FIRE-RES

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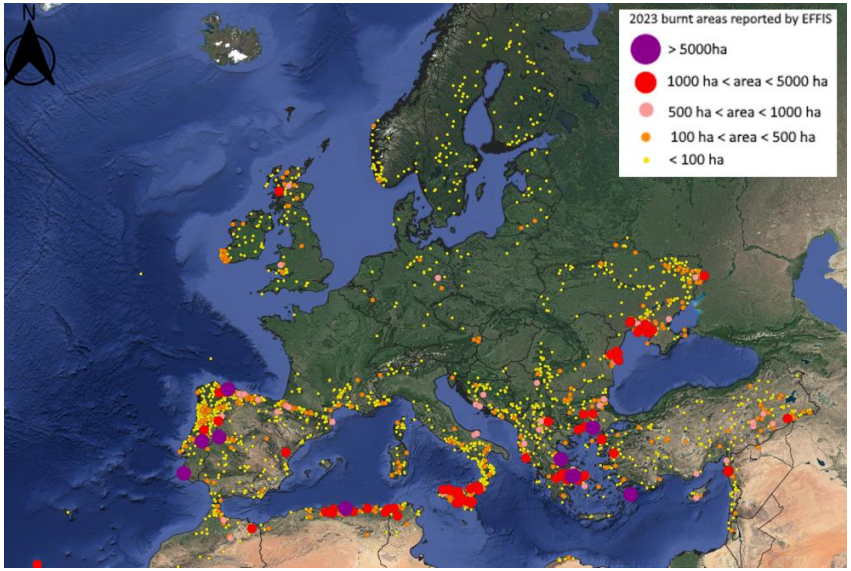
Small and light machinery to prevent wildfire risk in Mediterranean forests

Martino Rogai, Gerard Alcoverro, Gianni Picchi

Funded by the European Union

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Wildfires in Mediterranean areas



Wildfires until the end of 2023 August. Source: EFFIS

Factors influencing the occurrence of fires:

- A combination of drought, low humidity, and record-breaking temperatures;
- Lack of land management leading to biomass accumulation.

Fire prevention systems:

- Early warning;
- Infrastructures (fuelbreaks, firebreaks, roads);
- Fuel removal (controlled grazing, prescribed burning, **preventive silviculture**).



Small and light Machinery

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Malwa 560C Combi	Specification
Weight	4900-5400 kg (depending on configuration)
Lenght	6.3 m
Width	1.94 m (wheels 500 mm)
Height	2.85 m
Ground dearance	400 mm
Load Area (gross load)	5500 kg
Engine type	Caterpillar 3.4B, Tier 4 Final EU Stage IIIB 55 kW
Crane type	Cranab FC45 with reach of 6.1 m
Harvester head type	Log Max 928A, light head designed for thinning (from 20 mm to 420 mm diameter)





Study Area



- 333,622 ha of Aleppo Pine (*Pinus halepensis* Mill.) in Catalonia (Spain),
- Viladecavalls, Catalonia fall months of 2023;
- Three Aleppo pine stands, naturally regenerated after a wildfire, with the presence of holm oak.
- Strong presence of climbing plants such as Smilax aspera L.

Plot	1		2		3
Species	*Pinus halepensis*	*Quercus Ilex*	*Pinus halepensis*	*Quercus Ilex*	*Pinus halepensis*
Density (p/ha)	1700	340	4980	283	9620
DBH (cm)	16.9	4.5	10.2	4.4	5.9
Basimetric Area (m^2/ha)	42.7	0.6	47.0	0.5	30.7
Mean height (m)	14.6	2.0	8.5	2.9	5.0



Harvesting Time elements

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- Felling
- Processing
- Movements between plots
- Movements within plot
- Processing felled trees
- Cleaning





Forwarding Time elements

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- Loading
- Unloading
- Movements between logs
- Travel empty
- Travel loaded

