.

Keywords: logging machines, soil damage, planning, soft logging

FUEL CONSUMPTION IN FINAL FELLING

LARS ELIASSON[1]; JOHN ARLINGER[2]*

[1]Skogforsk; [2]JDA Forest AB.

Corresponding author: lars.eliasson@skogforsk.se

ABSTRACT

Fuel consumption is an important factor affecting both logging costs and the environmental impact of a logging operation. Traditionally, fuel consumption has been estimated through studies of individual machines, through follow up studies based on company records or through questionnaires. Recently the use of automatically collected data from the machine computers has improved the possibilities for large scale studies of fuel consumption. This study is based on records from final felling crews during 2020 to 2022 and aims to estimate how fuel consumption for cut to length logging operations is affected by tree size, transport distance and wood concentration as well as other factors. More than 80 per cent of the variation in fuel consumption can be explained by the three main factors. However, one set of factors that explain some of the remaining variations are year and month. For the studied machines, the overall annual average fuel consumption for cutting and forwarding varies from 1.51 to 1.58 liters per cubic meter after correction for differences caused by tree size, transport distance and wood concentration. These differences between years necessitates further studies. As corrected differences between years are large during some months and non-existent during others a main hypothesis is that they are related to differences in weather conditions between years.

Keywords: Logging operations, diesel, Harvester, Forwarder

RUBBER-TRACKED FORWARDERS – PRODUCTIVITY AND COST EFFICIENCY POTENTIALS

MIKAEL LUNDBÄCK[1]; OLA LINDROOS[2]; MARTIN SERVIN[1]*

[1]Umeå University; [2]Swedish University of Agricultural Sciences.

Corresponding author: mikael.lundback@umu.se

ABSTRACT

Extraction of timber from forest to roadside is expensive, energy intensive, and potentially damaging to the forest soil. Machine development aims to mitigate risks for environmental impact and decrease energy consumption while maintaining or increasing cost efficiency. Development of rubber-tracked forwarders have gained renewed interest, partly due to climate change leading to unreliable weather seasonality and consistency, and the urgency of reducing fuel consumption and emissions. Apart from less soil impact, the development costs of rubber-tracked forwarders are believed to be offset by higher driving speeds and larger payloads compared to the wheeled equivalent machine. Thus, the aim of this study was to investigate how productivity and extraction cost of rubber-tracked forwarders theoretically exceeds that of wheeled forwarders by increased speed and load capacity. The calculations were made with both fixed parameters and with parameters from harvest areas as input. Scenarios were compared to a baseline corresponding to mid-sized wheeled forwarders. R statistical computing language was used for calculations and visualisations. The results show higher productivity with the increased driving speed enabled by rubber-tracks at all extraction distances, with a larger difference at longer extraction distances. As expected, the mirrored behaviour was visible for extraction cost. Assuming 15% higher machine price for the rubber-tracked forwarder, increased speed still enables reduced extraction cost, for 400 meters extraction distance by between 10 and 25% depending on the average driving speed. The results also show potential for reduced extraction cost with increased load sizes, with small potential on short extraction distances and growing with increased distance. Apart from direct extraction cost reductions, a rubber-tracked forwarder is likely to give access to a larger part of the harvest areas during longer seasons. For example, 8% of the total harvested volume in this study was found in stands with ground bearing capacity class 4 or 5, meaning very restricted seasonal accessibility for wheeled machines. With rubber-tracks, good accessibility can be combined with low soil impact in a favourable way for both industry and ecosystem.

Keywords: SFO, forwarding, soft ground, concept machine

HOW ACTIONABLE EXPLAINABLE AI (AXAI) CAN CONTRIBUTE TO A BETTER UNDERSTANDING OF FOREST ACCIDENTS

ANNA SARANTI[1]; ARNE GEVAERT[2]; FERDINAND HÖNIGSBERGER[1]; ALESSA ANGERSCHMID[1]; ANAHID JALALI[1]; CHRISTOPH GOLLOB[1]; CARL ORGE RETZLAFF[1]; FLORIAN SOMMER[1]; KARL STAMPFER[1]; ANDREAS HOLZINGER[1]*

[1]University of Natural Resources and Life Sciences (BOKU); [2]Ghent University.

Corresponding author: anna.saranti@boku.ac.at

ABSTRACT

The need for uncovering the impacting factors of a forest accident is vital; the loss of life is undoubtedly the most severe consequence. Nonetheless, serious injuries can impact life and working abilities apart from the acute hospitalization costs and losses in working hours. Learning to predict those accidents and their impact according to several criteria, leads to efficient predictive Machine Learning (ML) models that can reliably capture the dynamics between the influencing elements. This research work uses a detailed accident dataset of the Allgemeine Unfallversicherungsanstalt (AUVA), which is the general accident insurance institution in Austria for the years 2011–2021. Overall, 14611 registered accidents are described by 43 features. After extensive preprocessing and analysis of the data, simple Machine Learning (ML) models such as Decision Trees, Random Forests and Neural Networks provide sound performance results in both classification and regression tasks. Concretely, the number of lost working hours because of recovery, the severity of the accident to future working ability and fatality (immediate or long-term) are predicted. What is more, the importance of each of the features that are used by those models, as uncovered by various Explainable AI (xAI) methods, sheds light on the impactful elements of those accidents (as perceived by the models). The use of a state-of-the-art method for even more efficient processing of tabular data called Tabular Prior-data Fitted Network (TabPFN) which uses the Transformers architecture achieved much faster results. The approximation of Bayesian Inference that is achieved with this model can be considered a forefront to a future causal model of the accidents. The evolution of autonomous systems in forestry and agricultural applications has to prioritise the tasks that have a high degree of risk and harm. Uncovering impact factors such as the time of the accident, the affected body part, the used tools and their relative importance sheds light on the strategies that will be involved in the incorporation of robots to execute the most dangerous tasks in difficult conditions. xAI leads both human and AI agents to novel insights and actionable decisions that assure the safety of forest workers.

Keywords: Occupational accident, Artificial Intelligence, Explainable AI, Forestry, Machine learning, Safety

HARVESTING METHODS INFORMATION TOOL

FRAUKE BRIEGER[1]; UDO H. SAUTER[1]*

[1]Forest Research Institute of Baden-Wuerttemberg (FVA)

Corresponding author: frauke.brieger@forst.bwl.de

ABSTRACT

In 2022 Forest Research Institute of Baden-Wuerttemberg (FVA) has launched its "Informationsplattform Holzernteverfahren", i.e. "Harvesting methods information tool" (https://www.fva-bw.de/daten-und-tools/tools/holzernteverfahren/einfuehrung), containing currently presentations of 21 harvesting methods adapted to forest conditions in the federal state of Baden-Wuerttemberg in the southwest of Germany. Primarily descriptions and assessments of listed harvesting methods can serve as source of information for forest practitioners, forest apprenticeship and studies, and also for interested public. Additionally, there are integrated orientation values for productivity and costs of harvesting methods. The data collection behind this tool was developed about several years and refers to different sources like scientific investigations, practical trials and practical experience. Such data are of high interest when comparing the economic side of harvesting methods. However, it's hard to ensure timeliness of data. Both productivity and costs of harvesting methods vary because of various factors. Even the survey of current data depends on the availability of sources and the individual calculation methods. Considering the available scientific and general findings about this subject, consolidation of existing data base within the "Harvesting methods information tool" should help to ensure the relevance of orientation values. Correlation of determining factors throughout the observation period may give indications for deduction of reliable productivity and cost structure, even in times of high inflation rates and economic uncertainty.

Keywords: harvesting methods, information tool, productivity and cost data, forest operations

ASSISTING HARVESTER OPERATOR WITH REAL-TIME MOBILE LASER SCANNING SYSTEM IN CONTROLLING HARVESTING QUALITY IN THINNING STAND

JOHANNES POHJALA[1]; VILLE KANKARE[1]; JUHA HYYPPÄ[2]; KALLE KÄRHÄ[1]*

[1]University of Eastern Finland (UEF); [2]Finnish Geospatial Research Institute (FGI).

Corresponding author: johannes.pohjala@uef.fi

ABSTRACT

Harvesting work in thinning stands is complex and mentally demanding for the harvester operator. The operator selects the remaining trees based on stand quality, site productivity, stand structure, and silvicultural guidelines. The harvester operator must make these decisions rapidly and often simultaneously with controlling the functionalities of the machine, boom, or harvester head. In addition, the operator must monitor the harvesting quality, i.e., density of remaining trees, strip road width and spacing during harvesting operation, as excessive thinning can reduce the long-term economic value and sustainability of the forest management. Mobile Laser Scanning (MLS) can be used to create high-precision three-dimensional spatial data (point cloud) from which tree-specific characteristics can be retrieved (e.g., tree location and diameter). MLS creates a novel possibilities to assist harvester operator with artificial intelligence. Therefore, this study aimed to investigate the impact of an advanced operator assistance system based on novel sensor technology on the productivity and quality of thinning work. Study sites included first and later thinnings that were located in central Finland. These sites were thinned with cut-to-length harvesting machines, which were equipped with a sensor-based system that observed the harvester's surroundings using a MLS mounted on the front of the cabin. The system provides a real-time information about the spatial location of trees visualized as a tree-map in the user interface of the onboard computers. Trees, which were too close to each other were highlighted in red. Moreover, numerical information included tree diameter and predicted length, the number of remaining stems at the work location, and the distance between adjacent strip roads. Four experienced operators were selected for the comparative time and motion study, which was carried out in winter conditions. Time-study data were collected by analysing the video record of the cutting work and applying the tree data produced by harvesters. The function of effective time consumption was modelled using regression analysis. The harvesting quality was measured from the point cloud data collected using a handheld laser scanner before and after the harvesting operation and compared to the target values. As a result, new research information was obtained using of MLS based operator assistance system.

Keywords: MLS; productivity; thinning; time study; operator; Das ; cut-to-length method

HARVESTING METHODS AND OPERATIONS OF INDUSTRIAL ROUNDWOOD IN WESTERN EUROPE

KALLE KÄRHÄ[1]; NIKO PURMONEN[2]; CHRISTIAN KANZIAN[2]; NIKOLAUS NEMESTOTHY[3]; PHILIPPE RUCH[4]; ANDREA HAUCK[5]; RAFFAELE SPINELLI[6]; NATASCIA MAGAGNOTTI[6]; SIMON BERG[7]; EDUARDO TOLOSANA[8]; MIKAEL LUNDBÄCK[9]*

[1]University of Eastern Finland; [2]University of Natural Resources and Life Sciences Vienna (BOKU); [3]Austrian Research Centre for Forests (BFW); [4]Technological institute FCBA; [5]Kuratorium für Waldarbeit und Forsttechnik e.V (KWF); [6]CNR IBE; [7]Norwegian institute for bioeconomy research (NIBIO); [8]Universidad Politécnica de Madrid (U.P.M.); [9]Umeå University.

Corresponding author: kalle.karha@uef.fi

ABSTRACT

A few years ago, Moskalik et al. (2017) conducted a survey of the degree of mechanization in wood harvesting operations in eight Eastern European countries. This study investigated the degree of mechanization in Western European countries, what wood harvesting methods and machinery are used, what are the typical harvesting conditions in which industrial roundwood is harvested, and what are the average harvesting costs of industrial roundwood. Eight Western European countries (Austria, Finland, France, Germany, Italy, Norway, Spain and Sweden) participated in the study, accounting for a total industrial roundwood harvest of 292 million m3 solid over bark (sob) (i.e., 256 million m3 solid under bark [sub]) in 2021, according to the FAO Statistics Database. The research material was collected by sending a questionnaire to the top research scientists of wood harvesting operations in the respondent countries in 2022. In the studied countries, the degree of mechanization in wood harvesting operations averaged 70%, varying between 23 and 99% by participant country. In Finland, Sweden and Norway, the degree of mechanization was over 90%, while in Austria and Italy it was ≤30%. The most frequently used harvesting method was the cut-to-length (CTL) method; the proportion of which varied between 38 and 99% depending on the country. Tree-length (TL) and full-tree (FT) methods were commonly used in Austria, Italy, France and Spain. The respondents estimated that loggers utilize approximately 8,000 rubber-wheel harvesters and more than 300 tracked harvesters in the cutting operations of industrial roundwood. The corresponding extraction machine fleet amounts to approximately 10,000 forwarders, more than 900 grapple skidders, and almost 500 cable skidders. Moreover, respondents in Austria and Italy estimated that there are almost 1000 cable yarding systems in use in their countries. Agricultural tractors are also commonly used to extract industrial roundwood from the forests. Especially in Austria, Italy and Spain, it was calculated that almost 7,000 agricultural tractors are used to skid or forward industrial roundwood. Harvesting conditions varied widely, whereby some of the respondents could not provide accurate information about typical harvesting conditions in their country. The harvesting costs of industrial roundwood averaged EUR 20.2 m3 sob (EUR 23.0 m3 sub). The variation range was EUR 11.0–35.0 m3 sob (EUR 12.5–39.9 m3 sub) by country in ground-based harvesting operations. The lowest ground-based harvesting costs were found in Finland and Sweden, and the highest were in Italy, Austria and Spain. The harvesting costs of cable yarding systems were considerably higher than those of ground-based operations. The study gathered up-to-date information on the harvesting operations of industrial roundwood in Western Europe. On its basis, we

propose that the FORMEC community annually starts to collect those basic data and draw up statistics, what is the degree of mechanization, what harvesting methods are used, and what are the harvesting costs by country and on average in Europe. We envision strongly that this would support the development of mechanization in wood harvesting operations in Europe and thus strengthen the competitiveness of European companies on the global forest products market.

Keywords: mechanization, harvesting machinery, harvesting conditions, harvesting costs

USING MACHINE LEARNING APPROACHES IN THE PLANNING PROCESS OF QUEBEC PUBLIC FORESTS TO BETTER HARMONIZE ENVIRONMENTAL AND ECONOMIC GOALS

*ACHUT PARAJULI[1]; LUC LEBEL[1]; ALEXANDER MORNEAU[1]; SHUVA GAUTAM[1]**

[1]Université Laval

Corresponding author: shuva-hari.gautam@sbf.ulaval.ca

ABSTRACT

Planning of harvesting activities in public forests is a complex process that requires harmonization of social, environmental and economic objectives. Hierarchical planning approach is used to disaggregate the complex set of objectives into manageable tasks that leads to sequential development of plans. First, a strategic plan determines the annual allowable cut by species group and silvicultural treatments to be applied taking into consideration long-term forest productivity, ecological, and social concerns. Subsequently, a tactical plan spatially disaggregates the volume targets while considering economical, ecological, and social constraints. Finally, the specific harvest cutblocks available to meet industrial demand for timber are determined at the operational level. Developing an optimal plan is a complex challenge due to the uncertain and dynamic nature of the forest systems, social constructs, and economic parameters. Complex protocol of the planning process makes it quite rigid; exploring alternative plans and replanning is straining, both computationally and administratively. The objective of the project is to develop machine learning approaches to be able to rapidly generate a wide array of possible plans. These alternative plans can be evaluated in terms of economic profitability, carbon metrics and other strategic goals. Random forest and fully connected neural network were implemented to forecast carbon pool estimation associated with proposed plans. While the performance of the random forest (NEP: R2 = 0.885 & carbon pool R2 = 0.915) was slightly better, the fully connected neural network (NEP: R2 = 0.869 & carbon pool R2 = 0.904) was computationally efficient and required less time. Fossil-fuel consumption and CO2 emissions associated with logging operations will be estimated using these methods. It is envisioned that the trained models will be integrated into the planning tools used by forest planners.

Keywords: Wood supply, forest planning, Carbon, forest operations

MONITORING OF FOREST ROADS WITH MOBILE LASER SCANNING: AUTOMATIC IDENTIFICATION AND MEASUREMENT OF CROSS SECTION ELEMENTS

CHRISTOPH GOLLOB[1]; RALF KRASSNITZER[1]; TIM RITTER[1]; ANDREAS TOCKNER[1]; SARAH WITZMANN[1]; MARTIN KÜHMAIER[1]; CHRISTIAN KANZIAN[1]; FERDINAND HÖNIGSBERGER[1]; ALESSA ANGERSCHMID[1]; ANNA SARANTI[1]; ANDREAS HOLZINGER[1]; KARL STAMPFER[1]; ARNE NOTHDURFT[1]*

[1]University of Natural Resources and Life Sciences, Vienna

Corresponding author: christoph.gollob@boku.ac.at

ABSTRACT

The need for data and data analysis in forestry has grown steadily over the past decades and, with increasing digitization, is reaching a level that can no longer be achieved with traditional on-site data collection. Forest roads are essential for sustainable and multifunctional forest management. In traditional forest road monitoring, road attributes including cross section elements are manually delimited and measured using mechanical or optical instruments such as compasses, measuring tapes or total stations. The application of these traditional measurement techniques is time-consuming, cost-intensive, and prone to manifold measurement errors. Sensor technologies based on mobile laser scanning (MLS) enable the development of intelligent user guidance and provide a higher level of automation and digitalization in forest road monitoring. The goal of the present study was to assess the detection accuracy of the automatic identification and measurement of forest road cross section elements obtained by a mobile laser scanning system mounted on a car. A sample 47 forest roads (in total 52 km) was scanned in January 2023 using a GeoSLAM ZEB Horizon mobile laser scanner mounted on a Volkswagen Transporter. In order to reference the collected data globally, two GNSS antennas (Septentrio PolaNt-x MF.v2) and a receiver (Septentrio AsteRx SB3 Pro) were used to record tracks. The forest roads were selected in such a way that a broad variation in road type, vegetation on the road and road condition (no maintenance necessary to maintenance necessary) was represented. The scans were performed at an average speed of 6 km/h. Based on the extracted 3D point clouds, the forest roads were manually detected and segmented to the cross section elements (fill slope, carriageway with shoulder, ditch, cut slope and terrain). These manually segmented forest roads can serve as a training dataset in a Geometric Deep Learning setting. Taking into account the 3D coordinates of the road segments as well as their relative orientations, the forest roads can be processed as graphs with their characteristics encoded through informative embeddings. This gives the ability for reliable automatic prediction of road segments through the differentiation of their geometric structure. The preliminary results showed that 93% of the 3D points could be assigned correctly and automatically to the reference cross section elements. The widths of the fill slope, carriageway with shoulder, ditch and cut slope could automatically be estimated with an RMSE (root mean square error) of 1.41 m, 0.44 m, 0.32 m and 0.68 m. The corresponding bias was -0.14 m, -0.30 m, 0.08 m and 0.04 m. The uphill and downhill slope angles could be measured with an RMSE of 0.64° and 2.12°. The corresponding bias was -0.05° and -0.06°. The results of this study have shown that with mobile laser scanners

and corresponding algorithms an automatic detection of forest road cross sections is feasible. The use of laser scanner technologies including automated algorithms for forest road monitoring offers the possibility for interesting future research questions (e.g. water drainage, maintenance prediction, expansion, trafficability).

Keywords: forest road digitalization, mobile LiDAR, Geometric Deep Learning

BOOSTING RURAL BIOECONOMY BY FOSTERING KNOWLEDGE TRANSFER, ENHANCING COMPETITIVENESS OF BIOMASS SUPPLY CHAINS AND PROMOTING INNOVATIVE TECHNOLOGIES

ROBERT PRINZ[1]; JOHANNA ROUTA[2]; RAFFAELE SPINELLI[3]*

[1]Natural Resources Institute Finland (Luke); [2]National Research Council of Italy (CNR); [3]Institute of Bioeconomy (IBE).

Corresponding author: robert.prinz@luke.fi

ABSTRACT

A key challenge to modern bioeconomy is the low profitability of many of its value chains. Over the years, the EU and the National Governments of its member States have supported countless projects to find effective solutions to the hurdles that slow down the affirmation of the bioeconomy. Unfortunately, the valuable results obtained from that work are often hidden from the final users, preventing successful implementation. To overcome such fundamental communication issue, the European Union has sponsored a new Communication and support Action within the scope of the Horizon2020 programme. The new action goes under the acronym of BRANCHES (Boosting Rural Bioeconomy Networks following multi-actor approaches) and brings together 12 partners from 5 different countries. The goal of BRANCHES is to foster knowledge transfer and innovation in rural areas, enhancing the viability and competitiveness of biomass supply chains and promoting innovative technologies, rural bioeconomy solutions and sustainable agricultural and forest management. BRANCHES aims to strengthen and scale-up the bio-based sectors by offering the information on new technologies and best practices in different regions, building capacity, and facilitating uptake and exploitation. The BRANCHES project summarizes, shares, and presents the existing best practices and research results from earlier and running EU and national projects to promote bioeconomy and rural development through new bio-based initiatives. Selected knowledge on forest biomass supply chains is integrated with available and innovative technologies and best-practice cases that exemplify successful bioeconomy solutions with bioenergy conversion systems in wider bioeconomy context. The objective is to accelerate the uptake of best practices that are “close to put into practice” although not sufficiently known by practitioners, by exchanging knowledge of the most cost-efficient supplies of forest, agricultural, and short rotation coppice biomass. Therefore, in the FORMEC/FEC poster session we present a selected number of relevant best practices from different regions to foster knowledge transfer, to enhance competitiveness of biomass supply chains and to promote promising innovative technologies. Altogether, BRANCHES has produced and shared more than 50 case studies, considered Best Practices. Their results are summarized in as many Practice Abstracts (PAs), tailored for practitioners, shared through the project media and collected on following webpage: https://www.branchesproject.eu/materials/practice-abstracts-and-factsheets

Keywords: biomass supply chains; profitability; innovative technologies; rural bioeconomy solutions.

PROCESSOR DEBARKING IN WHOLE TREE CABLE YARDING OPERATIONS

FRANZ HOLZLEITNER[1]; STEPHAN BÖHM[1]; ELIAS AMERHAUSER[1]; CHRISTIAN KANZIAN[1]*

[1]Institute of Forest Engineering, Department of Forest- and Soil Sciences, University of Natural Resources and Life Sciences, Vienna

Corresponding author: franz.holzleitner@boku.ac.at

ABSTRACT

Due to climate change, the supply chain of roundwood is increasingly subject to unpredictable fluctuations caused by abiotic disturbances and subsequent bark beetle calamities. Finally, timber transport and the downstream processing are reaching its capacity limits in handling additional volumes. Large quantities of processed logs within bark can no longer be transported out of the forest in a timely manner. Assortments must then be stored for longer periods of time on site in accordance with phytosanitary requirements. Temporary storage outside the customer requires appropriate preventive measures to ensure the quality of the logs, which can be affected by insect infestation, fungal infection and abiotic factors.

In Austria, an average of 3.5 to 4.0 million cubic meters of timber has been extracted annually by cable yarding within the last 10 years. This corresponds to one fifth of the total harvest volume, whereby the amount of damaged timber is already included. However, an effective and long-proven measure against bark beetle infestation is the debarking of logs already at the site.

The aim of this presentation is to present first results of an ongoing project with applied processor debarking at the forest road during full-tree operation a with cable yarder. During the field experiment the processor, Konrad Woody H60 was adapted by feed-roller replacement and pressure-settings of the delimbing knives. The processor was mounted on a truck together with a Konrad Mounty 5000 tower yarder. A thinning operation was carried out in a pure spruce stand, whereby two cable lines have been setup. Prior to the operation, the DBH of all trees was measured and for a sample of trees, heights were determined. At one cable line, operation was done without debarking, while for the second line debarking was applied. Two video cameras recorded the operation for a detailed post-analysis of all harvesting processes. Altogether 209 trees on both lines were extracted uphill and processed at the forest road. The focus will be set on the additional effort required for debarking as well as on the remaining bark surface on the assortments.

Keywords: productivity, timber harvesting, steep terrain, roundwood supply, bark beetle

USING UWB SENSORS TO MONITOR THE DANGER ZONE OF TIMBER HARVESTING OPERATIONS

FERDINAND HÖNIGSBERGER[1]; CHRISTOPH GOLLOB[2]; ERWIN STAMPFER[3]; ANDREAS HOLZINGER[1]; KARL STAMPFER[1]*

[1]Institute of Forest Engineering, Department of Forest and Soil Sciences, University of Natural Resources and Life Sciences, Vienna; [2]Institute of Forest Growth, Department of Forest and Soil Sciences, University of Natural Resources and Life Sciences, Vienna; [3]Forest management unit Flachgau-Tennengau, Österreichische Bundesforste AG.

Corresponding author: ferdinand.hoenigsberger@boku.ac.at

ABSTRACT

Sensor technologies to monitor danger zones of harvesting operations are not yet used on a broader scale, even though they are expected to bring great benefits to occupational safety. In our study, we applied an Ultra-wideband (UWB) sensor for the detection of people in the danger zone of motor-manual harvesting operations. The sensor system showed accurate and precise detection within a 30 m and 50 m zone during a performed field test. The objective of the present study was to determine if the system also achieves the same requested performance in practical use, without hindering the work or diminishing the performance. The trials took place in the forest management unit Flachgau-Tennengau of the Österreichische Bundesforste (ÖBf). Here, the sensor system, consisting of a UWB sensor and up to five UWB tags, was used. The feller was equipped with the sensor and the others involved in the harvesting process, for example other forest workers or foresters, were equipped with tags. The sensor was set according to the danger zone, which is defined as 1.5 times the tree height, at 30 or 50 m, depending on the operation. The distances to each tag with the associated timestamps were logged via the sensor. Data on the harvesting operations themselves and the forest stand were also recorded. To obtain information about whether each approach was detected, we randomly conducted test approaches and verified whether they were displayed in the logged data. For the data analyses, we focused on the position changes of the detected tags, measurements during which the sensor was triggered (entering the danger zone) and interruptions of the sensor reception. An interruption is thereby defined as a time interval between two signals greater than or equal to two seconds. Since the UWB sensor had a recording frequency of one measurement per second, this implies at least one missing distance value. The expected results are insights into the detection rate and detection delay, as well as length and frequency of interruptions occurring between sensor and tags. By linking the measurement data with data on the harvesting operation and on the forest stands, also conclusions about the performance of the sensor in different environments and application situations can be drawn.

Keywords: Ultra-wideband, work safety, danger zone, hazard detection, forest work

HOW MUCH DOES IT COST TO INCREASE THE PROCUREMENT OF LOGGING RESIDUES IN SWEDEN?

RAUL FERNANDEZ-LACRUZ[1]; ANDERS ERIKSSON[1]; THOMAS PARKLUND[1]; LARS ELIASSON[1]; ARON DAVIDSSON[1]*

[1]The Forestry Research Institute of Sweden (Skogforsk)

Corresponding author: raul.fernandezlacruz@skogforsk.se

ABSTRACT

There is an underutilized potential of logging residues (tops and branches) from final fellings in Sweden, especially in the northern parts of the country. In practice, the extraction of logging residues is concentrated in areas with good conditions for providing a net revenue, i.e. in final fellings that produce large amounts of residues per hectare, which are relatively close to the customer (heat and power plants), and with short forwarding and relocation distances. Increasing the use of this residual biomass can increase our energy security in the current energy crisis. However, scaling up supply of wood chips from logging residues will increase procurement costs, as the biomass will unavoidably be collected from areas with poorer conditions, for example further away from the customer or with more difficult driving conditions. Results will present regional marginal abatement cost curves for logging residues in Sweden, visualizing which volumes can be mobilized at a specified price.

Keywords: bioenergy; biomass potential; supply-cost curves; supply chain

PROMOTING WILDFIRE RESILIENCE USING IRREGULAR SHELTERWOOD SILVICULTURAL SYSTEM

MINGRUI (ROVER) LIU[1]; DOMINIK ROESER[1]*

[1]The University of British Columbia

Corresponding author: roverliu@student.ubc.ca

ABSTRACT

Climate change has significantly impacted the wildfire regimes in lodgepole pine forests, resulting in prolonged fire seasons and altered fire behavior. In North America, fire patterns have shifted towards less frequent but more severe wildfires due to a century of fire suppression. In response, silviculture practices in fire-prone areas aim to restore diverse forest structures that are resistant or resilient to wildfires. In Western Canada, where forestry is a key industry, interest in seeking silvicultural solutions for promoting forest resilience to wildfires has increased following the devastating wildfire seasons in 2017 and 2018. Irregular shelterwood, a silviculture system with a relatively short history of implementation in British Columbia, has been deployed in ecologically sensitive areas to promote structural heterogeneity and meet management goals for aesthetics, biodiversity, and wildlife. Although the impacts of irregular shelterwood on wildlife habitat and abundance have been well studied, the interaction between wildfire and the stand structure created by irregular shelterwood remains poorly understood. The effectiveness of irregular shelterwood in building wildfire resilience remains unclear. This project presents a case study of a lodgepole pine stand that was treated with irregular shelterwood and partially burned in a wildfire in 2017. The study collected ground fuel, canopy fuel, and timber cruising data from four stand types (irregular shelterwood treated-burnt, treated-unburnt, untreated-burnt, and untreated-unburnt) and analyzed the difference in fuel load change and fire-induced mortality between burnt and unburnt with irregular shelterwood treatment being a variable. The results are expected to demonstrate if reduced impact of wildfire is observed in an irregular shelterwood stand. Additionally, the same data were used to generate a treated stand in US and Canadian fire models (BEHAVE PLUS and CCP), and the results were compared to the field data. The study will provide valuable initial insights into the effectiveness of irregular shelterwood in mitigating wildfire risk and proposes a potential silviculture solution to promote forest resilience to wildfire. The findings from fire modelling will also inform the applicability and accuracy of contemporary wildfire models in the lodgepole pine forests of interior British Columbia.

Keywords: wildfire ,irregular shelterwood, forest resilience, fire modelling

SURVEYING THE CENTRAL ASPECTS OF UNCERTAINTY MITIGATION IN LARGE-SCALE SWEDISH FORESTRY

OSKAR GUSTAVSSON[1]; LIVIU ENE[1]; LOVISA ENGBERG SUNDSTRÖM[1]; LARS ELIASSON[1]*

[1]Skogforsk

Corresponding author: Oskar.Gustavsson@skogforsk.se

ABSTRACT

As the market for wood products has evolved, focus for wood suppliers has shifted from delivering a bulk product to deliver logs that are cross-cut to customer demands. To supply these products to the customers in time and in the requested quantities requires an accurate operational planning. Achieving high precision in operational harvest planning requires accurate pre-harvest inventory. However, conducting precise inventory is both resource-intensive and time-consuming. Current pre-harvest inventory practices in the forestry industry are highly standardized, and the lack of information about deviations within forest stands further complicates the challenge of estimating inventory costs and uncertainty levels. Given the increasing importance of high-precision wood flow, new, cost-effective strategies are necessary to handle the uncertainty associated with pre-harvest inventory. In addition, intelligent methods for selecting among established strategies are required. To guide the development of new strategies and enable informed decision-making, we conducted a survey of parameters central to harvest planning, the current levels of uncertainty associated with them, and the strategies employed to minimize uncertainty effects. We interviewed representatives from most of the companies involved in Swedish forestry responsible for and using data from preharvest inventories. Our preliminary findings indicate varying levels of awareness regarding the relatively high uncertainty in the inventory data, and the effects this have on later processes. Furthermore, there are few explicit strategies how to use information on these uncertainties in the planning processes. More research is needed on methods for estimating uncertainty prior to inventory in order to enable decision support helping the industry to select appropriate inventory methods.

Keywords: Uncertainty, Precision forestry, Operational planning, Wood supply

USING DEEP LEARNING FOR TRACING LOGS AND ASSESSING LOG QUALITY

EERO HOLMSTRÖM[1]; ANTTI RAATEVAARA[2]; HENNA KAINULAINEN[1]; TUULA PIRI[1]; JONNE POHJANKUKKA[1]; HEIKKI KORPUNEN[3]; JUHA HONKANIEMI[1]; MIKKO PELTONIEMI[1]; ALEKSI LEHTONEN[1]; JORI UUSITALO[4]*

[1]Natural Resources Institute Finland; [2]MiCROTEC Innovating Wood Ltd; [3]NIBIO; [4]University of Helsinki.

Corresponding author: eero.holmstrom@luke.fi

ABSTRACT

Deep learning using convolutional neural networks (CNN) has proven to be a successful approach in a range of computer vision tasks. There are several points in the wood procurement chain where computer vision might bring significant advantages. In this work, we present two such examples. First, we develop and assess CNN-based models for uniquely identifying individual Scots pine logs along the logistics chain, using a "face recognition" approach for log end images. Our results show that the approach is promising, but trimming down the pool of logs registered as candidates in the identification process is likely required in real operations. Second, we show how CNNs can be used to identify root rot disease in Scots pine logs, as well as to automatically detect when large amounts of resin are present on the log end. Identifying the disease in question appears to be a challenging problem, but resin detection looks to be highly feasible. Finally, we discuss the key issues and potential benefits of these computer vision approaches regarding real forest operations.

Keywords: traceability, root rot, wood quality, deep learning, sawmills

ZONE THINNING TO INCREASE HARVESTING PRODUCTIVITY AND FOREST STRUCTURE VARIATION

HEIKKI OVASKAINEN[1]; ASKO POIKELA[1]; MATIAS KARHUMAA[2]*

[1]Metsäteho Oy; [2]University of Helsinki.

Corresponding author: heikki.ovaskainen@metsateho.fi

ABSTRACT

The productivity development of thinning with harvesters has been slow in recent years, which has led to a negative cost development in thinnings. As known, options to increase productivity in cutting is to decrease time-consuming work phases and increase those work phases that consume less time. On this basis, the so-called zone thinning method for harvester work was developed. The aim of this study was to study the effect of the zone thinning method on harvesting productivity. In the zone thinning method the idea is to make the harvester work more efficient by decreasing the thinning intensity at the harvester crane's maximum reach on the sides and increasing the thinning intensity closer the strip road and harvester. This is supposed to shorten the average catching distance of trees and thus making work more efficient. In addition, in the first thinning, outside of the maximum reach, is left an untreated zone, where the strip road is opened later in the second thinning. At that second treatment, strip roads opened in the first thinning are left untouched, as the surrounding zone of the first thinning have already been thinned to the target density of final felling. In the study experiment, harvesting studies were carried out in both harvester simulator and real environment by professional harvester operators. The thinning methods compared were: • traditional thinning at 20-meter strip road distance • zone thinning at 30-meter strip road distance. In the simulator environment, the zone thinning method increased cutting productivity compared to the traditional method by 7–8 % in the first thinning and 8–10 % in the second thinning. The idea in the zone thinning method is also that the same strip roads are not used again in the second thinning, thus avoiding additional soil disturbance. In addition, the area thinned in the first thinning may start to grow new saplings naturally in suitable locations, in which case the understory utilization options may come into question in the further development of the forest. Another advantage of the zone thinning method is the increase in forest variability factors due to the untreated zone left in the first thinning phase between the strip roads, whereby the variation in tree density contributes to the diversity of the forest.

Keywords: harvester, thinning, strip road, simulator, time study, harvesting method

BIOENERGY IN A TIME OF CRISIS

RAFFAELE SPINELLI[1]; NATASCIA MAGAGNOTTI[1]; ROBERT PRINZ[2]; JOHANNA ROUTA[2]; JANUSZ GOLASZEWSKI[3]*

[1]CNR IBE; [2]LUKE; [3]University of Warmia.

Corresponding author: raffaele.spinelli@ibe.cnr.it

ABSTRACT

In the summer 2022, the post-pandemic rebound and an escalation in the Ukrainian conflict determined a severe energy crisis. Within few months, gas and fuel prices climbed to unprecedented heights, endangering many businesses and applying new pressure onto the economy of Europe. Energy-demanding industries took the hardest hit and many had to suspend operation. European governments had to pause or reverse their enlightened green policies and look again at coal or nuclear energy…That was the time when the financial and strategic benefits of local bioenergy chains could eventually show their worth. At the end 2022, CNR, LUKE and the University of Warmia conducted a quick survey among bioenergy businesses in Italy, Finland and Poland, respectively. Those three countries were taken as representative of Northern, Eastern and Southern Europe. The survey indicated that bioenergy users suffered a much lighter energy cost increase compared with conventional energy users. They also had to cope with fewer or no interruptions in their power supplies, compared to other users in the region. Bioenergy suppliers dramatically increased the financial sustainability of their operations due to a dramatic growth of market prices, which was much higher than the increase in fuel cost incurred by their equipment. Bioenergy plants had to expand the share of locally sourced material, due to the sudden drying out of all wood import channels, to the benefit of local rural economy that had been choked by global prices until recently. The sudden and significant increase of wood fuel prices provided sufficient motivation to forest owners and wood suppliers to get organized and overcome many of the obstacles that had previously constrained correct exploitation and blocked access to an abundant local resource.

Keywords: Biomass; Bioeconomy; Energy; Efficiency; Sustainability

HYBRID-ELECTRIC SELF-PROPELLED CARRIAGE - FIRST FIELD TESTS

*STEFAN LEITNER[1]; RENATO VIDONI[1]; MASSIMILIANO RENZI[1]; RAFFAELE SPINELLI[2]**

[1]Free University Bozen; [2]CNR IBE.

Corresponding author: raffaele.spinelli@ibe.cnr.it

ABSTRACT

Cable logging can benefit from electrification in many ways, and more than other forest technologies. A significant percentage of cable logging setups transport timber downhill, providing an excellent opportunity for energy recovery. It is widely known that electrification is ideally suited to handle this task. However, due to the highly dynamic duty cycles, harsh working conditions, and tight weight constraints of forestry equipment, technical implementation is difficult. Equipment manufacturers started to electrify cable logging equipment with the introduction of electric slack-pullers almost a decade ago. Electric slack pullers are now mainstream. More recently, the first models of a hybrid tower yarder and an electric dropline carriage have been presented. This poster presents the second prototype and the early test results of a hybrid-electric self-propelled carriage, developed by the Italian start-up Leitalpin Ltd., with the scientific support of the Free University of Bolzano and CNR IBE. The machine is named HULK and is accordingly powerful and green. Its patented concepts enable it to efficiently transport uphill, downhill, and on flat terrain. HULK's traction drive and dropline winch are powered via independent electric motors, powered from an on-board energy storage system. When moving downhill and when lowering the load, energy is recovered and stored in the storage system. On sufficiently long and steep lines, energy neutral operation is possible. In all other cases, an on-board combustion engine supplies electric energy to the storage system. A first field test of HULK was conducted on a single-span line in the Northern Italian Alps. Travelling speeds and winch forces beyond 10 m/s and 40 kN were verified, respectively. Moreover, it was verified that the transport of 20 kN of timber 350 m downhill on the skyline with an average slope of 21 degrees could be performed energy neutrally. After extensive field trials throughout 2023, this new product is expected to achieve its market launch in early 2024.

Keywords: Cable; Steep; Energy; Efficiency

PRODUCTIVITY ANALYSIS AND COSTS OF WHEEL CABLE SKIDDER DURING SALVAGE LOGGING IN EUROPEAN BEECH STAND

SALVATORE F. PAPANDREA[1]; MARIA F. CATALDO[1]; STANIMIR STOILOV[2]; GEORGI ANGELOV[2]; DELYAN OSLEKOV[2]; GIUSEPPE ZIMBALATTI[1]; ANDREA R. PROTO[1]*

[1]Department of Agricolture - Technologies and Mechanization of Forestry, University of Reggio Calabria; [2]Department of Technologies and Mechanization of Forestry, University of Forestry.

Corresponding author: maria.cataldo@unirc.it

ABSTRACT

Salvage logging is increasing in Central Europe because of the growth of severe meteorological events and timber harvesting in these conditions is challenging in terms of both productivity performances and the safety of the operations. In recent years, with the increase of natural calamities, such as the accretion of heavy wet snow that poses the greatest risk to forests in the Northern Hemisphere, several researchers studied machinery productivity performances regarding salvage logging carried out by ground-based systems. In fact, a common post-disturbance management approach is salvage logging which consists of the widespread removal of damaged trees. In this research, system productivity and the cost of salvage logging are analysed in a European beech stand affected by wet snow. This type of snow adheres more effectively to tree crowns and branches when temperatures are close to freezing at the time of precipitation. In these conditions, trees may break or bend, and they may be uprooted when the soil is unfrozen. This study aimed to evaluate the productivity and cost-effectiveness of extraction in salvage logging deployed with a skidder in the beech stand affected by two different types of wet snow damages. The results show that the productivity of the four-wheel-drive cable skidder despite operating in salvage cutting with a removal intensity of 10% is 14.73 m3·SMH-1, similar to skidder performances in “ordinary” cuttings. Skidder’s productive time was 86% of the scheduled time, whereas the delays are due to organizational reasons, mechanical delays, and those adverse weather conditions. The mean travel speed of the cable skidder obtained in this study is close to the results obtained from other studies on similar machines. The costs per unit are lower compared to the effective cost consumptions for the other cable skidders and agricultural tractors, adapted for skidding operated in hardwood salvage logging. Therefore, under the given conditions, the operation of the four-wheel-drive cable skidder is viable from silvicultural, technical, and economic points of view in the salvage operation logging.

Keywords: Post-disturbance, Damaged timber, Forest operation, Timber harvesting, Ground-based systems

EVALUATION OF FOREST OPERATIONS ON SOIL COMPACTION IN SOUTH ITALIAN FORESTS

ANGELO MAMMOLITI[1]; MARIA F. CATALDO[1]; SALVATORE F. PAPANDREA[1]; GIUSEPPE ZIMBALATTI[1]; ANDREA R. PROTO[1]*

[1]Department of AGRARIA, University of Reggio Calabria

Corresponding author: maria.cataldo@unirc.it

ABSTRACT

In the last decades, the technological evolution in the forestry sector and in particular in the topics of mechanization and forest operations has led to an almost exponential increase in the use of more powerful but also heavier machines. At the same time, interest has also grown in more eco-sustainable and environmentally friendly working methods, also turning attention to the perturbations of trees and soil caused by the use of these new machines in forestry operations. In fact, forest practices such as wood harvesting by mechanized methods tend to induce soil compaction and reduce soil organic matter. Soil compaction alters soil structure and consequently the rate of nutrient and water movement from the soil matrix to the plant roots. The soil compaction increases the bulk density, therefore, reducing the pore space of the soil. Primary effects of skidding machinery through pressures brought about during their passages cause direct damage to large-diameter roots which can be macroscopically observable in shallow-rooting species and damage to the absorption zones in the thinnest parts of the roots which can only be detected by special instruments. For these reasons, the effects of forestry operations on soil compaction have been investigated and experimental investigations were conducted to determine the effects on soil caused during wood extraction with several machines (farm tractor, skidder, forwarder). To determine the effect of passages of forwarder on soil bulk density, soil samples were taken from trail locations within the site and a cone penetrometer was used to assess the resistance. The effects of forest operations on soil have been studied in the Calabria region (Southern Italy) and in particular on the Tyrrhenian side of the Calabrian Aspromonte Mountain, nearest to a sensitive area of the Aspromonte National Forest Park. The aim of this study was to present the preliminary results of the changes in soil characteristics and compaction. A well-organized and adequately supervised forest work should aim to minimize the amount of soil compaction and soil disturbance caused by wood harvesting operations using machines.

Keywords: Soil perturbation, Environmental disturbance, Harvesting operation, Skidding, Passage frequency

APPLYING OPTIMUM BUCKING METHOD TO COMPARE VOLUME AND VALUE RECOVERY OF FULL TREE AND CUT-TO-LENGTH SYSTEMS IN SOUTH US

*CARLOS DINIZ[1]; MATHEW SMIDT[1]**

[1]USDA Forest Service

Corresponding author: mathew.smidt@usda.gov

ABSTRACT

In the Southern USA, harvest systems are predominately mechanized, full-tree systems using feller-bunchers, grapple skidders and knuckleboom loaders. Timber specifications are based on large and small end diameters for mostly random tree-length dimensions. Since diameters and lengths are typically estimated by the knuckleboom operator and not measured, errors in bucking are likely. If well calibrated, bucking solutions from a harvester may be optimized for value recovery with accurate diameter and lengths. While most southern saw mills have integrated scanning and optimal bucking for tree-length stems, changes over time in tree dimensions and the relative value of certain products may change opportunities for merchandizing at the stump. In this study, stem-level optimum bucking approach was implemented by using dynamic programming algorithm to determine the optimum bucking pattern that maximizes the stem value for two harvest systems: full tree and cut-to-length. Trees from a loblolly pine stand in the Alabama coastal plain were cut and bucked by using a modern cut-to-length Ponsse harvester machine. The onboard computer (OBC) captured and stored data in the StanForD Classic formatted stem files (*.stm). We applied sets of specifications from locations in Coastal Plain and Piedmont to apply to the optimization techniques. Average state-wide delivered prices for pulpwood, chip-n-saw, and sawtimber were based on the regional price reporting. Differences between timber volume and value recovery between harvesting systems and regions can be important in determining the best harvesting and marketing methods for landowners.

Keywords: bucking, dynamic programing, logging, optimization, loblolly pine

SENSING TECHNOLOGY AND AI ALGORITHMS FOR DETECTING TREE QUALITY FEATURES AND OPTIMIZING BUCKING DURING HARVESTING OPERATIONS IN RADIATA PINE PLANTATIONS

MAURICIO ACUNA[1]; JAN ROMBOUTS[2]; COVADONGA PRENDES[3]*

[1]Natural Resources Centre (LUKE); [2]OneFortyOne; [3]Fundacion CETEMAS.

Corresponding author: mrcacuna@gmail.com

ABSTRACT

Achieving the highest value from a plantation resource relies on quality, timely and accurate measurement of key-value influencing tree quality features (e.g. sweep, branchiness) to support optimized stem bucking decisions. Due to the difficulties associated with measuring tree quality features in the field during forest inventory work, these attributes are usually excluded from optimal bucking procedures. At harvest time, in addition to diameter and length measurements, current onboard machine optimization systems rely on operator assessment of key features like stem sweep, limb diameter, limb angle, and internal characteristics like stiffness and strength. These repeated observations, judgments and operations performed by the operators may result in reduced productivity and value losses. Emerging and new sensing technology like LiDAR, photogrammetric point clouds, and high-definition stereo imaging represents an opportunity to leverage more accessible and affordable data collection to capture some of the factors currently estimated by operators with accurate measurements and improve the value recovery. Our study presents a non-destructive, automated methodology to optimize stem bucking based on point cloud data acquired with a mobile laser scanner (Hovermap LiDAR system), which maximizes tree value. The raw point cloud was processed with AI, which enabled the automatic detection of the trees in the plot and the estimation of diameters at different tree heights and stem sweep. This information was then used as input to a dynamic programming bucking algorithm that optimized the value of each tree based on market and tree data. The methodology was tested on two Radiata pine (Pinus radiata D. Don) plots in South Australia, consisting of about 50 trees each. The bucking results were compared for three sets of input data: two generated from point cloud data collected with the LiDAR scanner (including and excluding sweep) and one generated from a taper equation based on manual DBH measurements. The metrics used for the comparison included total value, value per product, total volume, volume per product, and the number of logs per product.

Keywords: Lidar, Artificial Intelligence, Tree quality features, Bucking optimization, Radiata pine

ASSESSING THE EFFICIENCY OF MECHANISED HARDWOOD THINNING OPERATIONS AND TREE QUALITY FEATURES USING MACHINE TIME STUDY DATA AND LIDAR/AI TECHNOLOGIES

MAURICIO ACUNA[1]; STEPHEN CLARKE[2]; MARTIN STRANDGARD[3]; COVADONGA PRENDES[4]*

[1]Natural Resources Centre (LUKE); [2]Private Forests Tasmania; [3]University of the Sunshine Coast; [4]Fundacion CETEMAS.

Corresponding author: mrcacuna@gmail.com

ABSTRACT

Mechanical thinning of stands to produce high-value logs is expensive and might be carefully executed to control costs and meet the silvicultural outcomes. Some Australian forest companies are transitioning from pulp to solid wood plantation regimes, which requires a good understanding of the costs involved during the thinning operations and the factors that explain the efficiency of mechanised equipment in hardwood (Eucalyptus) stands. Although several harvesting studies have been conducted across Australia, they have focused on clearfelling operations of Eucalyptus stands and thinning of Radiata pine stands. Thus, it is critical to investigate the thinning strategies and harvesting equipment that have the potential to meet the silvicultural outcomes, minimise harvesting costs, and produce high-value logs at harvest time. Before thinning, LiDAR technology can be used to determine the total volume per ha, which is then compared to the remaining volume after thinning. Remaining trees after thinning must also be assessed regarding stem quality features such as branchiness, tree form, and any defects caused during the thinning operation. These assessments have been traditionally performed using manual and visual methods. Sensing technologies like LiDAR have emerged and evolved in the last decade representing a more affordable and accurate way to capture tree and stem data. In addition, LiDAR technology is being proposed and tested to assist operators with tree selection during thinning operations and create high-density maps of the remaining trees/stand after the thinning. The objectives of this project were: 1. To quantify productivity and costs of mechanised thinning operations in Eucalyptus nitens stands, pinpointing those factors with the most significant impacts on productivity and costs, 2. To develop a methodology to capture tree quality features in thinned stands from sensor data, 3. To provide data and methods for more efficient hardwood plantation thinning operations, 4. To test optimisation and AI algorithms for more effective and efficient tree selection decisions during thinning operations. The project was implemented in Northwest Tasmania in two sites owned and managed by FORICO Ltd Ply. A single thinning regime and intensity at age 9 was implemented, with the remaining trees growing through to around 25 years of age. A wheeled harvester/processor performed the mechanised thinning operations.

Keywords: hardwood mechanised thinning operations, artificial intelligence, LiDAR sensors, optimization

FINAL RESULTS OF A SURVEY ON MACHINE EQUIPMENT AN HARVESTING CAPACITIES OF AUSTRIAN FOREST SERVICE COMPANIES AND FOREST ENTERPRISES

NIKOLAUS NEMESTOTHY[1]; CHRISTOPH HUBER[1]; JÜRGEN RICHTER[1]*

[1]Austrian Research Centre for Forests (BFW), Department of Forest Engineering

Corresponding author: nikolaus.nemestothy@bfw.gv.at

ABSTRACT

According to former federal statistics, 9 to 10 million solid cubic meters, i.e. about 50% of the total felling, were harvested by forest service companies as contractors every year. For forest enterprises with more than 200 ha of forest land, more than 75% of the harvested wood was harvested by forest contractors. In order to obtain a comprehensive overview of the regionally available harvesting capacities, a survey was carried out in 2020 among a) Austrian forest owners with more than 200 ha of forest land each and b) all registered forest service companies (forest entrepreneurs). They were asked about their equipment, their employees and their skills. The design and the first results of this survey were presented online at FORMEC 2021. The survey has now been completed and the final results are available. A database was set up based on the results in order to be able to identify the availability of various machines or harvesting systems according to geographical criterias. In addition to the regionally available number of machines, it was also possible to evaluate the market shares of different manufacturers, the service life of different machines, as well as their annual utilization and distribution of the size classes for example. Surprisingly only about 50% of registered forest service companies are actually active in timber harvesting. However, the active forest entreprerneurs recorded are significantly better and more modernly equipped than the forest enterprises with more when 200 ha of forest land.

Keywords: harvesting capacity, forest machine statistics, data base, forest service entrepreneurs

CRITERIA AND INDICATORS FOR ASSESSING THE SUSTAINABILITY OF TIMBER HARVESTING OPERATIONS — A SYSTEMATIC REVIEW

*JULIAN GRÜNBERG[1]; MOHAMMAD REZA GHAFFARIYAN[2]; MEGHDAD JOURGHOLAMI[3]; ERIC R LABELLE[4]; NOPPARAT KAAKKURIVAARA[5]; RENATO CESAR GONCALVES ROBERT[6]; MARTIN KÜHMAIER[1]**

[1]University of Natural Resources and Life Sciences, Vienna; [2]University of the Sunshine Coast, Forest Industries Research Centre; [3]University of Tehran, Department of Forestry and Forest Economics, Faculty of Natural Resources; [4]Université Laval, Department of Wood and Forest Sciences; [5]Kasetsart University, Department of Forest Engineering, Faculty of Forestry; [6]Federal University of Paraná, Forestry & Wood Science Center.

Corresponding author: martin.kuehmaier@boku.ac.at

ABSTRACT

The comprehensive assessment of timber harvesting operations through the consideration of the three pillars of sustainability (Economic, Social and Environmental) has not received much attention so far. The use of various sustainability criteria and indicators can significantly improve impact assessment. Therefore, the objective of this research was to compile and analyze the most commonly used criteria and indicators for each dimension of sustainability in timber harvesting over the last five years. It was intended to provide an overview of these criteria for different harvesting machines, geographical areas, slope classes, time periods, types of research, and silvicultural systems. The environmental pillar was the most studied, followed by the economic and lastly the social pillar. Most of the 336 studies (n = 182) were related to the environmental dimension of sustainability, with soil nutrients (n = 94) being the most discussed criterion, followed by soil compaction (n = 82). Productivity (n = 123) and costs (n = 84) were the most frequently examined criteria within the economic pillar. Exposure to vibration (n = 19) and physical workload (n = 16) were the most commonly investigated criteria within the social pillar. Sustainability is achieved when all three dimensions are balanced. The results of this review show an imbalance, with economic and environmental aspects being weighted more heavily than social aspects. Balancing all three dimensions normally require an assessment of trade–offs. This review provides a comprehensive summary of the criteria that have been studied to date and can be used as a checklist and guideline for future sustainability assessments of harvesting operations.

Keywords: Timber Harvesting; Sustainability; Environmental Impact; SDGs

COMPARISON OF SOIL BULK DENSITY, PENETRATION RESISTANCE AND RUTTING BETWEEN FORWARDING AND SKIDDING.

ELENA MARRA[1]; CHRISTIAN HÖÖK[2]; ENRICO MARCHI[1]; TOMAS NORDFJELL[2]*

[1]Dipartimento di Scienze e Tecnologie Agrarie, Alimentari, Ambientali e Forestali (DAGRI) – University of Florence; [2]Department of Forest Biomaterials and Technology (SLU), Swedish University of Agricultural Sciences, Skogsmarksgränd, Umeå.

Corresponding author: elena.marra@unifi.it

ABSTRACT

Intensive forest harvesting operations may cause soil compaction, plastic soil disturbances and rutting, which are responsible for undesirable effects on soils, vegetation and water bodies. Despite the numerous studies aimed to identify the main factors affecting soil damages, it remains unclear whether wood transportation methods and driving direction may affect the soil impacts from forest machines. In this context, the overall objective of this study was to compare physical soil parameters for assessing compaction (i.e., bulk density and soil penetration resistance) and rutting caused by forwarding and skidding. Rutting was recorded with images collected using drones and Structure from Motion photogrammetry creating 3D soil models. The effects of wood transportation in different transporting directions (flat, up- downhill and in a curve on flat terrain) was also tested. The same forest machine, a 12.4 ton forwarder with eight wheels, was used during both skidding and forwarding, in order to maintain machine parameters (i.e., wheel dimensions, tyre tread and pressure) constant. In forwarding, the machine was used as an ordinary forwarder for transporting the logs. In forwarding, 27 logs were loaded on the forwarder for a total of 9,817 kg. In skidding, 16 m long trunks, 7,849 kg in total, were fixed with chains on the forwarder rear load bunk to simulate a clambunk. For forwarding, our findings showed that up- or downhill transportation did not affect soil damage severity (bulk density) in a 15% slope. On the contrary, for skidding downhill transportation is preferred in order to reduce soil compaction. The results showed that the pressure on the ground caused by vehicles also is distributed horizontally, thus highlighting the effect on soil also between the wheel tracks. The soil bulk density in the tracks for forwarding increased by 38-40% and 15-25% between the wheel tracks after 20 passages. After transportation of the same total volume (338 m3) the soil bulk density did not differ significantly between forwarding and skidding in uphill transportation, but was significantly higher for forwarding on flat terrain or in downhill transportation. However, the soil penetration resistance did not differ significantly between forwarding and skidding in any transportation direction after 338 m3 transported volume. The comparison of the area affected by soil impacts showed a larger area in skidding than forwarding due to the effect of dragged tree trunks. The soil displacement in skidding trails (9.06 m3 per 100 m of trail) was significantly higher than in forwarding (2.30 m3 per 100 m of trail) driving uphill. The comparison of driving in a curve and in a straight line highlight that curvature caused larger soil damages. In addition, these results allude to a relationship between soil compaction and rutting in low-moisture soil condition In conclusion, these results show important information

on soil impact, which can be a useful criterion for choosing a proper wood transportation technique and for operative planning of harvesting sites.