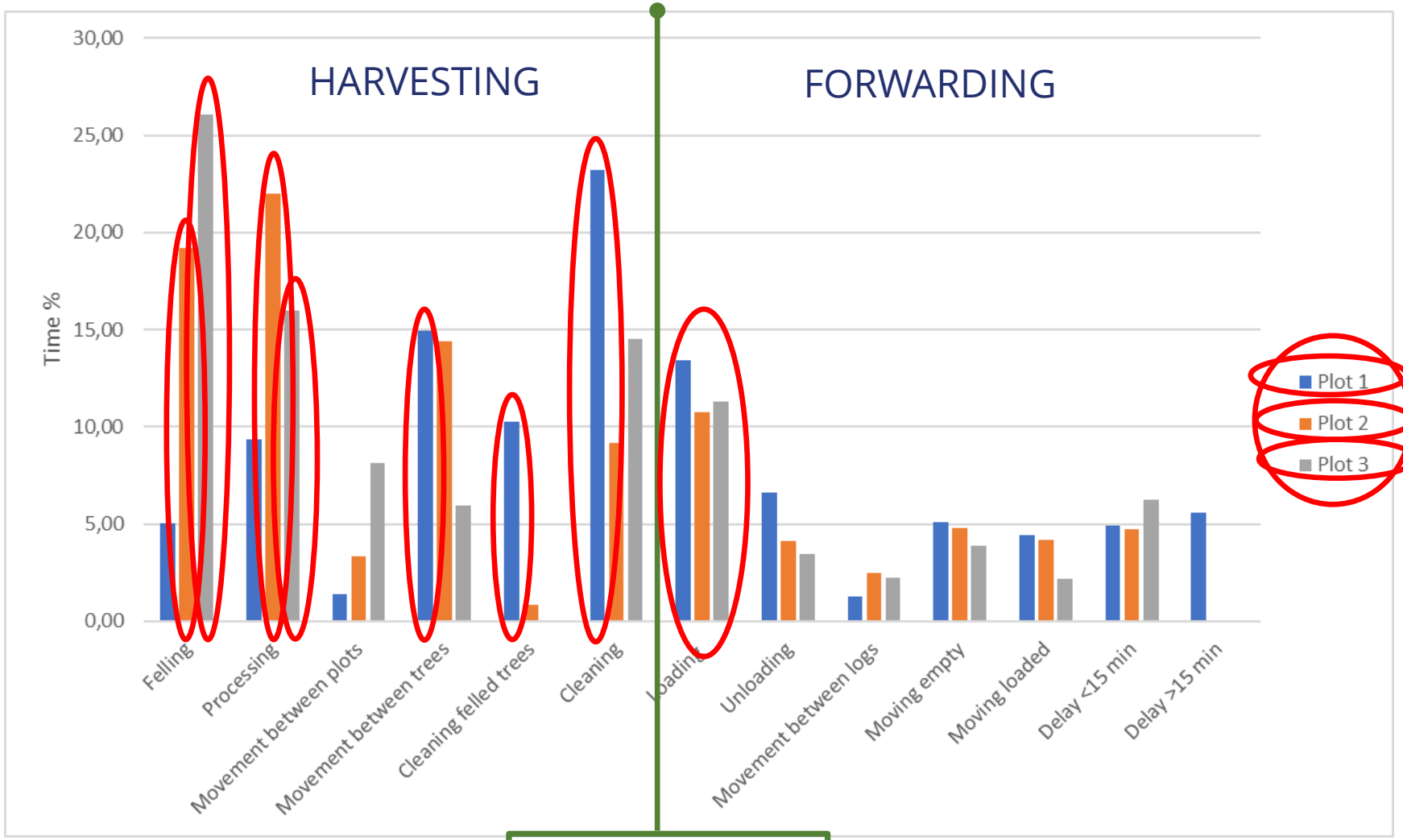
BOTH

- Delay <15 min
- Delay >15 min



Time elements analysis

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Conversion time
1.2%

Productivity of thinning operation

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Plot	1	2	3
Productive Machine Hours (PMH_{15})	5:09:52	10:21:06	9:36:52
Total Volume (m^3)	10.36	17.01	4.69
Productivity harvesting (m^3/PMH_{15})	2.93	2.24	0.64
Productivity forwarding (m^3/PMH_{15})	6.43	6.17	2.09
Total productivity (ha/PMH_{15})	0.041	0.027	0.018