Keywords: cone penetrometer, curve, drone, photogrammetry, slope

DEVELOPMENT AND EVALUATION OF A FELLING HEAD FOR A LIGHT FOREST CRAWLER

*CHRISTIAN KNOBLOCH[1]; JOERN ERLER[1]**

[1]Tu Dresden, Professorship for Forest Technology

Corresponding author: joern.erler1@tu-dresden.de

ABSTRACT

With motor-manual wood harvesting (by a forest worker with a chainsaw) fatal accidents happen every year when the tree is felled or when parts of the crown fall down. The alternative is to fell trees mechanized using a timber harvester head, which, however, must be brought up to the trees in the forest by means of its crane. With the usual crane reach of 10 m, the harvester needs a system of parallel strip roads with a spacing of 20 m. Furthermore, the harvester needs a dead weight of around 20 tons, that compacts the soil. Both consequences increasingly evoke critics. The requirement to fell trees mechanized and to enlarge the distance between the strip roads calls for a solution to fell trees with a small, light machine that can apply its felling tool to the tree in close proximity. Together Pfanzelt Maschinenbau GmbH and the Professorship for Forest Technology of Technische Universität Dresden have run a project, with that a compact, new type of felling head was developed, which is attached to the existing forest crawler "Moritz FR70/75" by means of a short manipulation arm. This head imitates the felling technique, which is applied by a forest worker, in a mechanical way with a high grade of automatization. Even though this machine works with higher system costs, it is significantly faster and more precise than the motor-manual version. The functional principle of the felling head was developed, patented, conceptualized and optimized with the help of prototypes and individual tests at the TU Dresden, Professorship for Forest Technology. After that, it was completely designed, manufactured and automated in terms of control technology by the Pfanzelt company. More than 100 conifers with a felling diameter up to 50 cm were felled safely and without any problems with the prototype. The possible integration into harvesting processes as well as the effects on the use in the forest stands were analyzed in detail. The project has shown that it is possible to fell trees fully mechanized without danger for the forest worker with a machine that weights roughly a tenth of the dead weight of a conventional harvester.

Keywords: felling head, accident avoidance, mechanization of motor-manual harvesting, automatization

CALAHARI- CALAMITY ADAPTED HARVESTING INNOVATION

LISA JENSEN[1]*

[1]German Center for Forest Work and Technology Research (KWF e.V.)

Corresponding author: lisa.jensen@kwf-online.de

ABSTRACT

The aim of the CALAHARI project, which is funded by the German Federal Ministry of Food and Agriculture through its project executing agency (BMEL), the Agency for renewable raw materials e.V. (FNR), and the German Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV), is to develop a robot-assisted, partial-autonomous timber harvesting process. Together with STIHL and the German Research Center for Artificial Intelligence (DFKI), the opportunities offered by robotics and digitalization are being used to develop a multidimensional solution for logging. Forestry is still one of the most accident-prone sectors in Germany. This is due in particular to the difficult terrain, obstructions to visibility, slopes, uneven and sometimes highly yielding ground. Soil wounding by harvesters and forwarders is just as problematic in bad weather as soil compaction. The size of the harvesters also prevents them from driving over the whole area of the stand. In addition, working with large forestry machines poses the risk of noise pollution and a sense of disturbance among large sections of the population. A robot that is controlled remotely and has a low weight should minimize these risk factors. What is the added value of a robot-assisted, semi-autonomous timber harvesting process on the ecology of the forest? To what extent does a robot-assisted, semi-autonomous timber harvesting process have an impact on occupational safety? In which work steps does it make sense to use a robot-assisted, semi-autonomous timber harvesting process? Possible benefits of the robotic, semi-autonomous harvesting method are positive effects on the ecosystem in terms of soil degradation, due to the lower weight, noise pollution and the CO2 footprint. The control of the systems should be facilitated by the use of adapted AI methods and partial autonomy in order to relieve the forester physically and mentally. Furthermore, intelligent networking of the systems should make it possible to build up a long-term database so that adapted control, as well as analysis and forecasting of forest development, is possible. Robot-assisted timber harvesting methods offer great potential here for working in collaboration, even together with the forest workers, over a longer period of time and also protect the environment. The first step is to define the requirements and analyse the conditions for logging. Based on this, the second step is to present a concept design for a robot system for semi-autonomous tree felling, including sensors, felling and control technology, and communication infrastructure. The envisaged vision requires various intermediate steps in the areas of robotics, sensor technology, process planning and technology assessment. The current status in timber harvesting will be systematically recorded and requirements for automated systems will be derived from this. At the same time, existing robotic solutions will be investigated with regard to locomotion apparatus, sensor technology and partial-autonomy, as well as teleoperation and telepresence systems. The

synthesis of the results then presents initial proposals for the further development of an automated harvesting system.

Keywords: robotic, innovation, harvesting, forestry

TECHNODIVERSITY - INTERNATIONAL COOPERATION IN TEACHING

*JÖRN ERLER[1]**

[1]TU Dresden

Corresponding author: joern.erler1@tu-dresden.de

ABSTRACT

Technodiversity – International cooperation in teaching Collaboration among forest technology scientists is a good practice in research projects, but in teaching each university usually has its own program. With increasing demands on science and training and often declining staff, we see the need for a better network with regard to teaching. That is why 6 universities and 2 research institutes have started the Erasmus+ project Technodiversity. The goals are: To work out and explain the technological diversity of harvesting measures in Europe and to promote it through teaching modules. The target groups are students from all universities in Europe at master's level and management staff from forest service companies as advanced training. The project is divided into 4 project results: PR1 facts and methods: The aim is to create a couple of lectures and a glossary about the basics of forest technology and the methods for optimizing the selection of harvesting processes. As a first step, 32 lectures were developed and discussed with all partners. On the basis of this intellectual discussions, a glossary for forest operations is extracted that is interlinked with the lectures. PR2 scientific audiovisuals: Parallel to the lectures, short films are produced about forest machines, harvesting methods and research standards for forest operations. They all follow a common guideline, which makes it easy to use them for lectures with students. PR3 knowledge platform: A Moodle tool is developed as a common interface for all partners and participants. It is intuitive, didactically flexible, barrier-free and open to changes and extensions. This platform is hosted by CNR in Italy and will be assessable for the public from the end of the project. PR4 E-learning platform: Though the access to the platform will be free for everybody, we will give the opportunity to use it for a final examination on master's level, that can be selected by forest students as an eligible Erasmus+ course with 5 ECTS. Herefore, the course will be integrated into the curriculum of the University of Poznań as a regular course, so that both the examination management and the periodic evaluation are secured by the university. The project started in November 2021 and will last until March 2024. Most elements are prepared and discussed. The rest of the project duration will be used for tests and improvements before Technodiversity will free for public in April 2024. Project leader is the University of Technology Dresden (Germany). Further members are the universities BOKU Wien (Austria), University Zagreb (Croatia), Transylvanian University Brasov (Romania), PULS Poznań (Poland) and SLU Umeå (Sweden) as well as the research organizations CNR Firence (Italy), and FCBA Camps sur Marne (France).

Keywords: e-learning, forest operations, technology

LOG-LOADING AUTOMATION WITH FPI CRANE TESTBED

INNA SHARF[1]; HESHAN FERNANDO[1]; JEAN-FRANCOIS GINGRAS[1]*

[1]FPInnovations

Corresponding author: inna.sharf@fpinnovations.ca

ABSTRACT

FPInnovations (FPI), a Canadian non-profit organization dedicated to advancing all aspects of Canadian forestry industry, is actively engaged in bringing automation, robotics and AI to forestry operations. The loading automation project was initiated in 2020, and its ultimate objective is to increase the autonomy of log loading operations. The motivation for this work stems from the issues around acute and enduring shortage of skilled machine operators. In addition, machine productivity has reached a limit, which linked with the shortage of skilled operators, contributes to the escalating costs of the harvesting operations. Thus, increasing the autonomy of harvesting machines by gradually transitioning from an operator-assistive setup to a mostly autonomous setup, where the operator is removed from the machine and interacts with it occasionally through a remote interface, offers both the appeal to younger operators and will ultimately improve the overall productivity. The log loading operation, which is the focus of the current automation effort at FPI, was chosen because this operation is carried out multiple times in forestry operations as the logs/stems are delivered from the forest to the infeed of a sawmill. Towards the aforementioned goals, FPI purchased a commercial small scale log loader—the crane—and instrumented it with the necessary sensors and controllers to enable the development of autonomy. The crane testbed is installed in the parking lot on FPI's premises and includes a controls cabin to house the relevant electronics, laptops and two-three users for conducting experiments. In this presentation, we will give an overview of the key milestones achieved in the development of the crane testbed over the past three years, summarize its current capabilities and outline the roadmap for our future work. Beyond retrofitting the crane with the automation hardware, a substantial code base has been created to enable three main autonomous functionalities, which will be described in the presentation: ---motion planning and control to allow the crane arm to be relocated autonomously from one position to another, as for example, to move the arm from being over the trailer to being above a log pile. ---vision-based perception: a ZED 2i 3D camera has been mounted on the stick of the crane, and an AI-based algorithm was developed to detect, segment, and characterize logs to determine their length, diameter and location with respect to the crane. ---grasp planning: an AI-based algorithm was developed to determine where the logs should be grasped by the grapple. This algorithm can produce grasp locations for both individual isolated logs and logs in mini-pile arrangements—typical of what one might see in certain areas of the mill yard and in the forest. In addition, a simulator of the crane testbed was created in Omniverse Isaac Sim—a high-fidelity commercial simulator for robotic applications. We will demonstrate the current capabilities of the crane vis a vis autonomous log loading operations with several videos of the experiments with the testbed conducted over the past year. The talk will

conclude with our plans for transitioning the developed technologies to a mill yard for technology demonstration.

Keywords: harvesting, log loading, automation, planning, control, perception, grasping, AI, simulation

TECHNODIVERSITY – HARMONISING EUROPEAN EDUCATION IN FOREST ENGINEERING BY IMPLEMENTING AN E-LEARNING PLATFORM TO SUPPORT ADAPTATION AND EVALUATION OF FOREST OPERATIONS

ANDREJA ĐUKA[1]; JÖRN ERLER[2]; PIOTR MEDERSKI[3]; STELIAN A. BORZ[4]; OLA LINDROOS[5]; KARL STAMPFER[6]; PHILIPPE RUCH[7]; RAFAELLE SPINELLI[8]*

[1]University of Zagreb Faculty of Forestry and Wood Technology; [2]Technische Universität Dresden; [3]Uniwersytet Przyrodniczy w Poznaniu; [4]Transilvania din Braşov; [5]Sveriges Lantbruksuniversitet; [6]Universität für Bodenkultur Wien; [7]Institut Technologique FCBA; [8]Consiglio Nazionale delle Ricerche.

Corresponding author: aduka@sumfak.unizg.hr

ABSTRACT

The Technodiversity project addresses the technological diversity of forest operations by gathering technical knowledge and acknowledging the wide and valuable variety of local conditions. It promotes sensitivity to technological diversity. This project aims to bring together and make available the existing knowledge in forest operations scattered across various European countries. With the help of teaching modules, the content will be available to the students as an e-learning course with exercise and examination units. The course will be recognized by European forest faculties in the forest master curriculum. In addition, it can also be used as a further training unit for forestry practitioners. Four project results are produced: 1) lectures on forest operations deliver the intellectual knowledge necessary for the optimization, together with a glossary; 2) scientific audiovisuals which illustrate typical harvesting methods under regional forest situations; 3) a knowledge platform based on MOODLE and 4) an e-learning course which organizes exams that applicants can use for exams or for life-long learning. Partners in the project are Dresden University of Technology (TUD), Germany - leader; Poznań University of Life Sciences, Poland; National Research Council, Italy; Transilvania University of Brașov, Romania; University of Natural Resources and Life Sciences, Austria; Swedish University of Agricultural Sciences, Sweden; University of Zagreb Faculty of Forestry and Wood Technology, Croatia; Technological Institute FCBA, France. The Technodiversity project is funded by the Erasmus+ programme of the European Union in the field of higher education and will end in March 2024.

Keywords: higher education, student mobility, forest engineering, forestry practitioners

INTERMODAL TIMBER TRANSPORT LOGISTICS – OPERATIONAL AND STRATEGIC PLANNING IN FORESTRY

HANS-ULRICH DIETZ[1]; THOMAS SMALTSCHINSKI[1]; THOMAS PURFUERST[1]*

[1]University of Freiburg, Chair of Forest Operations

Corresponding author: hans-ulrich.dietz@foresteng.uni-freiburg.de

ABSTRACT

Accumulation of forest damage at the main tree species in a progressive rate as a result of climate change, a declining number of employees at truck transport companies, as well as the need to reduce carbon emission and coevally increase resource efficiency in the wood supply chain lead to constant efforts to increase the share of timber transport by rail significantly. Due to forest damage, mainly caused by insect infestation, a mean value of 77.5 million cubic metres of timber has been logged annually in Germany within the years 2019-2021. The Federal Statistical Office reports that a total amount of around 13 million cubic metres were transported by rail in 2019-2021, corresponding to 6% of the total amount of logged timber within these three years. In an ongoing R&D project with the acronym "VEHIT" future prospects for intermodal transport logistics have been analysed in the Federal Region of Bavaria in order to boost the carriage of roundwood by rail. Joint partners in this state-funded R&D project are the German railway company DB Cargo Logistics and the Bavarian State Forestry Enterprise (BaySF) as well as associated forest owner and timber marketing associations. The project's methodological approach and results will be presented to solve this classic but complex minimal cost flow problem in Operation Research. The basic concept for transport optimisation is the compilation of service areas, i.e. route-related transport distances from roundwood origin to customer via existing timber loading hubs, so-called timberports. Geo-coordinates of BaySF timber piles at roadside from the years 2015 and 2019 were mapped to these service areas and alternate rail and truck transport routes were calculated by linear programming for mandatory customers depending on the product assortments. In a first analysis, costs, time requirement of truck transportation and carbon emissions of different intermodal transport alternatives were matched. Time requirements for transportation and carbon emissions clearly show a priority of intermodal long-distance transport by truck and rail. Considering the costs for intermodal timber transportation, there is still some potential and needs for optimising future timber logistics.

Keywords: Intermodal transport, operation research, roundwood logistics, rail transportation

MAPPING ROOT ROT WITH HARVESTER DATA

SIMON BERG[1]*

[1]Norwegian Institute of Bioeconomy Research

Corresponding author: simon.berg@nibio.no

ABSTRACT

The root rot fungi (Heterobasidion annosum) are causing significant economic losses for Norwegian forestry every year. These losses are both due to that the fungi reduces wood quality, through reduced growth and sometimes also fatalities. Furthermore, are there also losses for the forest industry and society at large as only lower-value short-lived products as paper and energy can be made from rot infected wood. Only the reduction in timer value is estimated to cost the forest owners in Norway at least 200 MNOK/year (~18-22 M€/year). Root rot fungi can infect trees through two main avenues through root contact and with spores. Spores that land on a fresh wound that goes through the bark of a tree can infect the tree with root rot. The fungi can also infect trees through root contact with trees or stumps that are already infected, which means that the infection can spread in the stand to undamaged trees. The fungi also survive in the stump and root system after a clear-cut for an extended time period, which means that the next generation will be infected. Stumps can also be infected with spores after logging while the wood is fresh and then spread from the stump. Altogether is root rot a persistent problem that is very expensive and that also worsens over time on a site. There are some opportunities to reduce the risk of root rot spreading to the next forest generation. Stumps can after harvest be chemically (urea) or biologically (Phlebiopsis gigantea) treated to prevent root rot infection. However, this treatment does not prevent the spread from already infected stump and root systems. In Norway is the Heterobasidion variant that only infects Norway spruce (Picea abies) completely dominant so therefore are both planting Scots pine (Pinus sylvestris) and birch (Betula spp.) around infected stump viable options for reducing root rot as these species are resistant to that variant. There is also ongoing research into more root rot resistant clones of Norway spruce which might become an option in the future. However, a more root rot-resistant clone will most likely have some other drawbacks. Another alternative is to physically remove the infected stump through stump harvesting. Stump removal will not get rid of all infected roots so there will be an infection in the next generation. However, the infection will occur later, and fewer trees will be infected compared to no treatment. Anyway, stump harvesting is not a good option for reducing root rot in Norwegian conditions. The forest is often in quite steep terrain, and many areas have a high annual precipitation so stump removal would increase the risk for erosion and landslides. In addition is there also an increasing debate and criticism of the ground disturbance of normal logging operations so stump removal is very unlikely to be socially accepted in Norway. However, stump removal could be an option in other areas.

Regardless of what treatment options that is interesting is the location of the root rot infected trees needed to be able to implement the treatment. Traditionally have the information about the presence of root rot been

limited to only an indication based on the amount of energy wood and low-quality pulpwood that have been produced at a site. These assortments are related to the amount of root rot. Based on that knowledge have the decision been to either treat the whole site or to continue with business as usual. The only option to get better information has been costly and difficult inventories. Stumps are covered with slash and other debris during the harvest, stumps are destroyed by the machines when they drive at the site, and the stumps also change colour so only more severely infected stumps can be detected when some time has passed since harvest. However, with a combination of new and older technology is it possible to map root rot in more detail. The information about the presence of root rot can be registered by the harvester operator. The operator already has to reduce the quality of the stem when root rot is detected. The bucking optimisation assumes damage-free stems as long as the operator does not input other information. So, currently are the reduction in quality recorded but not the reason for the reduction. There has also been a development over the last decades that has enabled GPS with high accuracy that isn't too expensive. Lastly, lately, has there been a development of sensors that can detect the harvester head with high accuracy, and thereby also the stumps of felt trees with high accuracy.

In this study were additional assortment of rotten pulp wood and rotten cut-offs added to the bucking instructions, while all energy wood was assumed to be rotten. The main difference between energy wood and low-quality pulp wood for Norway spruce in Norway is the amount of rot that is allowed. There is also a limitation to the number of buttons on the joysticks and their locations are more or less easy to reach for the operators. Therefore, was no separate assortment for rotten energy wood added as it would add a minuscule amount of information while increasing the extra work for the operators. The operators practised registering root rot in several sites (until they felt confident about not making errors) before data collection for the study started. The information about tree species and log assortment were saved in StanForD or StanForD 2010 file format from where the information later was extracted. In these files were also the harvester's location when felling each tree and/or tree location saved.

In the study were there a mix of harvesters with different GPS accuracy included. From the traditional harvester location only (±10-12 m), guesstimation of tree location (±5-30 m), to high accuracy tree location (<±2 m). However, the most interesting is to compare the high accuracy locations of the trees to the traditional harvester locations when it comes to the possibilities for planning different treatments for reducing the impact of root rot in future forest generation. The difference between registering tree and harvester locations for the stumps is shown for a small site in Figure 4. The locations of the stumps are as expected for the two methods. However, neither map provides that much help when planning future root rot preventing treatments. There is a zone with a high likelihood of infection for seedings of about 2-3 m from an infected stump. Further away from infected stumps is the likelihood of seedling infection relatively low.

Therefore, is there a need to estimate the area that has a high-risk for seedling infection, and then avoid planting Norway spruce in that area. A heatmap for the high-risk area for seedling infection is shown in Figure 5. The estimation is made based on the accuracy of the tree location (± 2 and 10 m) with an additional buffer of 3 m around the tree for the high-risk zone. With these estimations are there a quite clear difference between having tree or harvester locations. With harvester locations is it possible to see some likely hotspots but it seems like the entire site could be infected with root rot. This large high-risk area for seedling infection is due to the uncertainty added by the unknown location of a 10 m long crane. A rasterization of the heatmap was also

done as much of the forest information in Norway is published in a 16x16 raster (Figure 6). After the rasterization does it seem like the difference in usefulness increased between harvester locations and tree location. However, the general usefulness decreased for both data qualities.

Quite many sites were similar to the site shown here in the sense that the root rot was spread out in the site. The general pattern is that there are some hot spots with several infected trees close to one another and then singular infected trees spread out in the sites. There is of course difference between sites in the frequency of rot root but the general trend, that the rot is spread out is quite consistent. This is of course a situation that makes treatment a bit more difficult, particularly if "only" harvester locations are known. The situation also means that tree locations in many cases are the required data quality to make any more informed decision considering how to treat a site.

In the previously shown site is not harvester locations really useful, and it is basically still a decision to treat everything or nothing, if only harvester locations are available. However, there is of course a variation in how the root rot is spread at sites and particularly in larger sites can harvester locations be useful (Figure 7). So, harvester locations can, at least sometimes, be used to detect areas that are better or worse concerning root rot, and occasionally can root rot free areas be detected. That means that the treatment decision is changed to treat or not treat different areas of the site based on how severely infected the areas are.

However, for precision planting around infected stumps are tree locations needed. Efficient precision planting is desirable to minimise the economic impact of root rot. Currently are precision planting difficult as markings have to made in the field before planting. However, equipment that can help the planters to plant different tree species with high accuracy is being developed (Figure 8). There is an abstract in the proceedings called "SmartPlanter: a planting device for precision planting" for interested readers. This development means that it is likely that precision planting will be operationally possible in the not-too-distant future. The development also means that investment into GPS equipment and sensors for accurate tree locations (harvester head location) during harvest becomes more and more important. Accurate location of the harvesting head can of course be used for many other value-adding purposes (e.g., making it easier to find and forward all logs), so it is not only an investment into localising root rot.

Keywords: Presisson forestry; planing

WOOD-FIBER BASED HYDROGELS

GWENDOLIN HARTMANN[1]; BENJAMIN ENGLER[1]; THOMAS PURFÜRST[1]*

[1]Albert-Ludwigs-Universität Freiburg

Corresponding author: gwendolin.hartmann@foresteng.uni-freiburg.de

ABSTRACT

Wide areas of Europe, and also in other parts of the world, are faced with very dry weather conditions with low precipitation during the growing season and soil conditions being unfavorable for water storage, which challenges the planting of young trees. In consequence, there is a need to support tree growth during the first weeks after planting and to overcome dry periods without rain. There are various soil conditioners available at the market, which try to close this gap. One of these are hydrogels, basically, a water storing material, mainly a granulate, that works like a sponge. It fills up when there is a surplus of water or when it rains and releases the stored water in dry periods to the soils and thus to the root system of the trees. Unfortunately, most of these hydrogels consist of superabsorbent polymers based on polyacrylates, which are not fully degradable because of its micro-plastic ingredients. Within the EU-project "ONEforest" (funding ID 101000406), a hydrogel based on wood fibers and thickening agents, in particular gelatin or xanthan gum, both are commonly used in the food industry, is developed. Three applications are foreseen for the wood-based hydrogel: (i) as soil conditioner to improve the water storing capacity of the soil (ii) as top soil cover to reduce the evaporation from the soil and competition with weed around the young tree and (iii) as a gel for root treatment to reduce evaporation and dry out by using bare-root plants. Initial studies were performed to better understand the dosage and a possible application/spreading of these kinds of hydrogels. During the time the products were developed further and modified to simplify handling and application and to be comparable and competitive with conventional, already existing products on the market. Together with other biological components like sheep wool, tannin or citric acid the properties of the developed products were improved. The next trials, mainly tested in the different Case-Study-Regions of the project – Germany (Hesse/Thuringia), Spain (Catalonia) and Switzerland (Canton Grison), were conducted to test the new formulations and to perform a time study and cost calculations to know the productivity, cost efficiency and effectiveness. Also, the plant performance and soil were monitored to reveal possible harming or strengthening effects.

Keywords: wood-fiber based Hydrogel, planting tails, time study

MARKER-FREE TRACKING OF TREE LOGS FROM HARVEST TO THE SAWMILL – IMPACT FOR SUSTAINABILITY

*CATHERINE LAST[1]; UDO H. SAUTER[1]**

[1]Forest Research Institute Baden-Wuerttemberg (FVA)

Corresponding author: udo.sauter@forst.bwl.de

ABSTRACT

The aim of this project is to develop, test and validate a traceability system for wood that is practical to use, provides reliable proof of origin and is tamper-proof through marker-free tracing. The fingerprint technology uses inherent wood microstructures that serve as uniquely recognizable patterns to identify individual log parts and enable tracking throughout the chain of custody. This is achieved by automatically capturing the "fingerprint" of the wood when it is cut and when it arrives at the sawmill with built-in camera systems, eliminating additional processing time. This collaborative project will deploy a robust camera system on a harvester and in a sawmill, coupled with state-of-the-art computer vision approaches to achieve optimal recognition rates under the harsh conditions of the wood process chain. Ultimately, this novel tool will enable unique attribution of log parts to the original tree, providing a control mechanism for accurate record keeping, incentivizing increased wood mobilization, particularly for the private forest sector, supporting certified sustainable wood sourcing, and contributing to overall logistics improvements. In order to evaluate the opportunities for sustainability of a marker-free roundwood tracking system, we conducted a sustainability analysis supported by the German Oeko-Institut e.V.. The aim was to identify relevant sustainability aspects with regard to the global community's 2030 Agenda and to assess whether the introduction of the tracking system would lead to a reduction in emissions. To achieve this, the carbon footprint of the implemented technology was quantified and changes in the log value chain through the application of the tracking system were estimated – on a federal and state level. For instance, we evaluated the expected plus of harvested roundwood and its wood products, as well as savings of materials and fuels through process optimization.

Keywords: traceability system, marker-free, supply chain, sustainability impact, process optimization

EXPERIENCES FROM CABLE YARDER PRODUCTIVITIES IN HORIZONTAL YARDING DIRECTION

JANINE SCHWEIER[1]; MARC WERDER[1]; LEO G. BONT[1]*

[1]Swiss Federal Institute for Forest, Snow and Landscape Research WSL

Corresponding author: janine.schweier@wsl.ch

ABSTRACT

Cable-based timber extraction offers some advantages regarding impacts to forest stands and soils and can be used under a wide range of conditions. It is important not only in steep terrain, but also increasingly in flat terrain when soils are sensitive to traffic for various reasons, e.g. due to a low bearing capacity. Extracting timber from such stands is a challenge, and cable-based systems might be an alternative to ground-based systems. While damage to the remaining stand and to the soil during extraction is not always avoidable, the use of cable-based systems eliminates ground-based traffic in the case of fully suspended loads and at least reduces soil compaction, soil surface damage and erosion. We conducted working time studies in different commercial operations in flat terrain and developed a productivity model that makes it possible to predict the productivity of future comparable yarding operations beforehand. Collected data included explanatory variables, such as length of skyline, distance and difficulty of lateral yarding, experience of involved staff, diameter and weight of harvested timber, number of payloads per cycle. Data were analyzed regarding distribution of working steps, machine installation times and productivities and variables significantly influencing the productivity were identified. The poster will present the main findings of recent studies being conducted in the period 2021 to 2023 in Switzerland.

Keywords: flat terrain; forest operation; soil-sensitive terrain; working-time study

FORESTRY PERSONAL PROTECTIVE EQUIPMENT AND ITS INFLUENCE ONTO PSYCHOPHYSICAL LOAD

LUKA PAJEK[1]; MATEVŽ MIHELIČ[1]; ANTON POJE[1]*

[1]University of Ljubljana, Biotechnical Faculty, Department of Forestry and Renewable Forest Resources

Corresponding author: luka.pajek@bf.uni-lj.si

ABSTRACT

Use of proper personal protective equipment, depending on conditions of work, can reduce workload of forestry workers. In order to identify differences between three protective clothing systems, a study using a cycling-ergometer measuring several psychophysical indexes was conducted. The results show no differences in the amount of lactic acid in blood, or the temperature measured in the individual´s ear prior and after the trial, however significant differences occur in body mass, however relation between the duration of the test and consumption of energy has been established. The ergometer´s resistance caused significant differences to the measured indexes. There are significant differences between the heart rate measurements while using different types of clothes, except summer and transitional system. No differences have been determined, between the results measuring skin´s conductivity in transitional and winter systems, nor between the summer and winter equipment.

Keywords: Forestry, ergonomy, personal protecitve eqipment, psychophysical load

SEILAPLAN: A QGIS PLUGIN FOR OPTIMIZED CABLE ROAD LAYOUT PLANNING

LEO GALLUS BONT[1]; LAURA RAMSTEIN[1]; PATRICIA MOLL[1]; JANINE SCHWEIER[1]*

[1]Swiss Federal Institute for Forest, Snow and Landscape Research WSL

Corresponding author: leo.bont@wsl.ch

ABSTRACT

Cable-based technologies have been a backbone for harvesting on steep slopes. The planning of a cable road is a complex task. It essentially comprises the definition of the start and end points of a cable road, as well as the intermediate supports. It must be ensured that the permissible forces (in particular skyline tensile forces) are not exceeded, that there is a sufficient clearance between the load path and the ground, that suitable anchor trees are found and that at the same time the number of intermediate supports is minimised as far as possible. On the other hand, for ergonomic and silvicultural reasons (work safety, damages to the forest), the skyline should be as high as possible. In practice, the search for a solution is often iterative; especially with long lines, several attempts may be necessary until a good line is found. The presented QGIS plugin assists in designing cables roads by searching automatically for the optimal cable road layout. However, it also allows a manual editing of the cable road. As the plugin is embedded in a QGIS system, elevation data can easily be accessed and incorporated. With the four-tongue tool Seilaplan, the design process of cable roads can be considerably simplified. The plugin is designed for Central European conditions and assumes a standing skyline (fixed anchored skyline at both ends). For the calculation of the mechanical properties of the skyline a close to catenary method is used (Zweifel 1960). When testing the feasibility of the cable line, care is taken that 1) the maximum permissible stresses in the skyline are not exceeded, 2) there is a minimum distance between the load path and the ground and 3) when using a gravitational system, there is a minimum inclination in the load path. The newly developed method calculates the load path curve and the forces occurring in it more accurately than other tools available on the market. Since the first appearance in 2019, 7 new releases have been introduced. The poster will present the main features of Seilaplan and put a focus on the latest new releases.

Keywords: cable road, cable yarder, forest harvesting, forest management, standing skyline,

CHARACTERIZATION OF SWEDISH FORESTRY CONTRACTORS' PRACTICES REGARDING OCCUPATIONAL SAFETY AND HEALTH

THOMAS KRONHOLM[1]; RIKARD OLSSON[1]; CAROLA HÄGGSTRÖM[1]*

[1]Swedish University of Agricultural Sciences (SLU)

Corresponding author: thomas.kronholm@slu.se

ABSTRACT

From an international perspective, forestry is a dangerous industry in terms of the number of occupational accidents that occur each year. In Sweden alone, an average of 2-3 people die each year as a result of work accidents in forestry. In addition, approximately one hundred accidents serious enough to cause sick leave are reported in a single year. It is therefore clear that a lot of work remains in the areas of occupational safety and health (OSH) to reduce the number of accidents, but perhaps above all to create better working conditions for the employees. Indeed, several initiatives have been taken to improve the situation, for example by updating the requirements of the FSC and PEFC certification systems. However, the extent to which the forest contractors live up to all requirements and whether this has a connection to their financial situation or other factors has so far been studied to a relatively small extent. Therefore, this study aimed to describe the current practices of Swedish forest contractors in terms of systematic work environment management, identify variations in relation to the contractors' characteristics and finances, and highlight areas in need of improvement. Data were collected through a survey distributed to limited liability companies registered to perform logging or silvicultural services. To examine variations in relation to contractors' profitability, the companies were divided into three populations based on their operating margins before a stratified random selection of 1200 companies was made. The survey was sent by post at the beginning of February 2023, resulting in 219 valid responses being analyzed by the end of the month. The results show that the largest forestry contractors in terms of turnover were the most likely to have modern equipment, written guidelines for hazardous work tasks and to provide their staff access to workplace facilities in the forest. Furthermore, the trend was that larger companies were more likely to have an updated action plan for their working environment. In terms of profitability and working environment, it was found that employees in the companies with the highest operating margin had the least access to workplace facilities in the forest, while employees in the somewhat profitable ones had access to the greatest extent. A geographical difference was noted between companies in the northern and southern parts of Sweden; companies located in the northern parts more often provided access to workplace facilities in the forest. In conclusion, the study shows that there are clear relationships between contractors' characteristics and how they work with their work environment, where company size seems to be an important factor. Given that most forestry contractors today are small businesses, a consolidation of the forestry contracting sector could therefore be desirable from an OSH perspective.

Keywords: contractor finances; injury prevention; logging contractors; occupational health; safety management

TRADE-OFFS BETWEEN WOOD FLOW AND MACHINE-USE EFFICIENCY IN HARVESTING OPERATIONS

*MALIN JOHANSSON[1]; MIKAEL LUNDBÄCK[2]; OLA LINDROOS[3]**

[1]Stora Enso Skog AB; [2]Umeå University; [3]Swedish University of Agricultural Sciences.

Corresponding author: ola.lindroos@slu.se

ABSTRACT

For customer-oriented wood supply, buffering is required to create flexibility in the wood procurement system. This includes balancing flow and resource efficiency by using stocks and production capacity as buffers. Despite the well-known challenge to balance the interactions between harvesting and forwarding, there has been limited research on how the machine groups can be staffed to enable flexibility. Therefore, this study explored trade-offs between flow and resource efficiency by altering staffing of harvesting groups, leading to more or less flexibility in wood flow control. This was achieved by using discrete-event simulations implemented in Anylogic software. Input data included information about operational conditions in 1500 forest stands. The results revealed that the best balance was to have sufficient flexibility, in terms of capacity to adjust wood flow efficiency, at the expense of resource efficiency. Of the tested options, the best balance was achieved when staffing the machines with 3 operators, and thereby allocating 33% of the work time to flow adjustment, which resulted in the shortest lead times and the smallest cost increases. Compared to the option with no flexibility (4 operators), the average lead times could be reduced to one tenth, but the higher flow efficiency resulted in cost increases of 3.4%. These findings have the potential to improve decisions relating to how flow and resource efficiency of harvesting operations could be balanced to meet specific objectives.

Keywords: logging, flexible resources, collaboration, supply chain management, buffers, harvester, forwarder

SCIENTIFIC AUDIO-VISUALS FOR AN ENHANCED LEARNING EXPERIENCE OF MACHINE COMPONENTS, FUNCTIONS, OPERATIONS AND SETUPS, IN TIMBER HARVESTING: A CORE AMBITION OF THE TECHNODIVERSITY PROJECT

*STELIAN ALEXANDRU BORZ[1]**

[1]Department of Forest Engineering, Forest Management Planning and Terrestrial Measurements, Faculty of Silviculture and Forest Engineering, Transilvani

Corresponding author: stelian.borz@unitbv.ro

ABSTRACT

Digital revolution has changed profoundly the way people interact with their environment. Teaching forest operations requires important resources for practical applications and for a correct understanding of the way that machines and their setups work in real environments. However, there is a wide variety in the machines used and harvesting systems implemented across the world. In addition, in many cases, there is a limited access to all machine and harvesting system configurations to be observed in real operations in a limited amount of teaching time, or there might be other constrains such as machine unavailability in some regions, or pandemics. Alternative teaching methods may rely on using videos of various machines working in specific operational environments but often such media lacks a scientific description of the machines, their performance and limitations, and the typical operational steps which are relevant for learning and applied science. Technodiversity project has setup the ambition to develop high-quality scientific audiovisuals showing and explaining the important components of the machines, their operational setup and the sequence of elements in typical work cycles. A number of 35 films, are under development to explain the components of the machines used in forest operations, typical work cycles and the main methods used in forest operations research. These films are built based on a commonly agreed script, raw media sequences, and animated media components by the use of advanced media editing software; they were prototyped in advance so as to take the advantage of Technodiversity consortium's expertise over the content shown and the media enhancement features used. They cover the main operational setups, explain the performance and constraints in operations, show and describe the possible variants of use in a common media framework based on detailed case-by-case adapted scripts. The films are built by adding a background speaking voice to explain the media's content which is backed up by features pointing or emphasizing the machine components, features explaining the sequence of work elements, functiograms, and features pointing and explaining the workplace and work elements seen as they run. The developed set of scientific audio-visuals is based on the most frequent situations of timber harvesting, and further developments will be required to cover the diversity in options used. Nevertheless, it stands as a good starting point for an enhanced learning experience for those interested in forest operations such as students and professionals.

Keywords: diversity, technology, machines, systems, forest operations, learning, experience, media

FORWARDING BY FARM TRACTORS IN LOW REMOVAL INTENSITY, CONTINUOUS COVER FORESTRY: A SIMULATION OF OPERATIONAL PERFORMANCE AND FUEL CONSUMPTION

GABRIEL OSEI FORKUO[1]; MIRELLA ELIAS[1]; STELIAN ALEXANDRU BORZ[1]*

[1]Transilvania University of Brasov

Corresponding author: gabriel.forkuo@unitbv.ro

ABSTRACT

Forwarding by Farm Tractors in Low Removal Intensity, Continuous Cover Forestry: A Simulation of Operational Performance and Fuel Consumption Gabriel Osei Forkuo, Mirella Elias, Stelian Alexandru Borz Department of Forest Engineering, Forest Management Planning and Terrestrial Measurements, Faculty of Silviculture and Forest Engineering, Transilvania University of Brasov, Şirul Beethoven 1, 500123, Brasov, Romania, gabriel.forkuo@unitbv.ro, mirella.elias@unitbv.ro, stelian.borz@unitbv.ro Corresponding author: gabriel.forkuo@unitbv.ro Continuous cover forestry is generally characterized by lower removal intensities, a relatively high dispersion of timber to be removed, and increased concerns about the environmental impact of commonly used machines such as forwarders. A versatile, and probably cost-affordable option for such extractions may be that of fitting and using farm tractors for forwarding operations. Performance of these machines under the continuous cover forestry management was, however, less researched. In this study, a base performance scenario was taken into account based on field-documented data on operational speed, production and fuel use. Data collected in fine detail by a GPS handheld unit placed on the machine's cab, high-resolution video recording, and manual fuel measurements was used to define and delimitate the process elements of forwarding operations by a farm tractor fitted with an externally-operated crane and a bunk. In addition, high-resolution media was used for a detailed time-and-motion study carried out over the motions done by the crane during loading and unloading operations. Production was measured in high detail serving as inputs for performance assessment in the base scenario. The knowledge gained from the base scenario was then used to run performance simulations over a wide range of operational conditions defined in terms of tree size, silvicultural operation, removal intensity, location-based availability on the ground and size of the logs. These were complemented by adding the fuel use components, simulations of variability in time consumption, and productivity. Finally, the operational cost was estimated based on the developed scenarios. This step was supported by the COST tool for operational costing and a localized documentation of cost components. Results of simulation show a high variability in performance, fuel use and cost of operations which were driven by the factors considered in simulation. Also, they show the differences in performance based on the variability in extraction distance, and may serve as a guiding tool for operational planning, costing, and environmental assessment in terms of emissions under various operating conditions.

Keywords: simulation, performance, farm tractors, forwarding, selective extractions, low removal intensity

COMPARISON OF DIGITAL AND TRADITIONAL METHODS FOR THE ESTIMATION OF FUEL BIOMASS IN WILDFIRE-PRONE FORESTED AREAS OF THE MEDITERRANEAN REGION.

*MARTINO ROGAI[1]; MICHELE SALIS[1]; LORENZO ARCIDIACO[1]; ANDREA BERTON[2]; CARLA NATI[1]; GIANNI PICCHI[1]**

[1]CNR-IBE; [2]CNR-IGG.

Corresponding author: gianni.picchi@cnr.it

ABSTRACT

Wildfires are a growing threat in the Mediterranean area. Any preventive and firefighting action requires a detailed estimate of the biomass fuel load. This, for instance, is the main input data for wildfire simulation softwares. The estimation of forest biomass has been traditionally done either with satellite data or through direct measurements in the field by visual assessment and destructive sampling. The former can cover large areas, but provides a low level of detail on the ground. Field measurements provide a plethora of information with low cost instruments, however it is time consuming, spatially limited and largely based on the experience of the operator. The implementation of LiDAR technology for in-field biomass estimation discloses the possibility to perform fast and objective digital surveys. Through the use of different platforms, such as Unmanned Aerial Vehicle (UAV) and Mobile Laser Scanners (MLS) allows for above and below crown measurements, and even the fusion of both data, enhancing the detail of fuel load estimation as well as its spatial distribution. Yet, it requires expensive and delicate instruments operated by qualified pilots and operators as well as relevant data post-processing activity. Additionally, due to the complexity of the Mediterranean vegetation, it requires ground truthing training to convert digital data to actual fuel load. In the present study, LiDAR data have been compared with field data collected in two study areas of the north west and the center of the Autonomous Region of Sardinia (Italy). The fuel load has been measured in the entire surface by a UAV data collection along with field measurements within twelve subplots prior and after biomass removal. The MLS data collection has been realized wherever the high density of vegetation allowed the access of the instrument: five subplots out of twelve. Manual field measurements, regarded as control data, included diameter at breast height (DBH), total height (HT) and crown base height (CBH). Crown bulk density (CBD) and canopy cover (CC) were estimated with LiDAR data and destructive sampling in representative areas. The resulting data has been used to assess the fuel load on the experimental plots before and after preventive silviculture works. FLAMMAP simulation software was used to assess the actual wildfire risk reduction of the biomass removal.

Keywords: wildfire, preventive silviculture, LiDAR, UAV, fuel biomass, estimation methods

AUTOPLANT – CONCEPTS AND TESTS OF AUTONOMOUS FOREST REGENERATION

LINNEA HANSSON[1]; MORGAN ROSSANDER[1]; HÅKAN LIDESKOG[2]; GUSTAV STEN[3]; RUBEN VAN WESTENDORP[4]*

[1]Skogforsk, The Forestry Research Institute of Sweden; [2]Luleå University of Technology; [3]Royal Institute of Technology; [4]Bracke Forest AB.

Corresponding author: linnea.hansson@skogforsk.se

ABSTRACT

Sustainable forestry requires efficient regeneration methods to ensure that new forests are promptly established. In Sweden, 80 % of the clearcut forest stands are reforested using a twostep process. First, the site is mechanically prepared by scarifiers and later, planting is conducted manually. Finding skilled labor is difficult as the work is seasonal and physically demanding; driving scarifiers include high whole-body vibrations when the machine traverses the terrain and manual planting is arduous. Precise site preparation by a light scarifying head would decrease soil disturbance, which is good for nature and cultural conservation as well as recreation, berry picking and reindeer husbandry. An autonomous scarifying and planting machine with high precision, low environmental impact, and a good working environment would meet the needs of the forest industry as well as the public while also contributing to the sustainability goals in the 2030 Agenda for Sustainable Development (United Nations). For two years, a group of researchers, manufacturers, and users (forest companies) has worked together, in a collaborative project called Autoplant, to develop and test a new concept for autonomous forest regeneration . The concept includes several subsystems which by themselves also could be useful in developing existing forest technology: (1) new technology for gentle forest regeneration, i.e. a novel, light planting head including precision scarification; (2) automatic plant management from the seedling containers to the planting head; (3) route- and (4) path planning for autonomous vehicles ; (5) detection of suitable planting spots and (6) motion planning of the machine and boom to reach the spots efficiently; and (7) data for planting follow-up. The subsystems were tested separately in different lab and field environments. Finally, they were integrated together on an autonomous terrain vehicle platform developed by Luleå University (AORO). The whole cycle of autonomous scarification and planting were demonstrated during a field test at a forest clearcut. The concept indicates large potential, especially from an environmental perspective with significantly reduced soil disturbances from 50% to 2% compared to traditional methods. The Autoplant project highlight the challenges and opportunities of future development, e.g., the relation between machine cost and operating speed, sensor robustness to vibrations and weather, and precision in detecting size and type of obstacles during autonomous driving and planting. Further development includes creating suitable planting spots for several soil- and vegetation types and efficient seedling logistics from the nursery to the regeneration area.

Keywords: automation, silviculture, planting, mechanical site preparation, route planning, obstacle detection

PATHFINDER – A DECISION SUPPORT TOOL FOR OPERATIONAL PLANNING OF INTEGRATED MECHANICAL SITE PREPARATION AND PLANTING ON FOREST REGENERATION AREAS

LINNEA HANSSON[1]; PATRIK FLISBERG[1]; MIKAEL RÖNNQVIST[2]; FREDRIK JOHANSSON[1]; RASMUS SÖRENSEN[1]; PETRUS JÖNSSON[1]*

[1]Skogforsk, The Forestry Research Institute of Sweden; [2]Laval University.

Corresponding author: linnea.hansson@skogforsk.se

ABSTRACT

Manual planting is arduous and mechanical site preparation includes a high dose of whole-body vibrations when traversing the terrain. At the same time, there is an evident lack of skilled labor in silviculture operations in boreal forestry. Efficient regeneration methods are crucial to sustainable forestry, and in Sweden, where 99% of the planting is manual, the interest in mechanized planting is rising. Autoplant is one of several Swedish collaborative projects among forest companies, manufacturers and researchers within silvicultural technology. The aim of the project is to develop an integrated autonomous scarifying and planting system with high precision, low environmental impact, and a good work environment. A decision support tool is needed for the operational planning of the forest regeneration, including route planning for the machine. The software, Pathfinder, is divided into two sub-modules. The first module relies on harvester production data (hpr-file to model local growth potential distribution), digital elevation models (DEM), depth-to-water (DTW) maps, soil data and so-called no-go areas for culture or nature conservation. It proposes the net area that will be subjected to scarification and planting, as well as which species to plant in different zones of the area together with desired density. The second module uses the output from the first (boundaries of the net area and plant density) together with DEM (critical slope), forcing passages (e.g., temporary bridges), and machine data (e.g., machine working width, maximum slope, loading capacity, and time for U-turns) as input. There are various factors to consider when improving route efficiency for the machines, among which minimizing the number of U-turns is crucial. A four-step solution approach is developed to find optimal routes. Firstly, the DEM is utilized to discretize the area into hexagons with a side length of 10 m. Secondly, the preferred route directions within each hexagon are combined to create longer paths over multiple hexagons where turning costs can be modeled. Thirdly, the paths are modified to account for the width of the specific machine and the target plant density. This also include a phase to combines parts of routes to longer that follows the geometry of the area. Finally, the model suggests a set of vehicle routes considering planting and/or fuel capacity of the machine. These routes make up the overall planting solution that the machine follows, either autonomous or with an operator. The tool is tested on ten clearcuts throughout Sweden (3-10 ha). The results from the sub-module 1 have been validated in the field both by researchers and the forest owners. The results from sub-module 2 are compared with tracking data from the scarifier (when present) and evaluated by comparing total distance and estimated operation time. This decision support tool can be applied not only to planting machines but also to

traditional scarifiers, either as help in creating a rough plan of directions in different parts of the regeneration area, or as GNSS-routes to follow more strictly. The latter is even more convenient if the scarification is carried out via teleoperation.

Keywords: Route planning, silviculture, planting machines, soil scarification, mechanical site preparation

SOILS AND STEEP SLOPES - IS TETHERED CUT-TO-LENGTH A VIABLE SOLUTION FOR MITIGATING SOIL IMPACTS?

PRESTON GREEN[1]; CHARLES RHOADES[2]; MADELINE ROBERTS[3]*

[1]Miller Timber Services; [2]United States Forest Service, Rocky Mountain Research Station; [3]Montana State University.

Corresponding author: preston@millertimber.com

ABSTRACT

Cut-to-length (CTL) systems are the predominant mechanized harvesting systems used around the world, yet their adoption into steep-slope technology is still growing in many places. The United States is one of these places. This growth is also paired with an even younger body of research surrounding the soil impacts of CTL systems when applied to steep terrain. This project presents multi-year data derived from a working partnership with the United States Forest Service (USFS) Rocky Mountain Research Station and Miller Timber Services, a private contractor based in the US. The project, based in Colorado near the continental divide, applied a winch-assisted Ponsse CTL system to a beetle-killed stand with the silvicultural objectives of reducing catastrophic wildfire hazard, protecting major critical infrastructure in the area, increasing public safety and improving domestic water quality for the headwaters of the South Arkansas River and downstream community of Salida. This project collected soil data through the use of harvest corridor erosion fences with sediment yield, ground cover and rill surveys being the primary measured response variables. Erosion fences were built in both 2021 and 2022, with harvesting occurring every year since 2020. The 2023 data collection year will also include tree regeneration & understory plant cover surveys as well as rainfall simulations. Erosion fence measurements from 2022 indicated that erosion was concentrated in places with low soil cover, and some of these areas had low pre-harvest O-horizon cover and were subsequently sensitive to any level of disturbance. Trails with greater O-horizon and slash cover had lower amounts of sediment yield in the fences, suggesting that slash mats play an important role in mitigating erosion impacts on steep-slope CTL operations. This work also aims to contextualize the impacts of an active management approach against the risks of potentially catastrophic wildfire.

Keywords: steep slopes, soil impacts, fire prevention, erosion, harvesting

RTK-GNSS ACCURATELY DETECTS THE POSITION OF THE ROTARY BLADE OF A HAND-HELD ENGINE BRUSH CUTTER.

*TETSUYA MATSUMURA[1]**

[1]Shinshu-Honan College / University of Tokyo

Corresponding author: tetzmat@gmail.com

ABSTRACT

Clearing bushes with a hand-held engine brush cutter is a routine task for Japanese forestry workers. On the other hand, the situation of occupational accidents caused by engine brush cutters is serious, and there have been accidents in which a worker injured a colleague with a rotating blade because he did not notice the existence of a colleague who was doing the same work nearby. In order to prevent such accidents, measures are being taken such as planning work sites apart from each other and having workers wear high-visibility work clothes to emphasize each other's presence. However, no safety device has appeared that actively controls the operation of the brush cutter. The purpose of this research is to detect dangerous situations by monitoring the operation status of brush cutters with sensors, and to actively control operations to prevent accidents.As an experiment, we used RTK-GNSS technology to precisely detect the position of the rotary blade during work.As a result, the position of the rotary blade could be detected with centimeter-class accuracy. And it turned out that it could be used as an approach warning device with colleagues.

Keywords: brush cutter, occupational safety, RTK-GNSS, forestry in Japan

RESOURCE-EFFICIENCY AND TIME CONSUMPTION FOR CTL BEECH WOOD HARVESTING WITH TOP AND BOTTOM-SAW

BENJAMIN ENGLER[1]; GWENDOLIN HARTMANN[1]; HANS-ULRICH DIETZ[1]; THOMAS PURFÜRST[1]*

[1]University of Freiburg, Chair of Forest Operations

Corresponding author: benjamin.engler@foresteng.uni-freiburg.de

ABSTRACT

In light with the EU Forest Strategy to enlarge forest biodiversity and at the same time to more use renewable resources, such as wood, resource efficiency becomes of higher importance. Processing of the trunk of deciduous trees with common CTL harvester heads is often limited by big branches or forks, which hamper a forward moving of the harvester head. By bucking at that position with a common harvester head with bottom saw, to cut-off the branch or fork part, a part of the trunk is lost, due to the height of the harvester head. The study in Hesse, Germany analyzed work time and output volume of harvesting beech wood with a harvester. The Waratah H415 head was equipped with a custom made added top saw, to allow bucking close to big branches or fork. An elementary time study was performed to indicate time consuming work elements and data of the harvester on-board computer were analyzed in parallel to assess the resource efficiency, volume, and value creation per work time.

Keywords: Top saw, harvester head, CTL, deciduous trees, resource efficiency

COMPARISON OF MOTOR-MANUAL WORK WITH ELECTRIC AND PETROL CHAINSAW

BENJAMIN ENGLER[1]; FELIPE DE MIGUEL DIEZ[1]; GWENDOLIN HARTMANN[1]; THOMAS PURFÜRST[1]*

[1]University of Freiburg, Chair of Forest Operations

Corresponding author: benjamin.engler@foresteng.uni-freiburg.de

ABSTRACT

Electric chainsaws approach more and more professional forest work and substitute petrol chainsaws. Knowing about general benefits within the consumer market, there exist different requirements for professional forest work. An elementary time study and an ergonomic study were performed to compare work elements when using electric and petrol chainsaws. The major aim was to identify differences in ergonomic stress and impacts on the environment. Based on this, conclusions for adjusting work processes were drawn.

Keywords: Electric chainsaw, ergonomics, time consumption, emissions, motor-manual work

ASSESSING THE FEASIBILITY OF USING SUPER HIGH-RESOLUTION FOREST ENVIRONMENT MAPS IN HARVESTING SIMULATORS FOR PRECISION HARVESTING APPLICATIONS

JORI UUSITALO[1]; OMID ABDI[1]; VELI-PEKKA KIVINEN[1]; VILLE LAAMANEN[1]; JANNE RUOKONEN[2]*

[1]University of Helsinki Dept of For Sci; [2]Tampere Vocational College Tredu.

Corresponding author: jori.uusitalo@helsinki.fi

ABSTRACT

Harvesting simulators are computer programs that simulate the process of tree harvesting in a virtual environment. These simulators are often used in precision harvesting to train forestry workers on how to safely and efficiently use harvesting equipment, as well as to plan and optimize harvesting operations. The harvesting simulators are equipped with the exact same seats, joysticks, and control systems as those found in real machines. The simulators typically use 3D graphics and physics engines to simulate the location and characteristics of trees, logging equipment, terrain conditions, and other objects in a predefined virtual environment. The high level of augmentation is further enhanced by multiple screens or VR glasses. However, default maps in harvesting simulators may not accurately reflect the specific characteristics of a particular forest stand. They are typically designed based on broad generalizations about tree species, terrain conditions, and soil types, and may not account for the real conditions of a specific forest stand. This research was designed to evaluate the feasibility of utilizing of near-to-real forest environment maps, derived from super high-resolution data, in harvesting simulators. We selected three forest stands that were varied in tree species, age, thinning operations, soil types, and terrain conditions in southern Finland. We collected data using three sensors mounted on a GeoDrone X4L: a Sony RX1R (optic sensor), a MicaSense Altum (multispectral sensor), and a YellowScan Mapper LiDAR system. The Sony RX1R was used to capture very high-resolution images with a ground sampling distance (GSD) of approximately 1.5 cm/px, while the MicaSense Altum was used to acquire the multispectral bands (Blue, Green, Red, Red-edge, and Near-IR) with a slightly lower GSD of approximately 5 cm/px. The YellowScan Mapper was used to collect 3D cloud points with a high density of minimum 100 points per meter. Furthermore, we collected ground samples to obtain individual tree attributes and soil properties from our study sites. The locations and attributes of the trees were derived from a combination of optical, multispectral, and LiDAR data and tested via the ground tree samples, while logging trails and terrain conditions were mapped using LiDAR data. The soil type was determined from the ground soil samples. We imported all these layers, whether as vectors or rasters, into a harvesting simulator. We plan to conduct a survey among users to assess the effectiveness of the updated near-to-real forest environment maps compared to default maps in harvesting simulators. Our near-to-real forest maps will allow users to become familiar with the local forest composition and structure, forest rotation stages, terrain, obstacles, and other factors that can affect their performance in the simulator. By providing a simulated environment that closely mimics the real world, users can develop the skills and experience they need to perform well in actual forest operations. Additionally,

these maps can help users learn to navigate different types of terrain, work with stands in various stages of thinning operations, identify potential hazards, and make informed decisions in a safe and controlled environment.