Low productivity but the silvicultural objective is risk reduction:

- Elimination of ladder fuel
- Modification of fuel structure
- Minimize post-intervention regrowth of understory (Herbaceous and shrubs)
- Reduce damage to the soil and the overstory

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Cost analysis and comparison with the traditional method

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MECHANIZED WORK			
Plot	1	2	3
Costs per Productive Machine Hour (€/PMH_{15})		89,60	
Unitary cost (€/m^3)	44.67	54,52	183,58
Costs per Area (€/ha)	-2,257.24	-3,336.36	-4,950.89
Value at the road site (€/m^3)		30.00	
Value at the road site (€/ha)	1,516.10	1,835.72	809.05
Economic Balance (€/m^3)	-14.67	-24.52	-153.58
Economic Balance (€/ha)	-741.14	-1,500.65	-4,141.83
MANUAL WORK			
Plot	1	2	3
Cost per Area (€/ha)	> -4,000	-3,000	-4,408.78
Subsidy (€/ha)	**2,000**	**2,000**	**3,000**





Mechanized work in Plots 1 and 2 has an economic balance lower than the subsidies granted by the local public authorities.

Silvicultural results of the operations

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Plot	1	2	3
Species	*Pinus halepensis*	*Pinus halepensis*	*Pinus halepensis*
Trees removed	174	506	630
Resulting density (trees/ha)	849	3112	6055
Variation in density (%)	-50	-38	-37
DBH (cm)	21.8	11	6.53
Variation in DBH (%)	+29	+7.8	+11
Basimetric Area (m^2/ha)	32.54	35.57	23.63
Variation in Basimetric Area (%)	-24	-24	-23
Mean height (m)	8.73	5.96	4.52
Variation in mean height (%)	+22	-3	+5

- Manual system leaves all coarse biomass on the ground with the exception of larger logs while slash is manually accumulated and mulched on-site.
- Mechanized system is designed in order to accumulate all slash in front of the harvester. In such a way the residues are accumulated in specific areas and partially compressed and integrated in the ground, minimizing its role in the overall wildfire risk of the stand.
- Where necessary, a mulcher could be easily driven along the harvesting corridors.
- The narrow corridors and the layer of slash integrated in the ground constitute unfavorable conditions for the growth of understory, reducing the risk of a quick post-treatment accumulation of high-combustible biomass.

Conclusions

- A single machine does all the work and allows working on small fragmented plots, which is the typical condition of the Mediterranean situation (reducing transportation costs);
- Mechanical treatments have the potential to recover product value, so treatment costs are partially offset;
- In plots 1 and 2, the mechanized system has an overall cost of 33% and 75% of the subsidy, respectively. Allowing for treating larger areas with the same public funding;
- Thinning allows to improve the value of the stand while controlling fuel ladders and canopy density effectively reducing the wildfire risk.

- Ground slope and roughness is a relevant factor that can limit the use of most forest machinery. The Malwa Combi cannot negotiate terrain slope exceeding 25%;
- For plots with higher density (Plot 3) accumulating shear heads and whole trees removal may be a suitable solution.

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FORMEC
Gdańsk, Poland 2024

The 56th International Symposium on Forest Mechanization (FORMEC)



Timber harvesting: the reality of offsetting the needs of industry against those of the environment

BOOK OF ABSTRACTS

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Timber harvesting: the reality of offsetting the needs of industry against those of the environment

June 11-14, 2024
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Editors
Jennifer Kowalska
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Managing large scale plantations forests in New Zealand: adapting to technology opportunities and climate change challenges
Rien Visser

Precision forestry in forest management and monitoring
Krzysztof Stereńczak

Harvesting: All mechanized

Mechanized Pollarding For The New Agroforestry Plantations
Natascia Magagnotti, Raffaele Spinelli, Giustino Mezzalira

Assortment-Based Forwarder Productivity in Northeastern Italian Alps Salvage Logging Operations
Narcis Mihail Bacescu, Luca Marchi, Alberto Udali, Stefano Grigolato