Keywords: tree harvesting, precision forestry, forest simulators

USE AND OPERATION OF THE EXCAVATOR IN FORESTRY

FEDERICO BERTONE[1]; MARCO MANZONE[1]*

[1]Università degli Studi di Torino (DISAFA)

Corresponding author: federico.bertone@unito.it

ABSTRACT

In recent years, the cost of the manpower has increased due to its low availability. That situation has encouraged the forestry companies to improve the mechanization level of all activities. The purchase of dedicated machines is very expensive, so in this transition phase there is a tendency to purchase multipurpose machines to reduce depreciation costs. In this scenario, excavators play a fundamental role because they can be used in many forestry activities by changing the working tools. Usually, in forest are used excavators equipped with industrial tracks and with a gross mass between 8 and 16 tons. The main goal of this work was to analyse the advantages and limitations of the use of excavators in forestry yards through the study of working rate, fuel consumption, and reintegration and maintenance costs. Data analysed showed that the working rate and the fuel consumption are proportional to the engine power (kW) and to the gross mass of the excavator, in particular working rate is 0.14 t/h × kW and 0.71 t/h × t of gross mass, while fuel consumption is 0.13 l/h × kW and 0.72 l/h × t of gross mass. Furthermore, the productivity of the machine is linked to the opening size of the forestry grabs used (4.45 t/h × m of opening), forest structure and type of wood assortments worked (logs, residues…). The market value of the excavators is linked to the gross mass (R2= 0.91), with an indicative value of € 10.000 per ton. The average hourly cost is around € 4.20, but this varies according to the transport distances to reach the working sites and the level of maintenance performed within the company. In conclusion, the excavator can be a valid solution to increase the level of mechanization of the forestry companies thanks to the good productivity, the low purchase and maintenance costs and its high versatility.

Keywords: Excavator, productivity, costs, forestry

DETECTING AND VISUALIZING OLD LOGGING TRAILS FOR UPCOMING THINNING OPERATIONS

OMID ABDI[1]; JORI UUSITALO[1]; VELI-PEKKA KIVINEN[1]; VILLE LAAMANEN[1]*

[1]University of Helsinki

Corresponding author: omid.abdi@helsinki.fi

ABSTRACT

The Forest Technology Group at the UH has recently developed a new deep learning-based approach that uses high-density laser scanning data to automate the detection of old logging trails (OLT) in forest stands that have previously undergone commercial thinning. We assume that detecting old logging trails before any forest operation and visualizing the OLT layer during harvester operations will help operators place new logging trails more effectively. We conducted our test in four forest stands (ca. 23 ha) located in southern Finland. These stands were undergoing late thinning operations at the time of our study. The tests were carried out in close collaboration with Ponsse and Metsä Group. The thinning operation was executed using the Ponsse Cobra harvester by two operators. The harvester was equipped with a modern computer system, called PONSSE Opti 8. It displays the tracks of the harvester and the maps of the active area via Opti Map 2 programme. We predicted the OLT layers using our developed algorithm and imported them into Opti Map 2 as a vector layer. Additionally, we added other auxiliary layers such as stand boundaries, terrain layer, and canopy height model to the working area environment. To assess the effectiveness of the OLT layers, certain sections of the stands were operated using the new layers, while others were operated using the default maps in Opti Map 2. We evaluated the compatibility of the OLT layers with the tracks followed by the operators, both technically and verbally. Our preliminary experiments suggest that providing harvester operators with information about old logging trails and auxiliary layers through visualization on the harvester's computer system could be very beneficial to the upcoming thinning operation. The tests we conducted confirm that it is possible to provide machine operators with visualization of new precision harvesting objects, which will benefit them in their daily operations.

Keywords: old logging trails (OLT), precision harvesting, commercial thinning, Opti-Map2

OPTIMIZATION OF LANDINGS AND MAIN EXTRACTION TRAILS

MIKAEL FRISK[1]; ERIK RÖNNQVIST[1]; MIKAEL RÖNNQVIST[1]*

[1]Creative Optimization Sweden AB

Corresponding author: frisk@creativeoptimization.se

ABSTRACT

Detailed planning before harvest is important for the harvesting and forwarding work to be efficient and with as little negative impact on the soil as possible. With good planning, the risk of machines damaging the soil in sensitive areas is minimized, while resource utilization increases and energy consumption decreases. Several studies have shown that the use of high-resolution soil moisture information creates conditions for better planning before harvest, as well as that the use of mathematical models can provide support in planning for where the harvesting and forwarding machines should operate. Timbertrail is an advanced decision support system that uses high-resolution digital information about soil moisture, slope, forest density and conservation. The output is a proposal, in pre-harvest planning, of the optimal placement of the main extraction trails that the forwarder will use from the place for each log pile to the place for the roadside storage. The optimization model is extremely fast and calculates an optimal solution in less than a second, enabling efficient online planning as well as mass testing of large datasets. As a further development of Timbertrail, a complementary model, Log Landing, has been developed to automatically suggest the optimal placement of one or more landings along roads that are close to the logging area. The model uses information about the existing road network together with slope, soil moisture and, where applicable, buildings, power lines and conservation areas to calculate whether a section along a road is suitable or not as a landing site. Surfaces along the road network that have high soil moisture or slope, are close to a road crossing, building or under power lines, or are in sharp curves are given lower priority and are avoided by the model. By combining information about suitable landing areas with Timbertrail, Log Landing can calculate both the optimal location of landings and how long a continuous distance the landing requires. The length of the landing is decisive for whether all the felled volume will be accommodated on the site or if continuous transport by truck from the landing will be required during ongoing felling. In the model, we can also control how many landings are to be used and set limits on how large volume must or may be transported to each landing. By combining Log Landing with Timbertrail, we can use only the logging area as input to calculate the best placement of landings and optimal extraction routes for the forwarder. Because both models are extremely fast, we can calculate landing locations and base paths for a very large number of logging areas within a reasonable amount of time. In an evaluation of Log Landing and as part of the development, we have done a case study with more than 20,000 registered final fellings in Sweden where we analyze the effect of using one, two or three different landings for each felling surface. The results show the potential savings of using one, two and three different landings, respectively.

Keywords: precision forestry, harvest planning, landing, optimization, extraction trail, roadside storage

EFFECTS OF HARVESTING SYSTEMS ON STAND DAMAGE AND PRODUCTIVITY

CHRISTOPH HAAS[1]; NIKOLAUS NEMESTOTHY[1]; CHRISTOPH HUBER[1]*

[1]BFW Traunkirchen

Corresponding author: christoph.haas@bfw.gv.at

ABSTRACT

The mechanisation of forest operations is of great importance for the sustainable provision of the renewable raw material wood. Highly mechanised harvesting systems are often used on particularly productive stands with compaction-prone soils. The, often `heavy´ soils of the flysch zone are susceptible to compaction and therefore pose a challenge for mechanisation. As one part of the Project “Securing the Sustainability Forest Soil Functions via Optimized Harvesting Technologies” the effects of harvesting systems on stand damage and productivity were examined. Two comparable beech stands in eastern Austria were selected to examine two harvesting systems. On each site a late thinning was performed either by a cable yarding or harvester-forwarder system supported by a traction-aid winch. Both sites were suitable for ground based harvesting technologies based on the angle of slope of about 30% and prone to soil compaction. The implemented harvesting systems effect various soil- and site-related parameters. Site properties, but also other soil functions are covered by studies conducted by other groups of the project. The focus of this study is to compare the effects of the two harvesting systems in terms of productivity and damage to the residual stand. Productivity was examined by on-site and video-recorded time studies Residual stand damage was assessed by a field survey after the harvesting operations.

Keywords: system comparisson, harvester, forwarder, cable yarding, productivity, residual stand damage

PRODUCTIVITY AND COSTS OF THE HELICOPTER IN THE LOGGING PHASE

LORENZO BONINO[1]; FEDERICO BERTONE[1]; MARCO MANZONE[1]*

[1]Università degli studi di Torino (DISAFA)

Corresponding author: lorenzo.bonino@edu.unito.it

ABSTRACT

The use of helicopter in forestry is increasing in Italy, especially in the Alpine mountains. However, its use is limited by the lack of information about operational capabilities regarding the different working conditions. The aim of this work was improving information analysing productivity, working time and cost of the aircraft. Moreover, a calculation model was set up able to simplify the evaluation of the economic convenience in the use of helicopter in different working conditions. The calculation model was carried out using technical data of different helicopter model and operative values obtained in logging operations performed by two companies, site in Northwest Italy. The accuracy of the expected results of the calculation model, was carried out by inserting the variables found on two sites together with the technical information of the helicopters and comparing with measurement of the logging operations. The first site was in Lombardia with an AS 350 B3, the second site was in Susa valley in Piemonte with a BELL 205A++. Following these simulations, the results obtained using the calculation model differ from the real values only of about 4-8%. The error does not depend only on the calculation model, but on environmental conditions such as wind or soil conditions, load hooking conditions and preparation of the manpower. The calculation model created was subsequently implemented to be able to show the operator an interface that is easy to understand and intuitive to compile, making it only necessary to enter parameters that any forestry operator can detect on site when carrying out the logging. The calculation model also has a database in which the operating parameters of the helicopters considered in the two simulations were previously entered, as well as among the most widespread in Italy to carry out these operations. This database can be gradually implemented with other aircraft models, so as to adapt the calculation model to a greater number of operating situations.

Keywords: helicopter logging forestry productivity calculation model

WORK EFFICIENCY AND EXPOSURE TO NOISE DURING TREE FELLING WITH ELECTRIC SAW IN REAL FOREST CONDITIONS

ANTON POJE[1]; LUKA PAJEK[1]; BENJAMIN LIPUŽIČ[1]*

[1]Biotechnical Faculty, University of Ljubljana; [2]Slovenia Forest Service.

Corresponding author: anton.poje@bf.uni-lj.si

ABSTRACT

Electric machines and tools are unstoppably entering all economic fields, which also applies to forestry. Since previous research on felling with an electric chainsaw took place in a laboratory environment or in conditions that were mainly adapted to the use of an electric saw - i.e. in younger spruce stands - the purpose of the research was to determine the suitability of using an electric saw for felling 115 coniferous and deciduous trees with DBH from 13 to 79 cm. In the 10-days research, which took place in the southern part of Slovenia, we compared the Husqvarna 540i HP electric saw with the Husqvarna 543 XP petrol saw in terms of work efficiency and exposure to noise. The results of the research showed that the differences in felling efficiency (min/t) in productive time between the use of electric and gasoline saws are statistically insignificant. The same applies to all productive time work operations. In contrast, exposure to noise was significantly lower when working with an electric saw than with a petrol saw, and this was the case for all work operations where a saw is used to perform the work. Thus, according to the results of the research, we can conclude that the use of an electric saw mainly affects the worker's workload to noise, but not the work efficiency. It should be emphasized that currently the implementation of felling with an electric saw into real conditions, where big trees are also present in the forest, is difficult especially from the point of view of electricity supply, since for a full day's work of eight hours, at least twelve 5 Ah batteries would be needed.

Keywords: electric saw, felling, efficiency, exposure to noise,

THE LOSS OF HIGH-VALUE CHEMICALS IN THE FOREST BIOMASS SUPPLY CHAIN

HANNA BRÄNNSTRÖM[1]; JOHANNA ROUTA[1]; PETRI KILPELÄINEN[1]; ROBERT PRINZ[1]*

[1]Natural Resources Institute Finland (Luke)

Corresponding author: hanna.brannstrom@luke.fi

ABSTRACT

Forest biomass is an important feedstock for novel biomaterials, biofuels, and biorefinery products, along with the more traditional wood products, pulp and paper, and forest energy. Forestry side streams such as bark, logging residues and stumpwood are currently utilized mainly to produce energy, but the extraction of valuable components before combustion offers an interesting cascading use for biomass. Wood extractives are used in industry and recent research have shown that extractives have antioxidative, antibacterial and antiviral properties that can be used in industries to produce value added products. Buffer storing is an inevitable part of forest biomass logistics, but substantial dry matter and extractives losses can reduce the properties and economic value of the raw material during storage. The content of many extractives starts to decrease immediately after tree felling and this degradation continues during storage. Extractives are lost at all stages of processing. The most significant changes in extractives content and composition occurred within the first two weeks of storage when Norway spruce and Scots pine bark was stored in piles. Especially volatile compounds, such as monoterpenes, sesquiterpenes, and hydrophilic extractives were lost rapidly. The total amount of extractives decreased slightly during pile storage of pine and spruce stumps. However, due to the high variation in extractives content between samples, the determined effects of storage may be coincidental. Despite of this, changes occurred in chemical composition of extractives fraction. The gravimetric amount of extractives decreased significantly during pile storage of pine chain-flail residue (i.e., a mixed residue of wood, bark and needles). The extractives amount was roughly halved during the first four weeks of storage. The results of our studies confirm that extractives losses occur rapidly after debarking wood and piling the bark and chain-flail residue. Thus, to prevent the loss of these valuable compounds, the supply chain from the forest should be accelerated, and material should be sent for further processing as soon as possible after debarking. Stumps should also be stored unprocessed because any cutting could increase the likelihood of reactions leading to extractives losses. The comprehensive utilization of bark and other assortments requires that the whole supply chain is efficient to ensure trees' delivery times are kept short and the losses of material are avoided during harvest and transportation.

Keywords: Forest, biomass, supply chain, extractives, bark, logging residues, stump

ASSESSING THE OUTER SHAPE OF SAWLOGS AT THE MILL GATE USING STEREO CAMARAS AND DEEP LEARNING

MOSTAFA HOSEINI[1]; CAROLIN FISCHER[1]; MACIEJ WIELGOSZ[1]; CSONGOR HORVATH[1]; RASMUS ASTRUP[1]*

[1]Norwegian Institute of Bioeconomy Research (NIBIO)

Corresponding author: mostafa.hoseini@nibio.no

ABSTRACT

The economic efficiency of sawmilling depends on the expected volume and value of the produced timber. Size and quality of the logs define the yield of sawn timber and sawmills depend on specific log characteristics to be able to produce the timber that meets the end-users' requests. Therefore, detailed three-dimensional stem geometry helps to determine harvested timber values and products that can be made from it. We present the preliminary results of our recent experiment that utilizes two stereo cameras with different setups in terms of focal length, view angle, frame rate, and resolution for comparison purposes. The cameras were installed at the intake and sorting deck of the sawmill. The analysis is based on the raw output streams from the cameras. Each video frame in the raw data has a corresponding depth measurement matrix, and a 3D point cloud. Our processing approach leverages a deep learning-based instance segmentation method to detect and track individual logs on the deck by assigning a unique identification number to each of them throughout all video frames, allowing to extract 3D point cloud information. The extracted 3D points for each log from several consecutive frames are stacked and processed to quantify the geometric features of the logs, namely the length, diameter, and crookedness. The processing results are validated against the X-ray ground truth measurements available from the sawmill.

Keywords: log quality assessment, log geometric features, instance segmentation, 3D pointcloud

OUTCOMES OF APPLYING A TRIAD PERSPECTIVE FOR EVALUATING WOOD HARVESTING SERVICES

EMANUEL ERLANDSSON[1]; DAG FJELD[1]; GUN LIDESTAV[1]; IDA TJÄRNSTRÖM[2]*

[1]Swedish University of Agricultural Sciences; [2]SCA.

Corresponding author: emanuel.erlandsson@slu.se

ABSTRACT

Performance of harvesting operations strongly influences profitability and service satisfaction for both industries and wood suppliers. The service performing contractors must also be successful for retaining competitive wood supply. For Swedish wood purchasing companies, customer satisfaction of non-industrial private forest owners is crucial to keep loyal wood suppliers. Their satisfaction depends on how they perceive the quality of the harvesting service contracted when selling wood, which is directly influenced by the contractor operating for the wood-buying company. The company's satisfaction with their contractors is affected also by other quality aspects of performance. In turn, contractors' satisfaction with the company is affected by their received conditions. To achieve a more complete understanding of relationship success, a series of three studies was done. In the first study, quality perceptions from the different parties were explored and a tool was suggested for measuring their satisfaction. Values associated with services were identified by interviewing actors involved in triads linked to two companies. Company managers' and forest owners' expectations and perceptions of performances by a sample of contractors in relation to these values were then separately measured using an adapted version of the Servqual questionnaire. Similarly, contractors' views of associated planning conditions were evaluated. Quality perceptions varied widely among respondents. The surveyed forest owners commonly determined performance in a subjective manner. Consequently, many contractors not performing well from a manager perspective still met forest owners' service expectations well, and thus were considered valuable assets by the companies from a wood sourcing perspective. The second study builds on the assumption that contractor motivation depends not only on success in terms of profitability, but also on satisfaction with the conditions provided by their service-buyers. Data of operating margins were collected for the first study's sample of 30 contractors, in addition to their existing survey responses. PLS regression was used to analyze responses and to set VIP rankings of relative factor importance for explaining variation in achieved success. The characteristics most important for contractor satisfaction differed from those most important for achieving high operating margins, but a group of common key factors was identified. A framework was developed for sorting factors into three levels of importance when integrating the two perspectives. In general, contractors' perceptions of company performance best explained variation in success for both perspectives, however their expectations were also linked to this variation. The two most important factors for contractor success were a) provision of a consistent level of year-round capacity utilization and b) managers' helpfulness in solving practical problems arising in operations. The third study continued to develop the conceptual tool from the first study, aiming to simplify and tailor it for practical use for triad follow-up at a

case company. PCA and Cronbach's alpha was used to cluster and evaluate the survey statements based on the answers from the original questionnaire. Supported by interviewing representatives from all triad perspectives and continuous validations, the extensive tool could be stepwise simplified. The result is a set of questionnaires comprising only 8-12 key statements per perspective.

Keywords: Logging; entrepreneur; NIPF; wood procurement; Servqual

MAXIMIZED PROFIT THROUGH INTEGRATED OPTIMIZATION OF BUCKING SELECTION AND TRANSPORT PLANNING IN THE FOREST SUPPLY CHAIN

ERIK RÖNNQVIST[1]; MIKAEL FRISK[1]; MIKAEL RÖNNQVIST[1]*

[1]Creative Optimization Sweden AB

Corresponding author: frisk@creativeoptimization.se

ABSTRACT

Traditional planning of forestry logistics is usually done in several steps and rarely fully integrated because the planning models become very complex. Decisions must be made about which areas are to be harvested when, which bucking pattern (or price list for onboard bucking computers) should be used, when deliveries are to take place and to which industry the products are to be delivered. When planning is done in separate steps, e.g., selection of harvest areas and bucking pattern is done separately from transport planning, the risk of sub-optimality in the supply chain increases. With optimization models for transport planning, the possibility of creating optimal transport plans on strategic, tactical, and operational time horizons is facilitated. This is already done to a large extent in Swedish forestry with the Woodflow decision support system, used by a majority of the large Swedish forest companies. To maximize the value in the forestry supply chain, however, it is not enough to just minimize the costs of harvest and transport. You also need to include the value of the products when delivering to the customers so that the right product is produced at the harvest areas and delivered to the right customer at the right time. In the parts of the world where cut-to-length method is used, the value of the forest products is determined in the bucking process, i.e., when the harvester buck the tree trunk into logs. The bucking is controlled by a price list which produces logs that are cut to the lengths and diameter proportions demanded by the industry. In many cases, the sawmills have unique requests for length and diameter classes of the logs, and they also pay differently for specific classes. To obtain as high a value as possible for the harvested forest, the harvest organization must ensure that the correct price list is used in the forests that are harvested. Often, however, this is done without optimization of the overall picture and without consideration of other harvest operations which can lead to a harvest area being allocated to a non-optimal receiver. To manage this, the choice of bucking pattern on the respective harvest area and the choice of destination must be integrated so that transport costs are minimized while the value of the harvested forest is maximized. We present an optimization model and a system support (Woodflow) which in a combined optimization process considers both transport costs and timber value by minimizing costs and maximizing revenue. In this way, it is ensured that the company optimizes the overall picture and gets the highest possible net result. The model can handle different bucking outcomes for individual harvest areas. Based on the total order of products from different customers, the values of diameter and length classes, and transport distances, the model defines optimal bucking decisions at each harvest area and destination to best sawmill of aggregated classes. We illustrate results of integrated planning through a case study with a large Swedish forestry company.

Keywords: supply chain optimization, bucking, precision forestry, transport planning

SAFE FORESTS – DOES STEEP TERRAIN EFFECT PSYCHOPHYSIOLOGICAL STRESS AND STRAIN OF HARVESTING MACHINE OPERATORS?

VERA FOISNER[1]; CHRISTOPH HUBER[2]; ARNULF HARTL[3]; CHRISTOPH HAAS[2]*

[1]Paracelsus Medical University Salzburg; [2]Austrian Research Center For Forests; [3]Paracelsus Medical University Salzburg.

Corresponding author: vera.foisner@pmu.ac.at

ABSTRACT

Thinning is an essential criterion for climate-stable forests of the future. The use of harvesters and forwarders with traction-aid winches allows the machines to drive in steep terrain, hence reduces soil damage. However, in steep terrain, in addition to the high level of attention required for the complex operation of the machines and their continuous mental strain, operators face additional stressors and hazards - such as the steepness of the terrain, the density of the stand, soil and weather conditions, etc. These factors may lead to a lack of concentration and furthermore to higher stand damage rates. The aim of the present work is to identify and examine stressful work situations for both, harvester and forwarder drivers. Additionally, the influence of slope gradient on the psychophysiology of those drivers and their productivity is assessed. Experienced harvester and forwarder drivers were examined during a working day. Before, after and during an operation, psychological parameters (e.g. Recovery-Stress-Questionnaire) were taken. During an operation, physiological parameters, like heart rate, skin conductivity, and emotion and stress recognition were recorded in real time using the AI driven automated facial coding engine, Affectiva. Time-and-space-resolution of physiological data were gathered using eye tracking technology. In order to connect the psychophysiological parameters with machine and operation data, a time study was conducted using camera systems. Steepness of the terrain was measured by using a datalogger mounted on the chassis of the machine. Furthermore, an inclination and acceleration sensor was mounted inside the cabin next to the driver's seat. First data on the interlinkage between working conditions and psychophysiology are presented.

Keywords: eye tracking, facial expression, forwarder, GSR, harvester, slope, traction-aid-winch, productivity

SETTING UP AN EXPERIMENTABLE DIGITAL TWIN FOR CABLE YARDING SYSTEMS

MICHAEL STARKE[1]; LENNART SCHINKE[2]; ARTHUR WAHL[2]; PATRICK DIETSCH[1]; FRANCESCO SFORZA[1]; MICHAEL SCHLUSE[2]; MARTIN ZIESAK[1]; JUERGEN ROSSMANN[2]*

[1]Bern University of Applied Sciences; [2]Institute for Man-Machine Interaction, RWTH Aachen University.

Corresponding author: michael.starke@bfh.ch

ABSTRACT

Cable yarding systems are an important part of the timber supply process in mountainous regions. Due to their technical complexity in planning, construction and operation, estimating the impact of the selected installation on productivity and costs is difficult. For planning cable lines, productivity models help to estimate the costs but are limited to the parameters priorly observed in time-studies and additionally considered in the modelling step. Due to the resulting resolution of observation, existing models mostly neglect detailed information, as provided by individual objects such as trees, workers and the machine structure. To overcome these limitations, simulation techniques using data and frameworks based on digital twins open up new possibilities to describe work steps in high detail, integrate machine type-specific behaviour in the prediction or assess alternatives for action in a specific forest environment. To make these advantages usable, an experimentable digital twin (EDT) of a mountain harvester was set up in the 3D simulation platform VEROSIM. As basic structure, work steps of the felling and yarding process in a two-cable configuration were described and clustered as intermediate model design, which was further implemented in a petri net model. Necessary information about time estimates of the resulting work steps, were collected from existing time-studies, derived from productivity models, or based on time assumptions made for missing work elements. The resulting parametrised petri net is finally linked to the digital twins of the mountain harvester, the forest stand, as well as the digital terrain model. With this setup, the time-consumption for each individual work step can be simulated for each individual tree. Next to created time- and volume-related statistics, provided as main simulation output, a time-stamped 3D visualization is created, helping to analyse, optimise and discuss the yarding process also in a virtual world. The comparison of the simulation output with productivity model estimates shows the comparability of the results for whole logging-site assessments and supports the successful setup of the EDT as a basic structure. Especially with a subsequent integration of long-term machine-data, improved sorting algorithms to represent common working behaviour and an applied physics engine, this EDT can be used to assess tree-, terrain-, machine- and worker- interactions to optimise cable yarding and processing, meeting the various demands of a future, sustainable timber supply.

Keywords: cable yarding, discrete event simulation, VEROSIM, digital twin

SOIL STRUCTURE CHANGES CAUSED BY FORESTRY MACHINES WITH TRACKED AND WHEELED UNDERCARRIAGES AND THEIR NATURAL REGENERATION

*HERBERT BORCHERT[1]**

[1]Bavarian State Institute of Forestry

Corresponding author: Herbert.Borchert@lwf.bayern.de

ABSTRACT

Driving forestry machines on skid trails causes changes in soil structure and soil functionality. The extent of these changes depends largely on the soil texture, water content, contact surface pressure and terrain slope. Forest machines with tracked undercarriages usually have lower contact surface pressures compared to wheeled undercarriages. In a case study, new skid trails were created on a homogeneous site in a spruce stand, which were driven on for the first time. Four treatments were investigated: (1) tracked harvester, (2) wheeled harvester, (3) tracked harvester and wheeled forwarder, (4) wheeled harvester and wheeled forwarder. In the cases where only harvesters were used, the harvested logs were recovered from neighbouring skid trails. All treatments were investigated both on the slope and on flat terrain, so that a total of eight skid trail sections, each 150 m long, were considered. Soil samples were taken at two depth levels on the tracks and as references in the adjacent stand, and the bulk density, pore volume, air permeablility and water conductivity were measured in the laboratory. Six and twelve years later, soil samples were again taken and analysed to check whether regeneration of the structural and functional changes was taking place. With the tracked harvester, there were significant differences from the reference for some parameters only in the lower depth level. In all other cases, however, driving with the forestry machines showed significant changes in soil structure as well as impairments in water conductivity and air permeability. Even twelve years after the experiment, the differences to the undisturbed soil were still significant. For some parameters, there were significant differences between the time of measurement, indicating a regeneration process. In particular, the volume of the macropores and the water conductivity of the soil increased again over the twelve years.

Keywords: soil compaction, skid trails, regeneration

POTENTIAL IMPACTS OF EU POLICY PROPOSALS ON TIMBER HARVESTING IN FINLAND

KARI VÄÄTÄINEN[1]; PERTTU ANTTILA[1]; ANTTI MUTANEN[1]; ANSSI AHTIKOSKI[1]; JOHANNA ROUTA[1]; JUHA LAITILA[1]; JARI LINDBLAD[1]; MATLEENA KNIIVILÄ[1]*

[1]Luke

Corresponding author: kari.vaatainen@luke.fi

ABSTRACT

Currently in EU, there is a lot of activity on preparing and implementing several directives and regulations, which will have an impact on forestry. The planned directives and policies when realized in practice, will affect forest management practices, restoring of forest ecosystems, nature conservation, volumes and use of forests products, and eventually, timber harvesting. Four main parameters, in which the implementation of such regulations and directives would affect in timber harvesting, were determined: a) the average harvesting site removal, b) annual working weeks, c) the share of continuous cover forestry of removal and d) the share of non-productive preparation time. In addition, three future scenarios (low impact, moderate impact and high impact scenario), and present state-scenario were defined. Finally, a purpose-build static system analysis model was constructed and used to assess impacts of scenarios on timber harvesting; harvesting costs, productivities, and the demand of machinery and workforce. In Finland, depending on the scenario, the total additional costs in timber harvesting were estimated at 28–117 million euros compared to the present-state. Correspondingly, and assuming that the cutting volumes of timber would remain at the level of 2017–2021, the need for harvesting machinery and machine operators would increase by 2–15 percent.

Keywords: EU-policy, Forestry, CTL-harvesting, harvesting cost

FOREST ROAD GEOMETRY EXTRACTION WITH AI AND LARGE AREA AIRBORNE LASER SCANNING

JOHANNES RAHLF[1]; STEPHAN HOFFMANN[1]; RASMUS ASTRUP[1]*

[1]Norwegian Institute of Bioeconomy Research

Corresponding author: johannes.rahlf@nibio.no

ABSTRACT

Forest road networks are essential to timber logistics and a fundamental part of today's wood supply chain. However, missing information on forest road quality and design traffic can pose an impediment to reliable forest management, operations and timber logistics. Inadequate road geometry, such as narrow road width, steepness, or small curve radii, can limit the suitability of forest roads for present-day timber truck combinations. The identification of bottlenecks supports an efficient use of resources to maintain and upgrade road networks. However, manual road surveys are laborious, expensive, and time-consuming, making it difficult to obtain up-to-date and comprehensive information on the forest road network. In this study, we present a method for accurately detecting forest road geometry features from airborne laser scanning data from a nationwide campaign and a national dataset of proximate road locations in Norway. Deep learning methods are used to locate road edges in cross-sectional transects. In a second step, an edge line is obtained using a smoothing algorithm using confidence values from the deep learning model. From accurate edge locations, centerline location, road width, longitudinal slope, and curve radii can be deducted for every road segment. The proposed method allows the automated extraction of forest road geometric features with high accuracy. We manually annotated road edges in airborne laser scanning cross sections of road transects. A YOLO algorithm was trained on these annotations and showed an F1-score of 0.73. Overall accuracy of edge detection was 93%. These results demonstrate the feasibility of using deep learning-based methods for automated extraction of forest road geometry features, making it possible to obtain accurate and up-to-date information on the forest road network. Such information is vital for forest management and operations, helping to optimize the use of resources and ensure the sustainable use of forest resources.

Keywords: forest roads, road geometry, remote sensing, ALS, deep learning

SMARTPLANTER: A PLANTING DEVICE FOR PRECISION PLANTING

CSONGOR MARK HORVATH[1]; KJERSTI HOLT HANSSEN[1]; SIMON BERG[1]; RASMUS ASTRUP[1]*

[1]NIBIO (Norwegian Institute of Bioeconomy Research)

Corresponding author: csongor.horvath@nibio.no

ABSTRACT

The SmartPlanter is a dibble bar equipped with an accurate positioning system that serves two main purposes. During planting, the SmartPlanter supports the operator with real-time planting instructions to support precision planting, the implementation of spatially complex multi-species regeneration patterns. Secondly, the SmartPlanter records the exact position of each seedling and uploads it automatically to a cloud-based platform in order to utilize the information in the documentation of the planting measure as well as for future management and planning. The SmartPlanter system includes an augmented dibble bar (SmartPlanter device), a smartphone, and a cloud-based data interface. The SmartPlanter device is a standard dibble bar that has an attached instrument box, which hosts a single-board computer, a differential RTK capable GNSS receiver, a wide-angle camera, a radio module, and additional accessories like a replaceable battery pack, GNSS antenna, and user button. The SmartPlanter device is responsible for data collection and recording, and could operate in two modes – standalone or with an on-site base station mode. The standalone mode is available when cellular network coverage is adequate to receive the correction information for RTK service, while the on-site base station mode is used when correction signals are received from a base station established on the operation field. In both cases, the post-processing of the positioning data is supported by the cloud base infrastructure. The smartphone with the user application allows users to access mapping information tailored for the given planting job, including instructions for certain planting patterns, the precise location of each planted seedling, and analysis of job performance. The smartphone also provides cellular internet to the SmartPlanter device. The collected data, such as seedling positions and images of the surrounding area, are uploaded to the cloud-based service (ForestSense), where the data is analyzed and made available for forest managers. ForestSense provides a centralized platform for forest managers to access and analyze the data collected by (e.g.) SmartPlanters, enabling them to make more informed decisions about forest management practices. Overall, the SmartPlanter system offers a useful tool for improving the efficiency and effectiveness of forest management practices.

Keywords: Precision planting, Forest management, IoT device, Cloud-based service

FORESTSENS: COMBINING SENSORS AND AI FOR SUSTAINABLE FOREST MANAGEMENT AND OPERATIONS

JOHANNES RAHLF[1]; STEFANO PULITI[1]; RASMUS ASTRUP[1]*

[1]Norwegian Institute of Bioeconomy Research

Corresponding author: johannes.rahlf@nibio.no

ABSTRACT

Forest management and operations are increasingly being shaped by digitalization and the use of new technologies. One of the most promising areas for the use of digital technologies in the forest sector is the integration of sensors and artificial intelligence (AI) to support sustainable forest management practices. In this context, ForestSens is a cloud-based platform that aims to transform sensor data into actionable insights by utilizing the power of AI and cloud-based processing. ForestSens enables the collection of vast amounts of sensor data from cameras and lidars positioned throughout the forest production chain. The platform then applies AI algorithms to transform the data into information and actionable insights, which can be used to support more production and environmentally efficient forest value chains. The platform is designed to be easy to use, with an intuitive web interface that allows users to upload their data and select the type of analyses they wish to carry out. ForestSens utilizes a combination of sensors and algorithms, called "Senses," to analyze the sensor data. The Senses being developed include DroneSens, RoadSens, and HarvestSens. DroneSens uses cameras and lidars mounted on drones to generate pre-harvest, post-harvest, and forest damage assessment data. RoadSens, on the other hand, uses sensors mounted on cars and trucks to assess road maintenance needs, while HarvestSens uses cameras and lidars on forest machines to map harvest progress and monitor environmental impacts. ForestSens does not take over the role of existing management or decision support systems but enables easy integration of a flow of information from sensor data combined with AI as input to existing systems. The results of the analyses carried out in ForestSens can be used in existing GIS-based forest management and decision support systems, thereby supporting more sustainable forest management practices while also enhancing production efficiency.

Keywords: Sensor data, decision support, drone, cloud, AI, road, harvester, LiDAR

A NEW METHODOLOGICAL APPROACH TO EXPEDITE WOOD STACKS MEASUREMENT WITH SMARTPHONE APPS.: A CASE STUDY IN EUCALYPTUS AND MARITIME PINE PLANTATIONS IN PORTUGAL

MARIANA AMARO[1]; ALEXANDRA MARQUES[1]; JOSÉ LUIS CARVALHO[2]; MARIA TERESA SILVA[2]; SUSANA MORAIS[2]; BEATRIZ LOURENÇO[3]; AFONSO COSTA[3]; REINALDO GOMES[4]; PEDRO BRITTO[1]*

[1]ForestWISE - Collaborative Laboratory for Integrated Forest & Fire Management; [2]The Navigator Company; [3]Altri Florestal; [4]INESCTEC - Centre - Enterprise Systems Engineering Cluster - Industry and Innovation.

Corresponding author: mariana.amaro@forestwise.pt

ABSTRACT

Knowing the timber stock at the roadside is of fundamental importance for the planning and accounting for processes related to transportation logistics and wood trade. Moreover, in Portugal, traditional methods (based on manual stack measurements) are time-consuming, and the accuracy of volume estimation is often dependent on the experience of forest workers. Portuguese forestry companies are currently investing in the modernization and digitization of their production chains. Examples are the rePLANT and Transform projects, which aim to improve value chains through R&D and innovation, toward digital transition, economic resilience, and carbon neutrality. New technologies that bring potential advantages when compared to traditional methods have been assessed and adapted for the Portuguese forest sector. One example is the photo-optical stack measurement systems for portable devices and smartphones. These technologies are under international attention due to their simplicity of use and efficiency in the center/northern European countries. However, these are yet to be validated under Portuguese forests (Eucalyptus and Maritime pine plantations). Therefore, the study aims to: a) Determine the accuracy of measuring the net and gross stack volume as well as log count in wood piles estimated by five smartphone applications that are already available on the market. b) Assess the time consumption, productivity, and cost-benefit of these apps and decide upon the most suitable app to be used by Portuguese forest stakeholders; c) Propose a new methodological approach to estimate the net volume and weight of log stacks, making use of the most suitable app. For this, measurements will be performed with the five applications for assessing stack volume and by the manual method based on the German standard of stacks manual measurements. Subsequently, the wood stacks will be loaded and weighed, and the wood density measured at the mill entrance and then compared with the net volume estimated by the applications. The productivity will be calculated based on time study measurements. Preliminary results indicated a reduction of circa 60 % in productive time. However, additional tests will show the accuracy and suitability of these methods for Portuguese forest conditions.

Keywords: Forest 4.0; photo-optical measurement; stack volume determination; machine learning.

NEXT GENERATION SOLUTION FOR WOOD SUPPLY OPTIMIZATION.

*RAIMONDS ŠULCS[1]; ANDRIS KAMPERNOVS[1]**

[1]JSC Latvia's State Forests

Corresponding author: a.kampernovs@lvm.lv

ABSTRACT

One of the key business directions of JSC "Latvia's State Forests"(LVM) is production and deliveries of timber. Company chosen business model provides timber deliveries to wood processor companies within agreed timeframe, specification and quality. Actual timber deliveries from roadside storages to wood processor companies is done by precise planning of each load by load, defining for each load from which roadside storage timber must be loaded, to which wood processing company delivered, what route must be taken and finally by which truck load will be delivered and at what time. Deliveries are affected by many variable factors like unpredictable weather conditions, that changes road usage availability and lowers its bearing capacity, other road usage restrictions like limited truck turn around locations in forest, narrow one way roads, time restricted road usage, precision of timber volume information at roadside storages, each assortment maximum loading volume difference, timber delivery priorities, quality loss risk, wood processing company working hours and maximum daily acceptance limit. It is a huge challenge to plan deliveries for couple hundred customers from thousands of roadside storages and take into account all known restrictions. LVM daily delivers 140 different specifications of timber to 150-200 customers from 4000-6000 roadside storages by 190 outsourced trucks. It leads to millions of combinations how daily timber deliveries can be done. At 2012 LVM developed timber delivery optimization software which was unique up to now. The need to change and increase efficiency has significantly increased since. Up to now used optimization software technology limits its further development and adaptation to nowadays fast evolving company needs and challenges. Therefore, LVM has created next generation timber delivery optimization solution which will allow to accept and overcome new challenges. Newly developed tool will provide solution to many forestry industry specific requirements.

Keywords: Wood supply, Optimization, Solver, Supply Chain, Transportation, Logistics

PREDICTION OF SOIL STRENGTH

*ANDREAS HAGENBO[1]; NILS EGIL SØVDE[1]; STEPHAN HOFFMANN[1]; SIMON BERG[1]**

[1]Norwegian Institute of Bioeconomy Research (NIBIO), Division of Forest and Forest Resources

Corresponding author: simon.berg@nibio.no

ABSTRACT

Forest owners, public authorities, NGOs and the general public are becoming increasingly more and more concerned about how forest machines affect the forest soils. These concerns relate to the visual look of ruts, the hindrance ruts can cause for outdoor activities, and the environmental impacts of soil disturbance. Environmental impacts range from soil erosion, sediment disposal to creeks, increased risk for landslides, leaching of heavy metals (particularly methyl Mercury), impaired forest growth due to soil compaction, nutrient loss, to increased emission of greenhouse gases from the forest soil due to severe disturbance.

All these different aspects of ground disturbance make the situation complex, and several different soil and machine properties become important. One of the more important parameters is soil strength. Knowledge of the soil strength in different areas of a site could enable estimations of where it is possible to drive, where it could be possible to drive if reinforcing measures are implemented and where it is not possible to drive without damaging the soil. There is of course a wide range of possible reinforcing measurements but currently are almost exclusively logging residues and low-quality pulp wood used as reinforcement by placing them on top of the strip or base road, which distribute the weight of the machine over a large area.

Knowledge of soil strength could also enable more exact prediction of the ground disturbance of forest machines, i.e., how deep and long the ruts probably will be. Such predictions may facilitate planning ruts with reduced environmental impacts. It could also make it.

In recent years have several models for forest soil characteristics been developed for Norway. This includes models for soil C stock, soil depth, soil texture, soil type, water holding capacity, humus type, and soil taxonomy. These models are developed through machine learning approaches using a mix of different data sources such as metadata from SR16, remote-sensing sources, the Geological Survey of Norway and NFI data. These models and data sets in combination with additional measures of soil penetration resistance enable modelling of the penetration resistance of forest soils in Norway.

Keywords: penetration resistance; remote sensing; field mesurments

AUTONOMOUS TRUCK VEHICLE AND POSSIBILITIES TO REDUCE FUEL CONSUMPTION OF TRANSPORTING WOOD CHIPS IN MILL YARD OF FOREST INDUSTRY

*EETU DAHL[1]; AHTI ULLGREN[2]; PEKKA ALAJÄRVI[2]; KALLE KÄRHÄ[1]**

[1]University of Eastern Finland; [2]Stora Enso.

Corresponding author: kalle.karha@uef.fi

ABSTRACT

Stora Enso company, together with its partners, developed an autonomous self-driving "AutoWood" chip truck vehicle combination, which was defined as a SEA 4 level (i.e., High Driving Automation) automated vehicle. The AutoWood chip truck vehicle combination consisted of a Volvo FM 64 T-D13 (EURO VI) truck tractor and a Kome semi-trailer with a volume of 130 m3. The total weight of the laden semi-trailer truck combination was about 76 tonnes. The task of truck combination was to transport wood chips from the chip yard of sawmill to the production of the pulp mill and operate automatically around 2.6 km along the certain route. The main target of the study was to detect the safety, productivity, operational reliability of automation, and fuel consumption of the AutoWood chip truck vehicle combination. The study was carried out between April and October 2022 at Stora Enso Uimaharju pulp mill in eastern Finland. During the study period, the AutoWood chip truck vehicle was driven in total 272 km. Fuel consumption was related to the chip tonnes supplied. Our assumption was that driving options (i.e., manual vs. autonomous driving), as well as truck drivers and their driving styles have a significant effect on fuel consumption. The weight of payloads supplied was measured by mill's bridge scale. We have seven observations with automated driving option and 22 payloads with manual driving option using three different truck drivers. The results indicated that there is a significant potential to reduce fuel consumption and further greenhouse gas emissions with the autonomous truck vehicle. In the study, with the automated driving mode, fuel consumption averaged 0.43 liters per tonne less than that of the manual driving option. Moreover, the results revealed that there was a significant variation between the drivers in fuel consumption when using the manual driving mode.

Keywords: self-driving vehicle, automated driving, SEA category, terminal.

MACHINE EQUIPMENT OF AUSTRIAN FOREST ENTERPRISES AND FOREST SERVICE COMPANIES

NIKOLAUS NEMESTOTHY[1]; CHRISTOPH HUBER[1]; JÜRGEN RICHTER[1]*

[1]Austrian Research Centre for Forests (BFW), Department of Forest Engineering

Corresponding author: nikolaus.nemestothy@bfw.gv.at

ABSTRACT

In order to get a comprehensive overview of the regionally available harvesting capacities, a survey was carried out in 2020 among a) Austrian forest owners with more than 200 hectares of forest each and b) all registered forest service companies. They were asked about their equipment, staff and skills. With more than 3,500 completed questionnaires (response rate for forest companies 58% and for forest service companies 69%) reliable results were achieved. Surprisingly, only about 50% of the governmental-registered forest service companies are actually active in timber harvesting. However, the active forest entrepreneurs recorded are significantly better equipped and more modern than the forest enterprises. In total, almost 2000 tractors in combination with more than 2700 attachable machines and more than 1700 self-propelled forest machines (skidders, harvesters, forwarders and yarders) were counted at these forest companies and forest service companies. In addition to the number of machines available in the region, the market shares of various manufacturers, the service life of various machines and their annual utilization and distribution across the size classes were also evaluated. It should be noted that some of the existing machines could not be recorded in this study because 50% of the Austrian forest area is managed by 165,000 small forest owners with less than 200 ha forest land each. On average, over the last 5 years, this small forest owners have harvested 58 % of the Austria's total felling volume and 75% of the harvesting operations was carried out with their own machines. In order to record these machines as well, regional random samples are planned for the next few years.

Keywords: forest machine statistics, logging machine, forest service companies

AUTOMATIC PLANT POSITION SELECTOR FOR REFORESTATION MACHINES

MORGAN ROSSANDER[1]; SONGYU LI[2]; HÅKAN LIDESKOG[2]*

[1]Skogforsk, The Forestry Research Institute of Sweden; [2]Luleå University of Technology.

Corresponding author: morgan.rossander@skogforsk.se

ABSTRACT

Reforestation by manual seedling outplanting is a crucial operation in modern forestry. The work is labor intensive and usually has a significant impact on the soil and forest appearance. The Autoplant research project aimed to find solutions for a lightweight fully autonomous planting machine with precision site preparation. This work presents the plant position selection system that was used in Autoplant. The algorithm considers visually detectable obstacles such as stones and stumps and chooses positions that are unoccupied. It has been evaluated through simulation and field trials, with promising results demonstrating its potential for real-world implementation. The algorithm has been implemented as a ROS (Robot Operating System) node in Python. The Autoplant machine equipped with precision scarification and planting hardware and operates by incremental movements where each new position represents a work area. A stereo camera object detection system locates and estimates sizes for stumps and stones in the work area. The plant planner algorithm employs a map of the current work area, representing each detected obstacle with a weight and radius depending on their type and estimated size. Previously planted seedlings and planting attempts are also added. The weights represent the cost for the system of trying to place a plant within the region. By adjusting the weight values, it can be acceptable to have a small stone close to a plant, but unacceptable to have another seedling too close. To evaluate the unoccupied positions for a new seedling, a region called kernel is defined. The kernel has an inner and other radius of different weights which are adjusted to allow small obstacle amounts within the outer part while keeping the center part clear. The kernel is swept over all positions in the work area and in each position the product sum of the kernel and the weights in the map are calculated. The mathematical method of convolution allows this process to be done computationally effective. Unoccupied positions are identified by selecting positions where the convoluted map has a value below a chosen threshold. Different strategies can be used to select the next planting position from the available ones. The planting patterns obtained with varied selection strategies in the convoluted map and planned area sizes have been studied in simulation. Overall, the purposed algorithm is computationally efficient and offers flexibility in its behavior by adjustments to the weights and kernel design along with the selection strategy. In addition, the seedling kernel size can be adjusted by a controller to maintain a target for planting density. Future research is required to refine the algorithm to account for additional factors such as soil conditions, slash residue, slope, sunlight exposure and planting patterns. Further work is also needed to optimize the work area shape and size along with the selection order of unoccupied positions. Additional field trials are needed to determine the algorithm's performance over longer time periods and to ensure that avoiding surface obstacles is enough to sufficiently select suitable planting positions over time.

Keywords: reforestation, planting machine, plant planning, autonomous, obstacle detection, silviculture

CENTRAL EUROPEAN MULTI CRITERIA DECISION SUPPORT SYSTEMS TO ENHANCE FOREST MANAGEMENT UNDER CLIMATE CHANGE

JANINE SCHWEIER[1]; STEFAN HOLM[1]; LEO G. BONT[1]*

[1]Swiss Federal Institute for Forest, Snow and Landscape Research WSL

Corresponding author: janine.schweier@wsl.ch

ABSTRACT

To tackle climate change (CC) and its risks, many driving factors for resilient forest management are identified including diverse management approaches currently applied in Central-Europe, such as integrated forest management, close- and closer-to-nature management and climate-smart forestry. The aim of these approaches is to increase the resilience of future forests and to reduce and/or avoid ecosystem damage and social and economic effects caused by CC. Resilient and diverse managed forests are able to maintain and enhance the provision of biodiversity and multiple forest ecosystem services (ES). As a consequence, the ultimate aims of forest managers are or should be i) to increase forests resilience and reduce negative environmental, social and economic effects associated to CC and ii) to maintain and enhance the provision of biodiversity and ES, while considering the principles of sustainable development and iii) applying economic feasible concepts. This multifunctional approach may indicate that the needs and demands of various stakeholders need to be considered in decision-making. The underlying decision is complex, often conflicting and always depends – besides the governmental framework – on the involved people and their prioritization of management goals. Therefore, forest managers should be equipped with the best possible spatial Decision Support System (DSS) that can be flexibly applied on varying forest management units. Moreover, the DSS should allow to graphically visualize (digital forest twin) the consequences of the management strategies on the forest landscape, offering at the same time a new form of communication between stakeholders. The presentation will give an overview about the current state of DSS being applied in Central Europe and demonstrate their function by using a real example from a Swiss forest enterprise.

Keywords: visualization, digital forest twin, Unity, optimization, indicators, sustainability

PRIVATE FOREST OWNER WILLINGNESS TO MOBILISE WOOD FROM DENSE, SMALL-DIAMETER TREE STANDS

MATEVŽ TRIPLAT[1]; SATU HELENIUS[2]; RUBEN LAINA[3]; NIKE KRAJNC[1]; THOMAS KRONHOLM[4]; ZDENKA ŽENKO[5]; TEPPO HUJALA[2]*

[1]Slovenian Forestry Institute; [2]University of Eastern Finland, Faculty of Science and Forestry, School of Forest Sciences; [3]Polytechnic University of Madrid; [4]Department of Forest Biomaterials and Technology, Swedish University of Agricultural Sciences; [5]Faculty of Economics and Business, University of Maribor.

Corresponding author: matevz.triplat@gozdis.si

ABSTRACT

Forests are sources of renewable biomass, and their utilisation will play a vital role in the transition towards a climate-neutral economy. Small-diameter tree management may contribute to this transition via providing renewable biomass for sustainable uses and fostering tree growth towards long-lifecycle bioproducts. The utilisation of small-diameter trees in the EU is still low since new technologies and work models are required to make the operations economically profitable, environmentally sound, and socially attractive. The supply of biomass from small-diameter tree stands is dependent on forest owners with diverse perceptions on their forests and diverse ownership objectives. However, there is scarce research on forest owner perceptions on small-diameter tree management, which encompasses home consumption, self-active work, and commercial forestry services. A survey in four EU countries was designed to identify the main factors affecting the motivation of forest owners to mobilise biomass from small-diameter stands. Factor and clustering analyses were used to identify four forest owner segments: weakly-engaged traders, multi-benefit seekers, self-active profit-seekers, and well-informed service users. The willingness to utilise biomass from small-diameter tree stands and participate in the market was shaped by forest owner knowledge of forestry, economic and socio-cultural motivations, and sensitivity to service offerings. Forest owner preferences for market participation are heterogenous, and thus different policy implementation approaches are needed and proposed.

Keywords: Customer profiles; factor analysis; forestry services; management objectives; biomass

SEARCH FOR HARVESTER ENGINE'S OPTIMAL REVOLUTION PER MINUTE (RPM) TO ACHIEVE HIGH PRODUCTIVITY AND LOW DIESEL CONSUMPTION

PIOTR MEDERSKI[1]; MAGDALENA GLIWA[2]; PRZEMYSŁAW WELTROWSKI[2]; ANDRZEJ KONIECZNY[2]; ANDREA PROTO[3]; MARIUSZ BEMBENEK[1]*

[1]Poznań University of Life Sciences; [2]The State Forests; [3]Mediterranean University of Reggio Calabria.

Corresponding author: piotr.mederski@up.poznan.pl

ABSTRACT

Harvester use for thinnings and final fellings has become a common solution in Europe and numerous studies have focused on the optimisation of cut-to-length (CTL) technology. As a rule, the bigger the tree, the higher the harvester productivity, but there are also aspects of engine revolution per minute (RPM) that can have an impact on harvester power, and finally on productivity. The objective of this research was to discover how a change from 1500 to 1700 RPM would impact productivity and fuel consumption during thinning. The research was carried out in northern Poland, in two pine stands in which thinning and final felling were carried out with the same John Deer 1270 D harvester. After selection of the sample plots, fuel consumption was checked on each plot and its use calculated per m3 of harvested timber. Further analysis consisted of the calculation of costs - in particular, if a higher fuel consumption was economically justified by a higher productivity. In the thinning, for 1500 and 1700 RPM, a productivity of 13.83 and 15.91 m3 PMH0-1 was achieved and a fuel use of 1.01 and 1.37 l m-3, respectively. In the final felling with 1500 RPM, the productivity achieved was 32.47 m3 PMH0-1 as opposed to 34.36 m3 PMH0-1 when 1700 RPM was set. Fuel use totalled 0.42 and 0.70 l m-3 for 1500 and 1700 RPM, respectively. In both cases, in the thinning and final felling, higher costs of fuel per m3 of harvested timber were incurred when 1700 RPM was set in the harvester.

Keywords: thinnings, final fellings, fuel consumption, engine, economic efficiency

DOES THE TREE SPECIES INFLUENCE THE FRICTIONAL PERFORMANCE OF FORESTRY ROPES BENT OVER TREES?

JUERGEN RICHTER[1]; NIKOLAUS NEMESTOTHY[1]; CHRISTOPH HUBER[1]*

[1]Austrian Federal Research Centre for Forests, Natural Hazards and Landscape (BFW)

Corresponding author: juergen.richter@bfw.gv.at

ABSTRACT

When anchoring ropes in various forestry applications, the forces that occur are transferred to tree anchors through rope friction. As a rule, to reduce the force of the outgoing rope, the anchor and guy ropes are wrapped around the anchor tree several times. The holding force is mainly determined by the friction between the rope and the wood, therefore knowing the coefficient is essential for a secure anchorage. The analysis of rope friction thus guarantees an improvement in occupational safety. To determine the specific coefficients of friction of ropes on anchor trees, tests were carried out with common steel and synthetic forestry ropes in on stems from different tree species at different times of the year. The tests were carried out with stems of spruce and beech for a variety of surface roughness in a testing period over winter, spring and summer. On a testing station all kind of various wrapping angles were simulated, the main cylinder has a pulling capacity of 200 kN and the counterweight can be adjusted in eight steps up to 20 kN. These two forces are monitored simultaneously with the pulling speed of main cylinder and counterweight. All four measurements allow determining the exact moment of the first slipping of the rope as well as the maximum force. The results of the final tests and the values for the frictional coefficients of anchoring between ropes and trees for different wrapping angles are presented and discussed.

Keywords: rope friction; anchoring; yarders; anchor trees; steel ropes; fiber ropes

FINAL REVIEW OF ROPE END CONNECTORS AVAILABLE FOR FOREST APPLICATIONS

JUERGEN RICHTER[1]; NIKOLAUS NEMESTOTHY[1]; CHRISTOPH HUBER[1]; DOMINIK SECKLEHNER[2]*

[1]Austrian Federal Research Centre for Forests, Natural Hazards and Landscape (BFW); [2]Teufelberger Fiber Rope GmbH.

Corresponding author: juergen.richter@bfw.gv.at

ABSTRACT

According to the standard EN 14492-1, only simple aluminum ferrules and/or "Flemish Eye" with aluminum ferrules according to EN 13411-3 are permitted as rope end connectors for winching ropes in forestry applications specifically. In general, four variants of rope end connections are permitted for winches, whereby in addition to the two variants listed above, asymmetrical wedge sockets according to EN 13411-6 and symmetrical wedge sockets according to EN 13411-7 as well as metal and synthetic resin casting according to EN 13411-4 are permissible. To analyze the performance of various permitted and not permitted rope end connectors a series of break-tests at the Teufelberger test laboratory with a PERFECTION F30 – Woodrunner 12mm - rope and different setups were carried out. The testing was carried out in three steps: a) The end connector was fixed and pulled directly, b) the end connector was pulled indirectly by using a rope glider, and c) the end connector was pulled directly and indirectly. The performance of currently not permitted symmetrical and asymmetrical wedge sockets was around the demanded 85% of minimum breaking force of the rope. All other tested setups, including the currently allowed simple aluminum ferrules and “Flemish Eye” with aluminum ferrules broke at significantly lower pulling forces. On this poster the final results are highlighted and discussed.