Assessing The Efficiency of Mechanized Hardwood Thinning Operations Using Machine Time Study Data and Lidar/ai Technologies
Mauricio Acuna, Martin Strandgard

Analysis of Optimized Semi-Mechanized Timber Harvesting Methods For Pine (Pinus Sylvestris) In The German Federal State of Brandenburg
Maximilian Jakob, Ferréol Berendt, Tobias Cremer

Terrain Stability Assessment In The Context of Forestry Operations
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Mechanized Pollarding For The New Agroforestry Plantations

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ABSTRACT

Pollarding is an ancient agroforestry practice that offers many benefits but is slowly becoming extinct because traditional pollards lack financial and social sustainability. In particular, the cutting of pollards is too slow, expensive and dangerous for modern farmers to apply. This study presents the first test of mechanized pollarding, performed with two different devices: a set of shears and a disc saw. Both machines were fitted to the boom tip of a tracked excavator and were tested on poplar rows in a typical alley-cropping system. The introduction of those simple machines restored productivity and safety to pollarding as a modern practice. Tree topping incurred a cost around 1 € tree-1, or 250-350 € ha-1. That cost would need to be balanced against the revenue obtained from the treetops sold as biomass and the increased yields of the alley crop, prolonged for several years. Mechanization also allows cutting the treetops several meters above ground level, so that the trunks of the pollarded trees may yield valuable timber when they are eventually harvested. Both machines on test performed well, but the disc-saw seemed preferable, especially if installed on a compact excavator.

Assortment-Based Forwarder Productivity in Northeastern Italian Alps Salvage Logging Operations

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ABSTRACT

Salvage logging operations have grown increasingly common in response to the rising frequency of severe events, such as windthrows, droughts, wildfires, and insect outbreaks, which impact forest ecosystems. To maintain the sustainability of salvage logging, precise planning and execution of harvesting operations are essential, particularly in sensitive areas. In these contexts, fully mechanized harvesting systems are preferred for their safety level, cost-effectiveness and adaptability to complex terrains This study aims to address the knowledge gap concerning the efficiency and productivity of cut-to-length (CTL) harvesting operations, with a particular focus on forwarding operations. It examines the impact of multiple variables on productivity and fuel consumption, including wood assortment, load size, extraction distance, and terrain slope. Data collection campaign was carried out through a follow up study, where the data were automatically recorded by a CSS electronics® Controller Area Network bus (CAN-bus) data logger, able to register engine parameters while performing the harvesting activity, such as fuel consumption rate, engine speed, wheel-based speed, torque percentage, etc. Additionally, a detailed time and motion study was carried out using on-board digital cameras (Drift®, Ghost-HD) allowing the identification of 227 working cycles and 7 product assortment classes. Finally, high-resolution LIDAR flights were performed before and after the hauling operation, in order to identify the potential terrain disturbances. Preliminary results indicate that the type of product assortment and the average log size significantly impact productivity and fuel consumption, confirming that biomass and pulp and paper assortments are the most expensive to forward and have the highest fuel consumption rates per cubic meter extracted.

Assessing The Efficiency of Mechanized Hardwood Thinning Operations Using Machine Time Study Data and Lidar/ai Technologies

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ABSTRACT

Mechanical thinning of stands to yield high-value logs represents a significant investment, requiring careful planning to manage costs effectively while achieving desired silvicultural objectives. In Australia, an increasing number of forest companies are transitioning from pulp to solid wood plantation regimes, highlighting the importance of understanding the financial implications of thinning operations and identifying the key factors influencing the efficiency of mechanized equipment, particularly in hardwood stands. This study utilised machine productivity data to assess mechanised thinning operations in Eucalyptus nitens stands, pinpointing the key factors affecting productivity and costs. Additionally, sensing technology, including mobile LiDAR systems, has been employed to evaluate the quality features of the remaining trees, such as Diameter at Breast Height (DBH), height, branchiness, tree form, and stem damage.

The objectives of this study were as follows: 1. Quantify the productivity and costs associated with mechanized thinning operations in Eucalyptus nitens stands, identifying the key factors that significantly impact productivity and costs. 2. Develop a methodology to capture tree quality features in thinned stands using sensor data. 3. Provide data and methods aimed at enhancing the efficiency of hardwood plantation thinning operations. 4. Test optimization and artificial intelligence (AI) algorithms to improve the effectiveness and efficiency of tree selection decisions during thinning operations.

The research trial was conducted in Northwest Tasmania, where a single thinning regime and intensity were implemented at age 9, with the remaining trees allowed to grow until approximately 25 years of age. Mechanized thinning operations were carried out using a wheeled harvester/processor.
The results of the machine study revealed that over 85% of the variability in thinning productivity can be attributed to stem volume. Additional variability was explained by the location of the removed trees during thinning (outrows or outer rows). In contrast to the plot with marked trees, the Diameter at Breast Height (DBH) and stem volume of trees selected by the machine operator were consistently higher, irrespective of the location of the removed trees (whether in adjacent or outer rows), except for trees removed from outrows.

This study confirms the invaluable role of LiDAR technology in informed decision-making during thinning operations. LiDAR point cloud data collected before thinning empower harvest planners to make well-informed decisions regarding the optimal location of thinning roads, tree selection during thinning, and alternative thinning strategies before field implementation. Real-time or pre-thinning LiDAR data also aids harvester operators in making optimal tree selection decisions, incorporating variables like tree density for removal decisions and other factors such as basal area, tree form, and branchiness.

Analysis of Optimized Semi-Mechanized Timber Harvesting Methods For Pine (Pinus Sylvestris) In The German Federal State of Brandenburg

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ABSTRACT

Analysis of optimized semi-mechanized timber harvesting methods for pine (Pinus sylvestris) in the German federal state of Brandenburg Maximilian Jakob, Ferréol Berendt, Tobias Cremer

The framework conditions for timber production in Brandenburg are changing due to climate change and the changing demands of society on the forest. The provision of ecosystem services such as carbon sequestration, water storage and filtration therefore plays an increasingly important role in forest management. Wood harvesting technologies and concepts must be adapted accordingly. Today, in Brandenburg the proportion of FSC-certified forests is increasing. As one consequence, max. 10 % of the managed forest area are allowed to be used as skid trail in the long term. Therefore, there is a need to adapt and optimize the present timber harvesting systems to the specific conditions of Brandenburgs pine forests with extended skid trail spacing. In autumn 2023 a harvesting operation was carried out in a 20 ha pine forest in Northeastern Germany, to investigate different timber harvesting systems under comparable conditions: Four timber harvesting systems were used, each with two different thinning approaches. Fully mechanized timber harvesting with 20 m skid trail spacing was implemented as a reference scenario. In three differing semi-mechanized systems, the trees outside the boom reach of the harvester were motor-manually felled. In addition, a skidder was used in one harvesting system to winch the logs to the skid trails. For the calculation of productivity and cost, a time study was carried out according to the methods described in REFA - Association for Work Studies and Business Organization. In addition, the following data were collected and analyzed: processed timber volumes, damage to the remaining trees, distance and slope of the skid trails, amount of wood that could not be processed and remained in the forest, as well as fuel consumption of the machines. Based on this, the presentation will give insights in the productivity and costs of the various timber harvesting systems. As well, it will be shown, to what extent the skid trail distances and the respective harvesting methods do have an influence on the damages to the remaining trees. Finally, results will be presented on whether the use of a skidder for winching the trees is worthwhile in relation to the amount of wood that can be processed additionally.