Keywords: anchoring; winches; steel rope; fiber rope; wire rope; breaking force

DIGIFOREST PROJECT: TECHNOLOGIES TO ACHIEVE SUSTAINABLE DIGITAL FORESTRY

JANINE SCHWEIER[1]; HOLGER GRIESS[1]*

[1]Swiss Federal Institute for Forest, Snow and Landscape Research WSL

Corresponding author: janine.schweier@wsl.ch

ABSTRACT

The increasing complexity in decision-making forest managers have to tackle needs to be addressed by equipping them with the best possible spatial decision support system (DSS). Such systems are typically based on a database, a forest growth model and a multi-criteria decision support system. The availability of high-quality input data is the key for the efficiency and accuracy of any model and can significantly contribute to enhancing the quality of decisions. In the framework of the EU project DIGIFOREST we propose an innovative novel approach to transform to large scale precision forestry management. It is centered on the collection of detailed and diverse forest data at the tree level using different types of mobile robots and the turn of forest scans into actionable data. Moreover, the aim of the project is to go one step further and to foster digitalization along the whole forestry value chain, including the design of logging operations via desktop application and conducting autonomous selective cutting. Particularly lightweight harvester executing missions with high-level supervised autonomy are of interest because they are easier to apply in difficult terrain (e.g. limited soil bearing capacity), which is relevant especially with regard to climate change. The core question addressed in the project is how digital analytics and robotics can be used and made applicable to enhance forest management and the forestry value chain. The poster will present the projects `ambitions in more detail and give link to references and project activities.

Keywords: ALS, TLS, LiDAR, digitalization, value chain, forest management, robotics

CONCEPTS OF ENERGY EFFICIENT ELECTRIFIED CTL FORESTRY MACHINES

MARTIN ENGLUND[1]; MORGAN ROSSANDER[1]; SAMUEL KÄRNELL[2]; MATS ZACKRISSON[3]; KARIN ÅGREN[1]; LISELOTT ERICSON[2]*

[1]Skogforsk - the Forestry Research Institute of Sweden; [2]Linköping University; [3]RISE - The research institute of Sweden.

Corresponding author: martin.englund@skogforsk.se

ABSTRACT

For forest materials to be sustainable the harvesting needs to be performed with a fossil carbon footprint that is as small as possible. In Swedish forestry the fuel consumption per volume of material has not changed significantly in the last decades. This pilot study has investigated what technologies are available today that can be implemented to improve the energy efficiency of forest machines. The aim has been to inspire our own research group and the research community to identify research topics in this area. Several different aspects have been considered such as energy carriers, energy conversion to mechanical work, energy distribution on the machine and the losses in different processes. A detailed analysis of the use of hydraulic functions was performed on data from a machine simulator, combined with modelling and fuel consumption statistics to describe energy use and estimate the effect of alternative machine designs. With the goal of reduced carbon footprint in mind we have formulated several machine concepts with existing technology of which some are unconventional in forestry machines. The concepts are based on final felling harvesters and forwarders and are meant to be functionally equivalent. The difference in components, energy use and cost between the concepts and conventional machines have been analyzed using life cycle assessment methodology. One significant source of energy loss is in the current hydraulic systems is the simultaneous use of several functions with different pressure and flow demands. To address this modern hydraulic pump are incorporated into the concepts. The energy that is needed for useful work is highly variable between and within work elements. This means the internal combustion engine needs to constantly be kept at a high speed and power capacity to meet sudden demands of high power. The internal losses of the combustion engine and the fact that it frequently delivers a low degree of useful work compared to its capacity are significant sources of energy waste. To address this the concepts are suggested to be either serial hybrid battery electric or fully battery electric. Electric motors are highly efficient and are better suited to handle sudden variations in load as they don't need to be kept at idle. Another advantage of electricity is that it can be distributed on the machine with less losses compared to hydraulic pressure. This can be used to provide energy to the harvester head where significant losses occur from the long distance to the pump. Serial hybrid electric concepts use a combustion engine to charge the battery which in turn powers electrical motors that power the drive train and hydraulic pumps. The efficiency advantage in a hybrid concept is that a smaller engine can be used to charge at its point of optimum efficiency and only need to be in use intermittently. One advantage of a hybrid machine over battery electric is that fuel distribution to the harvesting site is already established. For fully electric concepts the battery size and weight become significant factors and energy distribution to the site a challenge.

Keywords: hybrid, battery, electric, forwarder, harvester, energy, efficiency

SMARTFOREST – DIGITAL TRANSFORMATION OF THE NORWEGIAN FOREST SECTOR

CAROLIN FISCHER[1]; RASMUS ASTRUP[1]*

[1]Norwegian Institute of Bioeconomy Research

Corresponding author: carolin.fischer@nibio.no

ABSTRACT

In the digital age, where digitalization is transforming various industries, the forest sector needs to embrace technology to stay competitive. SmartForest, a center for research-driven innovation, is contributing to the digitalization of the Norwegian forest sector. The center aims to increase environmental and production efficiency by implementing enabling technologies in the forest value chain for a digital revolution of the sector. This transformation will be enabled by a series of innovations that will form the foundation for the development of a strong forest-tech sector in Norway. SmartForest provides a coordinating role for R&D activities related to digitalization in the forest sector and generates momentum to act as a catalyst for significant sector-wide digitalization. SmartForest's industrial partners include most Norwegian forest management companies, technology and data companies, and a leading research environment in Precision Forestry. SmartForest works along the forest value chain to develop cost-efficient operational systems for continuously updated forest information, precision silvicultural practices, digital approaches that reduce the cost of forest harvesting and environmental impacts, precision wood supply approaches that reduce logistics costs, and enable full traceability of wood. It also enables a fully digital flow of information between key private and public actors in the forest sector. SmartForest's innovative solutions will result in a long-term, world-leading, industry-focused R&D environment centered around the application of enabling technology for the digital transformation of the forest sector. It will position the Norwegian forest sector at the forefront of digitalization resulting in large efficiency gains, increased production, reduced environmental impacts, and significant climate benefits. It will also be the catalyst for an internationally competitive forest-tech sector in Norway. This presentation will provide insights into SmartForest's concept, ongoing research and potential impacts on the forest sector.

Keywords: digitalization, precision forestry, enabling technology, AI, data-driven decision support

ENHANCING EFFICIENCY AND VALUE THROUGH FULL TRACEABILITY OF TIMBER FROM THE FOREST TO THE SAWMILL

CAROLIN FISCHER[1]; MOSTAFA HOSEINI[1]; CSONGOR HORVATH[1]; RASMUS ASTRUP[1]; YOHANN JACOB SANDVIK[1]*

[1]Norwegian Institute of Bioeconomy Research

Corresponding author: carolin.fischer@nibio.no

ABSTRACT

Tracing logs along the forest value chain is in strong demand within the forestry industry. The possibility to trace logs from the forest to the sawmill would not only provide benefits for certification purposes but would also allow for a more efficient utilization of a highly demanded but limited resource while simultaneously increasing its value. The size and quality of logs determine the yield of sawn timber. Detailed knowledge about the dimensions and quality of logs helps to increase the yield by adapting bucking and the produced sawn timber. Within SmartForest, a center for research driven innovation, we work on the identification of individual tree logs throughout the wood procurement chain including the collection and connection of log affiliated data on tree and log level. The aim is to make those data available for a more efficient production, utilization and distribution of the resource according to its characteristics. Sawlogs are marked with a unique tracking code, spray-painted on individual logs. Individual logs will be identified by a deep learning-based object detection model enhanced with a code reading feature allowing the connection of data from the forest to the sawmill.

Keywords: traceability, object detection, production optimization, efficiency, deep learning

USE OF MOBILE DEVICE INERTIAL MEASUREMENT UNIT (IMU) AND REAL-TIME KINETIC (RTK) GNSS TO QUANTIFY ERGONOMIC DIFFERENCES AMONG TRACKED AND RUBBER-TIRED GRAPPLE SKIDDERS.

AXEL WALL[1]; ROB KEEFE[1]; EBRU BILICI[1]*

[1]University of Idaho Experimental Forest

Corresponding author: andreawall@uidaho.edu

ABSTRACT

Logging is among the most dangerous professions in the United States due to hazards including exposure of equipment operators to jarring movements and vibrations. Mitigation of this risk can be achieved through strategic improvements to equipment. In this study, we are comparing ergonomic exposure associated with the use of rubber-tired and tracked grapple skidders in forestry. Using the inertial measurement unit (IMU) in a Google Pixel smartphone and RTK GNSS devices, we evaluated whether tracked skidders have less vertical oscillation than rubber-tired machines as they navigate skid trails during industrial harvesting operations. This research has the potential to unveil new knowledge about potential improvements to occupational health and safety in logging. In the future, we will expand this study by incorporating stand mastication as an additional treatment that may further improve ergonomics. We anticipate that tracked skidders will reduce exposure to adverse health effects, thereby reducing adverse health exposures in logging.

Keywords: Logging, skidder, ergonomics, operations, harvesting, safety, timber,

A COMPARISON BETWEEN BATTERY- AND PETROL-POWERED CHAINSAWS IN TERMS OF NOISE AND VIBRATIONS EXPOSURE

FRANCESCO NERI[1]; ANDREA LASCHI[2]; LUCIA BERTUZZI[3]; GIOVANNI GALIPÒ[4]; NICCOLÒ FRASSINELLI[1]; FABIO FABIANO[1]; ENRICO MARCHI[1]; CRISTIANO FODERI[1]; ELENA MARRA[1]*

[1]Department of Agriculture, Food, Environment and Forestry (DAGRI) - University of Florence; [2]Department of Agricultural, Food and Forest Sciences (SAAF) - University of Palermo; [3]Department of Prevention, Tuscan Agency of Public Health; [4]Arma dei Carabinieri–Raggruppamento Carabinieri Biodiversità– Reparto Biodiversità di Vallombrosa.

Corresponding author: andrea.laschi@unipa.it

ABSTRACT

The use of chainsaws in forestry is still common worldwide. In fact, felling, delimbing and cross-cutting operations are commonly made by chainsaw in many areas. It is universally known that forest operations are very dangerous for professional workers, in particular those made by chainsaw. In fact, the accident rates and severity, together with the medium and long-term occupational diseases, are very high on average and it is difficult to reduce this negative effect. Nevertheless, considering the low investment needed and its versatility, chainsaw continues to be the main tool used in forestry in many contexts. Also for this reason, the main producers of chainsaws made huge investments in the last years to develop a new generation of machines, powered by electric engines instead of endothermic ones. In this context, in the last years the use of battery-powered chainsaws rapidly increased, also in professional activities, especially gardening and tree maintenance. Moreover, the last models of chainsaws, characterised by similar performance in terms of power of cutting efficiency in comparison with "traditional" models, have been noticed by forest operators that started to ask if it would be possible to use battery-powered chainsaws in substitution of petrol-powered machines in forestry. In fact, first studies demonstrated that differences in terms of cutting performances and productivity are very low, null in some cases. The most important disadvantage is currently the battery duration and the problem of on-field recharging. On the other side, battery-powered tools are considered as a better alternative to petrol-powered systems in terms of noise and vibrations, contributing to reduce accident rates but especially occupational diseases. For these reasons, in this study noise and vibrations exposures were investigated, comparing the latest model of battery chainsaw and its correspondent powered by petrol. The comparison was made considering both hardwood and softwood, a forest operator made a series of cross-cutting on black pine and beech logs, alternating the two tested chainsaws: the Stihl MS 300-A and the Stihl MS261-CM. Four logs of pine and four logs of beech were used, characterised by diameters from 25 to 30 cm. During this operation, both noise and vibrations were measured according to ISO 11201 and to ISO 5349, respectively. Regarding vibrations, the results showed that, on average, the peak value of vibrations using battery chainsaw is about half of the value obtained by using the petrol-powered one. It is interesting to notice that the peak value on battery chainsaw has been obtained on the right handle, while on petrol chainsaw on the left one. Considering noise exposure, there is a significant difference between battery and petrol chainsaws, with a lower value of

the first one. However, the obtained values do not allow the operator to use the chainsaw without ears protections. In conclusion, this study confirmed that there is an important advantage using battery chainsaws in terms of both noise and vibrations exposures. For this reason, it is important to continue improving these tools to make their use in forestry possible.

Keywords: ergonomics; battery chainsaw; noise; vibrations; sustainable forest operations; occupational diseases

ROADMAP TO BOOST ELECTRIC MOTORIZATION OF THE PORTUGUESE FOREST SECTOR

PEDRO BRITTO[1]; ALEXANDRA MARQUES[2]; JOSÉ LUIS CARVALHO[2]; SUSANA MORAIS[2]; PEDRO SILVA[3]; PAULO MACHADO [4]; RUI IGREJA[5]; CARLOS AMARAL NETTO[5]; JOÃO GASPAR[6]; JORGE FILIPE MARTINS[6]; CARLOS VIEGAS[7]*

[1]ForestWISE: Collaborative Laboratory for Integrated Forest & Fire Management; [2]The Navigator Company; [3]Altri Florestal; [4]Unimadeiras S.A; [5]Florecha; [6]REN; [7]ADAI - Association for the Development of Industrial Aerodynamics.

Corresponding author: pedro.britto@forestwise.pt

ABSTRACT

The global challenges of decarbonizing the economy have encouraged investment in renewable energy all across the world. The European Green Deal, for example, aims to decouple economic growth from resource use and net zero emissions of greenhouse gases by 2050. Moreover, Portuguese industries and forestry companies interested in reducing their carbon footprint see a promising opportunity in the adoption of electric vehicles and machinery (EV) and hybrid or hydrogen powertrains (EV/HIB/H). Within this context, in 2022 the project "Agenda TransForm" was launched in Portugal. The project represents the largest consortium ever made for the Portuguese forest sector. TransForm project aims at the transformation of the value chains through R&D and innovation, toward digital transition, economic resilience, and carbon neutrality. The 59 participants represent Portugal's entire forest value chain (forestry producers, forest companies, territorial management entities, and the researchers center). The goals of "Agenda TransForm" address the European Green Deal commitment to cutting greenhouse gas emissions (GHG) and therefore promote R&D projects and the development of low carbon emissions for forest harvesting machinery. Although the electrification of forest machinery is already a reality in many Center/Northern European countries, the region known for its extensive Eucalyptus globulus plantations requires additional development and forest machinery suitable to local climatic and forest conditions. In this context, this pioneering project aims to: a) Present a global description of a low-carbon emission and/or electric solution suitable for the Portuguese forest sector by identifying priority operations and equipment based on benchmarking and local stakeholders; b) Implement different research lines in order to develop and assess the identified solutions, in particular on charging stations and transmission lines for the Forest; potential impacts on the logistic chains; and business models for new electric equipment and batteries; c) asses the sustainability and suitability of electric vehicles and machinery for the Portuguese wood supply chain; d) promote the adoption of electric vehicles and machinery, hybrid or hydrogen engines (EV/HIB/H2) for forestry operations and transport, supporting Portuguese forestry companies interested in reducing their carbon footprint. Within the results of this project, we expect to promote a roadmap and a timeline for the implementation of different actions and solutions as well as a basis to support public policies and decision-makers in implementing greener forest operations and transportation.

Keywords: European green deal, electric vehicles, renewable energy, low carbon emissions

INTEGRATING REAL-TIME LOCATION SHARING AND WEARABLE-BASED HUMAN ACTIVITY RECOGNITION TO IMPROVE SAFETY ON LOGGING OPERATIONS

ROB KEEFE[1]; ELOISE ZIMBELMAN[1]*

[1]University of Idaho Experimental Forest

Corresponding author: robk@uidaho.edu

ABSTRACT

In prior work, we have developed and evaluated methods using real-time GNSS-RF devices to map worker locations relative to jobsite hazards in order to increase situational awareness on logging operations. We have also recently published results that demonstrate use of lidar and satellite remote sensing to characterize the connectivity of networked devices in forested landscapes in order to understand the factors that affect the dependence of these systems in digitalized forest operations, as well as wildland fire response. Lastly, we have conducted successful research developing the first Human Activity Recognition (HAR) models to predict logging work activities using smartphones and smartwatches. Through a new project recently funded by the U.S. National Institute of Occupational Safety and Health and the Pacific Northwest Ag Safety and Health (PNASH) Center, we are now bringing together these areas of research by developing a swartwatch app that characterizes logging work activities using HAR models in mixed motor-manual and mechanized operations while simultaneously mapping worker locations in real time at the job site using ad hoc networks. We will discuss current progress and results on this project as we integrate multiple types of data to characterize worker safety and health interactively and discuss plans for future research over the next 4 years. This includes a pathway for transitioning from our wearable-based HAR modeling to future robotics and automation.

Keywords: Human Activity Recognition; wearables; smart forestry; forest digitalization; precision forestry

THE BURNING QUESTION: ADDRESSING HARVEST RESIDUE MANAGEMENT IN BRITISH COLUMBIA

ERIC NANCE[1]; DOMINIK ROESER[1]*

[1]University of British Columbia, Faculty of Forestry

Corresponding author: eric.nance@ubc.ca

ABSTRACT

The management of timber harvest residues has long been a challenge for British Columbia's (BC) foresters who are tasked with balancing wildfire fuel loading, planting space, and financial, operational, and regulatory constraints. Now, society's concerns about carbon emissions have been added to that list and practices will have to change. Slash-pile burning (SPB) is the low-cost practice of open-burning residues to reduce fuel loading after harvest, and while it may meet the minimum management requirements, it is a considerable GHG emissions source, with emissions estimates ranging from 3-8 megatonnes of carbon dioxide equivalent (Mt CO2 eq) each year over recent decades in BC. These emissions both enhance climate change and have negative human health impacts. In some areas, open burning of residues can also have negative impacts on ecological functions, such as future stand productivity and small mammal habitat. To better understand the current state of slash-pile burning emissions, and opportunities for alternative management practices, our team has carried out three research tasks: (1) uncertainty analysis for current modelling parameters used to estimate provincial SPB emissions, (2) survey of BC forest professionals across the province to better understand 'on-the-ground' management challenges, and (3) literature review of feasible harvest residue management alternatives to SPB for the province of BC. The evaluation of BC's SPB emissions estimates identified several modelling parameters which may no longer be representative of current harvesting practices. Three key uncertainties were identified to be validated and, where necessary, updated. These uncertainties are the ratio of merchantable timber removed vs. left for waste during clearcut harvesting, the proportion of harvest areas which receive SPB treatments in a given year, and the specific emissions profile (emissions factors) for SPB combustion. Validation of these parameters will be carried out in upcoming research. The survey of BC forest professionals successfully elicited baseline estimates of three SPB emissions modelling parameters. It also provided opinions on current operational challenges for harvest residue management, feasible alternative practices to slash-pile burning, and potential barriers to the implementation of such alternatives. Common operational challenges noted were low market prices for residual fiber, high costs of processing and transportation, inaccessibility of roads for biomass trucks, and restrictive forest policy and regulation. Participants also identified a number of alternative management practices to SPB, as well as policy opportunities to help support improved residue management. Finally, the literature review has identified several alternative management practices to SPB which may serve to better utilize residual fiber, mitigate provincial GHG emissions, and improve forest stewardship. Types of alternatives identified include utilizing residues as feedstock for liquid and solid bio-fuels, redistribution of residues back into the cutting area, and improved burning with mobile burning units. While the management of

harvest residues is a complex challenge with no 'one-size-fits-all' solution, our research thus far has shown that incremental steps away from SPB and towards more responsible alternative practices can reduce provincial emissions while having meaningful and positive impacts on the people and forests of BC.

Keywords: Slash-pile Burning, Harvest Residue, Emissions, Management, Alternatives

FORECASTING SOLUTIONS FOR CHARACTERIZING LOGGING CONDITIONS AND SUITABLE WEATHER CONDITIONS

AINARS GRINVALDS[1]; ARINA KIRJANOVA[1]*

[1]Latvijas valsts meži

Corresponding author: a.grinvalds@lvm.lv

ABSTRACT

The annual logging planning based on optimization solutions requires measurable criteria for characterizing the logging conditions of felling area and suitable weather conditions for felling. Thus, optimization can under measurable criteria determine the possibility to do logging in each felling area and model the impact of different weather scenarios. The aim of the study was to develop mathematical forecasting solutions that would allow, first, predict measurable logging conditions, based on the soil and forest inventory data of each felling area. Second, to predict probability to do logging in each felling area under different weather scenarios, based on measurable meteorological data. The study was realized on data of 8590 final fellings and 5188 commercial thinnings of JSC "Latvijas valsts meži" (Latvia state forests) from year 2017 to 2022. For each felling area was assigned points that characterize the proportion of bad and extreme logging conditions from total cutting volume in the last 7 days in each company region. The 7-day average proportion of bad and extreme logging conditions was found to have the best correlation with weather constrains. Each felling area were described by: area, harvesting and forwarding conditions (based on forest type and soil conditions), forwarding distance, felling volume, felling volume per hectare, forest type, species mixture, height above sea level, terrain of felling area. Additionally for each felling area the meteorological data (temperature of last 7, 15, 30 days and precipitation of last 7, 15, 30 days) for logging time was calculated based on Latvian State Geological and Meteorological Center 25 weather stations data. The regression analysis was used, and equation ($p<0.01$) was developed that allow to calculate logging conditions points (lowest points – easier logging, higher points – harder logging) of each felling area. Statistically significant ($p<0.05$) are following factors: felling area volume, felling areas volume per ha, forwarding distance, forwarding conditions (4 groups) and harvesting conditions (4 groups). By regression analysis the weather condition impact on logging possibilities was set. Equation ($p<0.01$) allows to calculate the maximum logging points under defined weather constrains (meteorological data). The most suitable factors ($p<0.05$) are temperature of the last 15 and 30 days and the precipitation of the last 30 days. Finally based on last 12 years weather stations data three measurable weather scenarios were set for each region. Measurable – for each month the average temperature of the last 15 and 30 days and the precipitation of the last 30 days was set. First scenario – best for logging, second – moderate for logging and third scenario – worst for logging. So, by first forecasting equation can calculate the measurable logging conditions – points. By defined weather scenarios can define measurable meteorological data – temperature and precipitation. By second forecasting equation can calculate for each weather scenario maximum logging conditions points for each month. Finally, you can give to optimization measurable criteria for felling areas and

weather scenarios that characterize logging possibility and find the most suitable logging month for each felling area.

Keywords: optimization, forecasting, logging constrains, weather scenarios

FULL-AUTOMATIC PRODUCTION ANALYSIS OF WINCH-ASSIST HARVESTING OPERATIONS BASED ON ANCHOR MACHINE CONFIGURATIONS

OMAR MOLOGNI[1]; STEFFEN LAHRSEN[1]; DOMINIK ROESER[1]*

[1]The University of British Columbia

Corresponding author: omar.mologni@ubc.ca

ABSTRACT

Winch-assist harvesting systems have emerged as a widely used solution for safe and cost-effective logging of forests located on steep ground. Despite significant research efforts made to develop best practices and validate the safety benefits of these newly introduced systems, there is still a significant gap of knowledge regarding their production performances in the multitude of possible configurations and applications. This is especially true when logging practices use whole-tree harvest methods and tethering solutions based on anchor machine configurations (i.e., dynamic systems), as it is common in North America and New Zealand. Production analyses of these practices are particularly challenging as they lack the capacity to directly measure tree volume at the stump (as done with most mechanized cut-to-length machinery) and require simultaneous and integrated monitoring of coupled machines (i.e., the primary and the anchor machine). To address this challenge, the authors propose a novel approach for fully-automatic analysis of production performance metrics of winch-assist harvesting operations, specifically designed for whole-tree operations based on anchor machine configurations. The proposed approach is based on the instrumentation of all machines involved in the operations with dedicated FPDat II on-board computer systems that provide machine movement and location information. These machine data, together with site and stand information, are then post-processed based on defined criteria for productive time analysis and area/volume allocation in order to calculate various production metrics, including tethering and anchoring time, productivity, and utilization. This work will describe the overall approach, criteria and algorithms used for the analysis, and report the preliminary findings of the field validation carried out on winch-assisted feller-directors, feller-bunchers, and loader-forwarders. The results will also provide evidence of the capabilities and limitations of fully-automatic production monitoring of winch-assist harvesting operations based on the integration of remotely collected machine data and forest inventories.

Keywords: harvesting, forest operations, winch-assist, tethering, productivity, utilization, steep slope

OPTIMIZING LANDING LOCATIONS USING LIDAR-DERIVED SINGLE TREE INVENTORY AND SITE FACTORS USING THE ANALYTIC HIERARCHY PROCESS

EBRU BILICI[1]; ROBERT F. KEEF[1]; MEHMET EKER[2]*

[1]University of Idaho; [2]Isparta University of Applied Sciences.

Corresponding author: ebilici@uidaho.edu

ABSTRACT

Log landing locations can have significant environmental impacts, such as increased soil erosion, compaction, and changes in water quality. Choice of location also affects skid distance, and may alter the net productivity of skidding, processing and loading logs in mixed conifer forests. For these reasons, careful planning of the landing site is critical. Multi-criteria decision-making method (MCDM) should be used to evaluate the many criteria that influence preferred landing sites such as terrain, direction of skidding, product species and volume, and forest road location. We evaluated use of the analytic hierarchy process (AHP) to aid in MCDM. The study used detailed tree features and topographic information obtained with single tree inventory (STI) lidar data from the University of Idaho Experimental Forest. The coefficients were carried out using literature-based weighting. The evaluation included slope, road, volume, species, and soil properties, with the volume being determined using a weight factor coefficient of 0.584. Using the coefficients, maps were created to identify the most suitable areas for harvesting based on species, volume, slope, and other factors. It is believed that the importance of inventory data has increased because the volume of trees is the dominant factor in the decision support system. The results have shown that future studies will include creating optimization models that use detailed tree characteristics from the STI data to identify the most suitable areas for landings.

Keywords: Landing Location, Single Tree Inventory, Lidar data

FELLER-BUNCHER PRODUCTION: VALIDATION OF AN INTEGRATED SOLUTION BASED ON FPDAT ON-BOARD COMPUTER SYSTEMS AND FOREST INVENTORIES

STEFFEN LAHRSEN[1]; OMAR MOLOGNI[1]; DOMINIK RÖSER[1]*

[1]University of British Columbia

Corresponding author: steffen.lahrsen@ubc.ca

ABSTRACT

The productivity and utilization of forest harvesting machines, such as feller-bunchers, can be compared in varying conditions through time studies and volume allocation. However, obtaining detailed information through field observations is costly and time-consuming. On-board computer systems, like the FPDatII, automate data collection for whole-tree harvesting machines but are typically limited to time observations and lack direct volume input. Therefore, automatic productivity estimations of feller-bunchers are typically limited to block-level analyses based on the total harvested volume. However, to stay competitive and optimize resource allocation, logging companies need a reliable and cost-effective solution to retain productivity information of their operations on a daily basis. This study introduces a novel approach to automate productivity data collection for whole-tree harvesting machines. The approach combines the engine status and machine travel information collected with FPDatII units with inventory data, including volume distribution, and site and stand information, to determine productivity. A digital platform was created in collaboration with industry partners to continuously collect this productivity data in the form of daily worklogs for numerous machines, allowing for operational analysis. To validate the productivity information provided by this platform, we compared detailed time studies based on video analysis and determination of daily area covered through orthomosaic photo interpretation with the worklogs created by the platform. We also compared the results of a conventional production study based on piece counting with the daily productivity calculations by the automated approach. The comparison will be presented and discussed. This new automated production data collection approach enables the analysis of the key site and stand factors influencing productivity on felling operations based on long-term data collection. It provides valuable information to the industry to benchmark operations in varying conditions, ultimately enhancing supply chain visibility.