Terrain Stability Assessment In The Context of Forestry Operations

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ABSTRACT

Terrain Stability Assessment (TSA) as it relates to forest harvesting operations is a process wherein an upcoming harvest area is evaluated on its hazards pertaining to land sliding/mass movement. While the process for TSA has undergone multiple changes with the advances in knowledge and technology over time, it is necessary to continue to evaluate them with regard to forestry operations to allow for optimal management decisions. To understand contemporary practise, interviews with nine different management companies in New Zealand highlighted an experience driven approach to the identification and management of unstable terrain. Ambiguity remains once unstable areas are identified, with respondents making the case for site specific evaluation and recommendations over blanket, nationwide prescriptions. Various assessment techniques were considered, with a goal of assessing the efficacy of implementing them under NZ steep slope plantation forestry conditions. Relevant techniques pertaining to the landslide issues faced in NZ forestry were compiled into one TSA process and are demonstrated via six case studies across New Zealand. This method involves three stages. Data collection and validation (LiDAR, geological information), modelling (susceptibility via empirical regression, 'Spiekermann Model'; morphometric ratios, 'Melton Ratio'), and field assessment. Overall, the TSA methodology demonstrated in the case studies captured landslide hazards specific to each site. Limitations and assumptions of the process are discussed, with areas of future study identified.

Operations: Some biomass

Analyzing The Views of Logging Contractors and Timber Haulers On The Idle Times of Their Machine and Truck Fleets
Jarkko Pesonen, Jeremias Jeskanen, Matias Kangas, Kari Palojärvi, Simo Jaakkola, Kalle Kärhä

A Machine Learning Based Modeling and Analytical Framework For Sustainable Biomass Supply Chain Management
Jinghan Zhao, Jingxin Wang, Nate Anderson

A Strategic-Tactical Analysis of Biomass To Bioenergy Value-Creation Network
Sättar Ezzati, Sättar Ezzati

Understanding Timber Harvesting Challenges On Small Family Forests In Northern Minnesota, USA
Charlie Blinn, William Sauerer

Comparison of The Operational Productivity and Quality of Manual and Semi-Mechanised Planting Techniques Kwazulu-Natal, South Africa
Junior Khoza, Muedanyi Ramantswana, Raffaele Spinelli, Natascia Magagnotti

Analyzing The Views of Logging Contractors and Timber Haulers On The Idle Times of Their Machine and Truck Fleets

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ABSTRACT

Fuel costs play an essential role in the operations and profitability of Finnish logging and timber hauling enterprises. The idle times of logging machines and timber trucks and their fuel consumption have remained for less research activities. In the study of the University of Eastern Finland, Trade Association of Finnish Forestry and Earth Moving Contractors and Finnish Transport and Logistics SKAL, the idle times of logging machinery and timber trucks and possibilities for reducing them were investigated. Study materials were collected by two Webropol inquiries. The response link was sent out to 339 timber haulers in February 2023. A total of 87 haulers responded to the survey. Furthermore, the response link was distributed to 817 logging contractors (loggers) in May 2023. Totally 146 loggers responded to the survey.

The study revealed that the timber haulers have detected idle times significantly more frequently than the loggers: Only a quarter of the loggers reported that they have investigated the idle times of their machine fleet. On the contrary, a half of the timber haulers said that they have sorted out the idle times of their truck fleet. Entrepreneurs who had explored the idle times of their fleets evaluated significantly higher idling percentages than entrepreneurs who had not searched the idle times. There was no statistically significant difference between loggers and haulers in their estimated idle times. Moreover, entrepreneurs who had examined the idle times of their forest machine or timber truck fleets noticed significantly more opportunities to reduce the idle times of machine and truck fleets in the wood supply chain than entrepreneurs who had not explored the idle times. The loggers pointed out that the best opportunities to reduce the idle times of forest machines are planning of logging operations carried out

by a machine operator at harvesting site, as well as starting and termination tasks at the harvesting site. Correspondingly, timber haulers underlined that the most significant opportunities to reduce the idle times of timber trucks are waiting times at the timber reception area of mill, breaks and rest periods of truck drivers, and refueling the truck.

The study concluded that there is a significant potential to reduce the idle times and further fuelconsumption and greenhouse gas emissions of forest machine and timber truck fleets in the wood supply chain of the Finnish forest industries. The comprehensive research data on the actual idle times are also needed in the future.