Keywords: Automated Productivity Calculation, Time Study, Productivity Study, Feller-Buncher, Whole-Tree Harvesting

HYBRID-ELECTRIC SELF-PROPELLED CARRIAGE - FIRST FIELD TESTS OF THE SECOND PROTOTYPE

STEFAN LEITNER[1]; RENATO VIDONI[1]; MASSIMILIANO RENZI[1]; RAFFAELE SPINELLI[2]*

[1]Free University of Bolzano; [2]Consiglio Nazionale delle Richerche-Istituto per la BioEconomia, CNR IBE.

Corresponding author: stefan.leitner@student.unibz.it

ABSTRACT

Cable logging can benefit from electrification in many ways, and more than other forest technologies. A significant percentage of cable logging setups transport timber downhill, providing an excellent opportunity for energy recovery. It is widely known that electrification is ideally suited to handle this task. However, due to the highly dynamic duty cycles, harsh working conditions, and tight weight constraints of forestry equipment, technical implementation is difficult. Equipment manufacturers started to electrify cable logging equipment with the introduction of electric slack-pulling carriages almost a decade ago. More recently, the first models of a hybrid tower yarder and an electric dropline carriage have been introduced. This presentation reports about the first test results of the second prototype of a hybrid-electric self-propelled carriage, developed by the Italian start-up Leitalpin Ltd., with the scientific support of the Free University of Bolzano and CNR IBE. The machine is powerful and green: hence it is named HULK. Its patented concepts enable it to efficiently transport uphill, downhill, and on flat terrain. HULK's traction drive and dropline winch are powered via independent electric motors, powered by an on-board energy storage system. When moving downhill and when lowering the load, energy is recovered. On sufficiently long and steep lines, energy neutral operation is possible. In all other cases, an on-board combustion engine supplies additional energy to the carriage. First field tests of HULK were conducted on a single-span line in the Northern Italian Alps. It was verified that the transport of timber downhill could be performed energy neutrally. After extensive field trials throughout 2023, this new product is expected to achieve its market launch in early 2024.

Keywords: self-propelled carriage, hybrid, electric, energy recovery,

SKYLINE FORCE ESTIMATION AND LIMITATION DURING CABLE YARDING: A NOVEL TECHNICAL SOLUTION BUILT INTO THE CARRIAGE

STEFAN LEITNER[1]; RAFFAELE SPINELLI[2]; MASSIMILIANO RENZI[1]; RENATO VIDONI[1]*

[1]Free University of Bolzano; [2]Consiglio Nazionale delle Richerche-Istituto per la BioEconomia, CNR IBE.

Corresponding author: stefan.leitner@student.unibz.it

ABSTRACT

In the European Alps, cable yarding combined with motor-manual felling is still the dominant approach to timber extraction. Being competitive demands quick cableway setup and dismantling, as well as high productivity and low operating cost during extraction. Unfortunately, the pressure to perform may come at the expense of safety. Forest operations are one of the most dangerous jobs in all fields of industrial production. Several studies concluded that the degree of mechanization and automation is key to reduce risks, with most accidents (63.2 %) being caused by broken spar and anchor trees, bouncing cables, and falling objects. In 55 % of the work cycles, safe skyline force limits are exceeded, with the highest peaks often being caused during break-out (lateral skidding). Dynamic factors during inhaul may also lead to excessive skyline loading. Unfortunately, many operators underestimate the effects of pretension, payload size, and cable line geometry on skyline loads. At the same time, the reliability of theoretical models is limited, and the load limiters installed on the machines may become inefficient. For all those reasons, technical solutions for continuous skyline tensile force monitoring should be developed. This work presents novel concepts to achieve precisely that. The proposed concepts enable the real-time determination of the skyline tensile force within the carriage itself. Based on such data, dropline and self-propelled carriages can be programmed to limit dropline pull automatically and dynamically in order to keep skyline loads within safe limits, especially during break-out. Self-propelled carriages can also be programmed to automatically limit driving speed to control dynamic effects, or to come to a complete stop, if skyline load limits are exceeded during inhaul. For example, that could occur when approaching the middle of a large span. Skyline loads measurements performed by the carriage can also be forwarded to the tower or sled winch to achieve the same level of automated safety. Finally, the continuous skyline load profile could also be logged and used for scheduling preventative maintenance.

Keywords: skyline loading, load break-out, dropline pull, preventive maintenance

CHALLENGES AND OPPORTUNITIES FOR USE OF DIGITAL TECHNOLOGIES FOR FOREST OPERATIONS IN PORTUGAL

ALEXANDRA MARQUES[1]; JOSÉ LUIS CARVALHO[2]; BEATRIZ LOURENÇO[3]; FRANCISCO MANSO[4]; CAROLINA CATORZE[5]; PEDRO BRITTO[1]*

[1]ForestWISE - Collaborative Laboratory for Integrated Forest & Fire Management; [2]The Navigator Company; [3]Altri Florestal; [4]Trigger Systems; [5]INESC TEC.

Corresponding author: alexandra.marques@forestwise.pt

ABSTRACT

The use of sensors to automatically collect data, in team time, about forest operations unveils numerous opportunities for enhanced planning and decision-making. Sensors can be embedded in harvesting machinery, combined with smartphone apps., combined with track-and-trace devices used in wood trucks and cameras and other devices inside the mill that provide valuable inputs for managing stocks and production. Although recent research brought significant progresses in terms of data standards and interoperability, the way to integrate them into single fully-fledged operational solutions still imposes challenges, both technological and business-related. In Portugal, the harvesting fleet is very diverse in terms of manufacturers and manufacturing age, therefore, technologies should be developed in the logic of "one-size-fits-all", with concerns of compatibility. On the other hand, the Portuguese wood-based wood supply chains involve multiple agents, from producers, to third-party contractors and industry players, each should find value in using the data that will be provided by the sensors, as well as agree upon the conditions for sharing that data with the other players. This research focused on ways to overcome these challenges that have been limiting the adoption of digital technologies by the Portuguese players. Case studies, field tests and demonstrators were set in place to assess the advantages of different technologies when compared with current processes. Novel players were introduced in the forest arena, such as electronics companies with interests in developing new business related with complementary devices to be installed in the forest machinery assuring compatibility. New business models are being set in place to foster the commercialization in Portugal of the best performing technologies selected in benchmark processes with the involvement of stakeholders. Progress is already perceived by the agents of the supply chain and some successful lessons-learned can be shared. Additional research and innovation is needed to its generalized adoption in Portugal. Gaining scale and moving from a research prototype into an operational system, addressing fire and other risks as well as sustainability criteria beyond cost efficiency, changing procedures to make use of the best performing technologies, governance of the shared data, assuring trust and setting in place adequate calibration and verification schema, more favorable public policies, are examples of opportunities and action items to a roadmap for digitizing forest operations.

Keywords: forest harvesting, digital technologies, forest 4.0, planning, governance

THE VIRTUAL WOOD SUPPLY ARENA – PERFORMANCE BENCHMARKING AFTER ONE YEAR OF ON-LINE TESTING

DAG FJELD[1]; PHILIPPE MARIER[2]; BJÖRN EDLUND[1]; LARS ELIASSON[3]; MIKAEL FRISK[4]; MIKAEL RÖNNQVIST[2]*

[1]Swedish university of agricultural sciences; [2]FORAC, Université Laval; [3]Skogforsk; [4]Creative Optimization Sweden, AB.

Corresponding author: Dag.Fjeld@slu.se

ABSTRACT

The Virtual Wood Supply Arena (VWSA) is an on-line training tool for managing roundwood purchase, production and transport in CTL supply systems. The training environment simulates 8 to 12-week periods with monthly mill delivery goals while handling weekly weather and site trafficability for harvesting and hauling. The VWSA is designed to come as close to reality as possible in an on-line environment with weekly variation in weather and trafficability. It includes three roles per company (purchase-, production- and transport managers) managing 10 harvesting teams and 10 trucks over 4 supply regions and 2 climate zones (highlands, lowlands). Deliveries of 5 assortments are managed to 5 mills (2 pulp mills and 3 saw mills). Each training scenario may be selected from 4 annual weather cycles (52 weeks). The annual cycles include 1) 10-year average, 2) cold winter, 3) dry summer and 4) warm-wet summer. The first version of the game was presented at FORMEC2022. Since 2022 the VWSA has been run with student groups in Canada, Norway, Sweden and Finland. Team KPIs include monthly delivery precision per mill assortment, capacity utilization, as well as relocation- and hauling distances. Stock levels are tracked for both purchased stands awaiting harvesting as well as harvested volumes at roadside. Monthly transport distances are benchmarked in comparison to an optimal monthly solution based on weekly availability. The system also tracks harvesting which was done with insufficient bearing capacity. This poster provides an overview of the team performance so far, for a variety of scenarios. The development of the VWSA was financed by the Ljungbergs Foundation of Sweden. The development team includes SLU, FORAC/Université Laval, Skogforsk and Creative Optimization Sweden.

Keywords: wood supply chain, manager training, coordinating operations, trafficability

AI IMAGE RECOGNITION – IS A POINT GOOD ENOUGH FOR TREE PLANTING OR NOT?

TOMAS NORDFJELL[1]; ALICE KÅREHAGEN[1]*

[1]Swedish university of agricultural sciences, department of forest biomaterials and technology

Corresponding author: tomas.nordfjell@slu.se

ABSTRACT

Declining labor force for manual planting in Sweden has contributed to an increased interest in the development of mechanized planting. Afforestation on rocky moraine soil with stumps and other obstacles is more difficult to mechanize than on sediment soils. A highly productive planting machine prepares the soil and plants during continuous movement. There are prototype machines for such planting, but one problem is that seedlings might be planted at inappropriate points with stone, logging residues and stumps. Admittedly, there are mechanical sensors that sense if the resistance in the ground is too high (a stone), but the frequency of incorrect planting points is still too high. To remedy this, there is an AI system under development based on image analysis and multiclass classification. At points where a plant is supposed to be set, digital camera images are taken. For each image, the AI system calculates with how high probability the image is showing the three parameters: Mineral soil; Humus; and Others (a point not possible to plant). It can then, for example, be that a picture is classified with 70% probability to be Mineral soil, to 20% probability to be Humus and to the remaining 10% probability to be Others. The AI system is previously trained on about 5000 manually classified images and can manage to analyze 8 pictures per second. The intention is to use image analysis and AI to avoid planting in inappropriate planting points. The purpose of the study was to determine how well the AI assessment matches a trained planter's assessment of whether a point is not suitable to be planted on. The study was conducted on 4 newly soil-prepared areas. At 420 randomly selected points, photographs were taken. At some of the points, photographs were taken both in shadow and in sunshine. On all points, a manual assessment was made as a reference of whether the point was good enough to be planted or not. The results showed that under overcast weather conditions, the tool has the ability to assess in 83.8% of cases in accordance with field assessment. Direct sunlight was shown to have a significant impact and compliance with field assessment dropped with 5-7%. However, the best possible compliance requires that appropriate thresholds of probability of Mineral soil and Others are selected. These thresholds varied between different areas but were most common in the range of at least 40-50% probability for Mineral soil and no more than 10% probability for Others. If the AI system is combined with mechanical sensors to detect if the resistance in the ground is too high, it is estimated that compliance with field assessment in overcast weather conditions increases from 83.8% to within the range of 88 to 90%. The conclusion of the study is that it is possible to use image recognition tools to avoid the majority of bad planting points. The conclusion is also that the studied tool is a step on the way but that continued development work is required to work better in sunshine.

Keywords: Artificial intelligence, reforestation, mechanical soil preparation, automation

CAN STATE-OF-THE-ART POSITIONING TECHNOLOGIES VALIDATE DEFLECTIONS IN CABLE YARDING?

LUCA MARCHI[1]; FRANCESCO ZANOTTO[1]; STEFANO GRIGOLATO[1]*

[1]University of Padova

Corresponding author: luca.marchi@unipd.it

ABSTRACT

In recent years, there is a growing interest of the scientific community in the assessment of the actual behaviour of steel ropes used in steep slope harvesting. In particular, with reference to cable yarding a great effort was given to assess the actual tensile forces excerpted on the main ropes on a variety of yarding systems (e.g., standing skyline systems in Europe, live skyline in North America, etc.). This allowed the research community to obtain direct assessment of several important parameters such as tension increments due to the yarded payloads, dynamic fluctuations, etc. An immediate consequence of these studies was to evaluate the actual level of the various design methods in terms of precision and consequently safety level with respect to their potential mechanical failure. In parallel to tension studies, a minority of works tried also to evaluate the behaviour of the ropes in terms of deflections, distance from the ground level. The aim was again to reconstruct the cable profile and assess whether the design methods were able to determine correctly the amount of sag applied to the cable for a given payload loaded on the carriage. In this context, the present work focused on the analysis of the cable deflection by using the most recent GNSS systems that adopt Real Time Kinematic (RTK) corrections. This technology has found great success in various surveying applications, e.g., aero photogrammetry. Thanks to the rapid progress in the technology employed from the sensors manufacturers, quality and details of the measurements has been greatly improved. In the present work, the aforementioned technology was successfully applied to a variety of carriages in standing skyline system configuration. Results shows that with sufficient network coverage, centimetric precision of the position of the carriage can be achieved. With absence of signal, post-processing data correction can also be pursued, with a reduced precision in terms of frequency of observations but still with a great amount of detail. Preliminary comparisons with recent design methods and tools are also reported.

Keywords: cable yarding; GNSS RTK, deflection, skyline, steel ropes

3D VISUALIZATION FOR CONSULTATION

SABRINA ST-ONGE[1]*; DOMINIK ROESER[1]; SHANNON HAGERMAN[1]

[1]University of British Columbia

Corresponding author: sabrina.stonge@ubc.ca

ABSTRACT

In the province of British Columbia, 95% of the forests are on crown land and forestry activities operate under the Sustainable Forest Management (SFM) principle. That makes most of the forest resources available to the market only if certain rules are respected. SFM must include practices to meet social expectations, respect the environment integrity and be economically viable. With increasing pressure on the forest sector to achieve higher standards of sustainable harvest of the forest, it is crucial for forest practitioners to engage in meaningful ways with relevant First Nations and local communities to provide the opportunity to build a socially acceptable managed forest and therefore access timber. This research project will examine and characterize the views of forest practitioners and First Nations representatives in British Columbia regarding the consultation process for forestry. Moreover, this research aims to characterize the strengths and weaknesses of introducing a 3D visualization tool in forest management and planning activities. The introduction of such a tool is an attempt to increase social acceptance of forest management and operations in the forests of British Columbia, by providing resources to all stakeholders and a visual component of the plans. This research project is framed within social sciences and used qualitative data analysis to gather rich and detail comments about participants' experiences in the current consultation system, within the framework of SFM. Individual semi-guided interviews were performed, recorded, transcribed, and then analyzed and summarized through the NVivo software. The first step was to understand the perceptions of participants regarding the consultation process. Additionally, understand on a deeper level the complexity of how consultation processes are conducted. There were four categories of information I wanted to cover in the interviews; (1) professional background, (2) approach to consultation, (3) result of the process and (4) potential impact of 3D visualization tool. The approach used to assess the second part of this research was a case study observing a consultation process conducted with the 3D visualization tool, followed by interviews with participants. Industries must provide forestry plans to communities for a reasonable amount of time, 30-60 days, to gather comments before submitting it for approval to the district manager. The tool used for the current processes are more commonly 2D maps and written reports to support the maps. Since the start of my research, few platforms have arisen to track communications and shared data for consultation, but none with a 3D visual of the forests. However, companies and First Nations have started to acquire those platforms. From preliminary results, it seems like even if 60 days is the legal requirement, companies prefer to establish relationships with relevant communities than go ahead without community's approval, on certain matters and depending on the region. Since qualitative data is more often suggestive and specific to the participant's reality it is can never really

produce a generalization for a group. The results of this research will be composed of stories, experiences, ideas and comments about the use of 3D visualization tool for forestry consultations purposes.

Keywords: Consultation, 3D Visualization, Sustainable Forest Management, Planning, Public perception

MINIMUM OPTIMUM RECORDING FREQUENCY IN TENSILE FORCE MONITORING OF WINCH-ASSIST HARVESTING OPERATIONS

MARIO STOLZ[1]; OMAR MOLOGNI[1]; DOMINIK ROESER[1]*

[1]The University of British Columbia

Corresponding author: mstolz@student.ubc.ca

ABSTRACT

Accessing wood fiber on steep terrain is a common challenge faced by the global forest industry. While ground-based harvesting operations using winch assist can improve performance, the use of heavy equipment supported by cables can result in high tensile forces with every movement, posing a safety risk. Although cable tensile force monitoring is used for safety, there is no standard for recording frequencies of these forces. Higher recording frequencies offer better resolution, but they require significant effort and may not be practical. This study aims to determine the minimum optimal recording frequency of tensile force for anchor machine configurations (i.e., dynamic systems) during harvesting operations on steep terrain. Two case studies in the Pacific Northwest were conducted, where tracked harvesting machines with directional felling heads were monitored for four consecutive days on ground slopes up to 103%. Tensile force was recorded at 100Hz on both the machines and the anchors. To find the minimum optimal recording frequency, the datasets were reduced from 100Hz to lower frequencies (50Hz, 25Hz, 10Hz, 5Hz, 2Hz), down to 1Hz, and the reduced data was interpolated to represent lower recording resolutions. A peak analysis was conducted on all subsets to compare the magnitude and occurrence of peaks at different recording frequencies, with particular attention given to peaks that exceeded safe working limits to see if they were missed at lower resolution. Loss of information was measured as the difference between the original 100Hz peaks and the down-sampled data. Work elements in the work cycle (e.g. felling, moving, boom movement etc.) of the machines were identified to determine where the largest discrepancies occurred. The study's results will show how much information is lost with decreasing recording frequencies and the difference in recorded tensile force between high and low frequencies. This information will help develop an optimal recording frequency for cable tensile forces during harvesting operations on steep terrain, balancing safety requirements and computational needs. The presentation will provide details on data acquisition and the statistical methods used, as well as a discussion of the most significant differences between recording frequencies.

Keywords: Forest operations, winch assist, Safety, tension, Steep slope, Harvest, Tethering

INTRODUCING TECHNODIVERSITY AS A SUBJECT OFFERED TO INTERNATIONAL STUDENTS OF FORESTRY

PIOTR MEDERSKI[1]; RAFFAELE SPINELLI[2]; STELIAN BORZ[3]; KARL STAMPFER[4]; OLA LINDROOS[5]; ANDREJA ĐUKA[6]; NATHALIE MIONETTO[7]; JÖRN ERLER[8]*

[1]Poznań University of Life Sciences; [2]National Research Council; [3]Transilvania University of Brașov; [4]University of Natural Resources and Life Sciences; [5]Swedish University of Agricultural Sciences; [6]University of Zagreb; [7]Technological Institute FCBA; [8]Dresden University of Technology.

Corresponding author: piotr.mederski@up.poznan.pl

ABSTRACT

Technodiversity (TDiv): Harmonising European education in forest engineering by implementing an e-learning platform to support adaptation and evaluation of forest operations is a new educational portal being developed for forestry students interested in forest operations. It is being completed within the Erasmus+ programme, Action Type KA220-HED – Cooperation partnerships in higher education. The aim is to make TDiv available for all Erasmus+ students who would like to broaden their knowledge in forest operations at Master's level. TDiv focuses on differences in the harvesting systems used in Europe as well as on criteria that can help to assess forest operations, taking into acccount ecological, economic and social aspects. The project was launched in November 2021 and is currently being completed by scientists from six universities and two research institutes: 1) Dresden University of Technology, Germany (leader), prof. Jörn Erler, PhD 2) Poznań University of Life Sciences, Poland, prof. Piotr S. Mederski, PhD 3) National Research Council, Italy, Raffaele Spinelli, PhD 4) Transilvania University of Brașov, Romania, prof. Stelian A. Borz, PhD 5) University of Natural Resources and Life Sciences, Austria, prof. Karl Stampfer, PhD 6) Swedish University of Agricultural Sciences, Sweden, prof. Ola Lindroos, PhD 7) University of Zagreb, Croatia, assist. prof. Andreja Đuka, PhD 8) Technological Institute FCBA, France, Nathalie Mionetto, PhD. While the content of the platform has been developed successfully, it is important that this course also has international recognition and can be completed as a part of students' curriculum. Therefore, Poznań University of Life Sciences (PULS) is in charge of making this course available for students from different countries. The objective of this presentation at Formec 2023 is to explain the university's task and how the TDiv course is being prepared for accreditation with ECTS points. A new procedure has been started at PULS to introduce TDiv as part of the curriculum in the Faculty of Forestry and Wood Technology. Once the subject is accreditated by the university's Council for Curriculum, it will be available for local students in Poland as well as for all students from abroad participating in the Erasmus+ programme.

Keywords: on-line platform, life-long learning, remote teaching, Moodle, PULS

LEVERAGING IMMERSIVE TECHNOLOGY FOR ENHANCED LEARNING IN THE FORESTRY SECTOR: A STUDY ON VIRTUAL AND AUGMENTED REALITY APPLICATIONS

*ALESSA ANGERSCHMID[1]**

[1]University of Natural Resources and Life Sciences, Vienna

Corresponding author: alessa.angerschmid@boku.ac.at

ABSTRACT

Immersive applications are widely used in the educational sector. Various test environments can be represented with Virtual Reality (VR), to provide a hands-on learning experience. Augmented Reality (AR) on the other hand enhances the user by overlaying virtual objects or providing detailed information in real-time. Both techniques enable a user to experiment with predefined conditions, without posing a risk to themselves. This is insofar beneficial, since humans have the ability to transfer learning from one situation to another, thus allowing them to apply their acquired knowledge from the simulation in the real world. When incorporating haptic controls, better learning outcomes can be achieved. This is due to the combination of visual and physical interaction, that creates stronger connections in the human brain. Hence, both technologies contribute to the user's learning process. This effect can be utilised for training in areas that might be harmful or hazardous. Training experiences with VR and AR can contribute to an increase in work safety and promote the digitalisation of forest engineering. Thus, both technologies, as well as, state-of-the-art approaches for training in forestry are discussed. This work provides an overview of teaching approaches with Virtual and Augmented Reality to promote a more sustainable way of education and training in the forestry sector. Thus increasing work safety and work efficiency, as a higher learning curve for trainees is achieved. This contributes to the ongoing endeavours of research to digitalize forestry and especially timber harvesting.

Keywords: Virtual Reality, Augmented Reality, Learning Environments, Forestry

FOREST OPERATIONS: A TOOL FOR FOREST MANAGEMENT

*HAN-SUP HAN[1]**

[1]Northern Arizona University

Corresponding author: Han-Sup.Han@nau.edu

ABSTRACT

Forest operations involves in the application of a variety of forest management tools and processes to achieve the objectives of sustainable forest management. This presentation illustrates how forest harvesting systems and practices can be used to accomplish a wide range of forest management objectives. Traditionally, wood production has been the main objective of timber extraction practices to supply raw materials (i.e., logs and wood chips) to the forest products manufacturing companies. While this still holds as an important goal of timber harvesting today, equipment and systems used in forest operations are now often employed to address other forest management issues such as stand condition improvement and fuel treatments to reduce wildfire risks. The use of harvesting systems as a tool to a wide range of forest management objectives is now increasingly common, as we often deal with man-made or second-growth stands. Forest operations need to be viewed as an integrated component of forest management and not an isolated field of study. Collaboration with other disciplines is increasingly important in order to address the challenging multiple objectives of today's forest management. Challenges and opportunities associated with utilization of small-diameter trees and biomass will be also discussed.

Keywords: timber harvesting, logging, forest roads, harvesting systems

SUBJECTIVE ASSESSMENT OF WORK ABILITY VERSUS EFFICIENCY OF LOGGING TECHNOLOGY

KRZYSZTOF LESZCZYNSKI[1]*

[1]University of Agriculture in Krakow

Corresponding author: krzysztof.leszczynski@urk.edu.pl

ABSTRACT

The forestry labour market is constantly fluctuating. After an economic boom, a slowdown or even a decline in forestry and logging employment can be observed. The need to increase work efficiency is certainly reflected in the pressures on employees. Workplace health investigations with Work Ability Index (WAI) questionnaire that take into account job requirements, employee health status and resources make it possible to diagnose target groups and prepare measures to increase motivation and commitment at work. They focus on the observed gradual decline in work ability. In the study prepared, an attempt was made to assess the workability of logging workers in the private sector. Excellent work readiness was found only among harvester operators aged 20 - 30 years. Different dynamics of WAI decline as a function of age were also observed. In general, for the study group, the WAI fluctuated at a moderate level depending on the technical equipment, age of the employees, BMI, silviculture treatment or machine productivity. The worst situation was observed during silvicultural treatments of deciduous (beech) stands using the cut-to-length (shortwood harvesting) method. Ageing, being overweight, deteriorating health and the mainly physical nature of work are risk factors for low (mediocre) work capacity. As shown in the literature, it can be modelled by increasing employee engagement through an appropriate incentive system or so-called compensation measures.

Keywords: work ability, stress, logging, ergonomics, health and safety

SUSPENSION RISK ANALYSIS TO PROMOTE USE OF CABLECRANE FOR QUALITY OAK

DIDIER PISCHEDDA[1]*

[1]Office National des Forêts

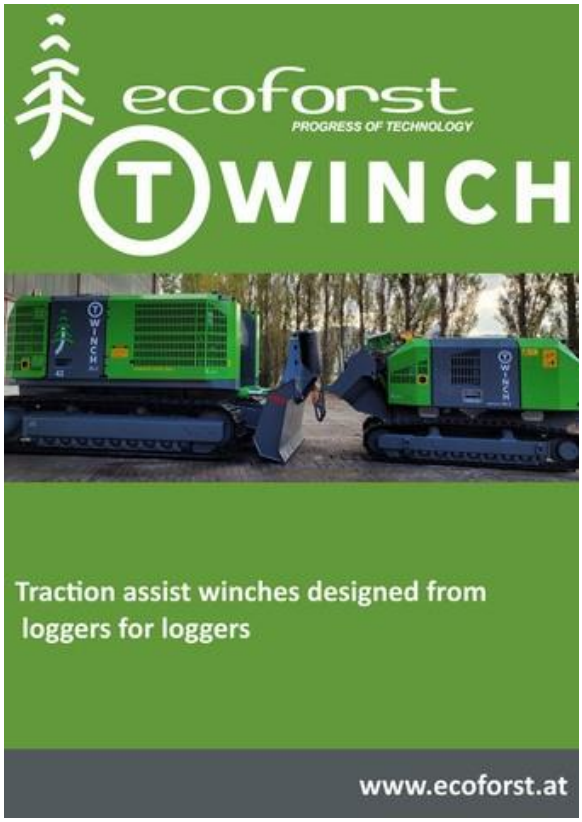
Corresponding author: didier.pischedda@onf.fr

ABSTRACT

Mobilisation of quality oak is a typical winter activity. Due to climate change, precipitations are increasing and oblige foresters to stop skidders to protect soils. Consequently, timber do not arrive to public oaksales in time.This leads to loss of tunover for the owner. Estimation of oak resources associated to these suspension risks was made to evaluate the use of cablecrane.

Keywords: Cablecrane, flat terrain, quality oak, suspension risk, climate change,

THANK YOU TO THE FOLLOWING SPONSORS AND SUPPORTERS WHO HAVE GENEROUSLY CONTRIBUTED TO THIS EVENT



THANK YOU TO THE FOLLOWING SPONSORS AND SUPPORTERS WHO HAVE GENEROUSLY CONTRIBUTED TO THIS EVENT

THANK YOU TO THE FOLLOWING SPONSORS AND SUPPORTERS WHO HAVE GENEROUSLY CONTRIBUTED TO THIS EVENT

THANK YOU TO THE FOLLOWING SPONSORS AND SUPPORTERS WHO HAVE GENEROUSLY CONTRIBUTED TO THIS EVENT

Thanks to all partners and participants,
for taking part in the event and for
all the valuable contributions
and collaboration in organizing it!

CONTACT INFORMATION

If you need additional information, please, do not hesitate to contact us by email at
firenze2023@formec.org
Thank you!