A Machine Learning Based Modeling and Analytical Framework For Sustainable Biomass Supply Chain Management

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ABSTRACT

The conversion of forest biomass and energy crops into sustainable value-added bioenergy and bioproducts can effectively mitigate climate change and promote the prosperity of the bioeconomy. Efficient supply chain management is crucial for optimizing the utilization of diverse biomass feedstocks and minimizing environmental impacts. Biomass supply chain management involves planning, coordinating, and optimizing various system processes, encompassing feedstock cultivation and establishment, harvesting, processing, storage, transportation, and conversion. A modeling and analysis framework integrating machine learning (ML), spatial analysis, and optimization algorithms was developed to provide strategic and operational decision support. Combining multi-criteria decision analysis (MCDA), geographic information system (GIS) identified areas suitable for establishing biomass facilities based on economic, environmental, and socio-economic criteria. ML technique, as a significant branch of artificial intelligence, automatically processes and trains models based on historical, empirical data from various sources to predict key parameters in the biomass supply chain. Mixed integer linear programming (MILP) was employed to minimize the total cost of biomass utilization under constraints of biomass supply, demand, and material balance. This study has promising implications for sustainable practices, bioenergy management, and regional bioeconomy development.

A Strategic-Tactical Analysis of Biomass To Bioenergy Value-Creation Network

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ABSTRACT

The initial step in effectively planning the biomass value-chain network is to obtain accurate information and employ consistent measurement methods for the spatial distribution, collection, and transportation of residues to energy producers. This study presents a generic integrated strategic-tactical decision-making tool that achieves two key objectives: (i) identifying the quantity and location of technically available residue biomass, which is a byproduct of commercial plantations and agriculture crops, across diverse landcover/landuse types, and (ii) determining the optimal sites for potential bioenergy facilities by utilizing logistics cost models. To do so, first, remote sensing techniques were employed, in combination with spatial analyses, to assess the feasibility of such initiatives in a spatially explicit manner for an extended pilot region located in northeast Iran. Next, a multi-objective bi-level optimization model was developed to estimate logistics costs and determine the optimal location for bioenergy facilities. The approach was implemented to a large case study covering an area of 20,000 km2, where the National Iranian Gas Company is seeking alternative energy sources to replace fossil fuels. The strategic analysis confirmed a mean annual density of residual biomass supply of 21.6±0.15 Mg ha−1 year−1 was determined, which resulted in an estimated yearly supply of 1,867 Gg across the entire 20,000 km2 study area. The numerical results of the optimization model indicated that the optimal solution involves the allocation of two sites, with a combined capacity of 3,888 Mwh-1 and a delivery cost of $16 Mwh-1 within a distance threshold of 75 km in order to utilize all accessible residues.

Understanding Timber Harvesting Challenges On Small Family Forests In Northern Minnesota, USA

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ABSTRACT

Family forests are an important landowner group in the United States. A high percentage of family forest ownerships are smaller than 8 hectares in size. A survey of logging business owners in northern Minnesota was conducted to better understand some of the primary obstacles to harvesting timber from small tracts. Results suggest that while logging businesses which harvest relatively small volumes of timber annually tend to focus their procurement on small tracts, small tracts are still an important component for businesses regardless of its annual production. The three factors which increase the likelihood of a logging business operating on a small tract are the tract's proximity to other tracts which have already been purchased by the logging business, presence of high quality timber in the buyer's preferred species and the option for a summer harvest occurring on the tract. As the volume of timber offered for sale increases, loggers are more likely to purchase a timber sale, regardless of whether it is in public or private ownership.

Comparison of The Operational Productivity and Quality of Manual and Semi-Mechanised Planting Techniques Kwazulu-Natal, South Africa

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ABSTRACT

Planting plays a significant role in commercial forestry. In South Africa, this operation is resource-intensive, costly, and labour reliant. Issues related to labour (increased wages, absenteeism, and high turnover), inconsistent work quality, increased operational costs, and poor ergonomics prompted the development of innovative planting techniques. The aim of this study was to assess the productivity (plants/hour) and work quality of a manual (Vastrap) and a semi-mechanised (Wasserplanter) planting system. The experimental conditions comprised of two study sites (Flatcrown and Kwambonambi) consisting of 20 plots per site (10 plots per planting system) alternating across the study site. Block-level and elemental-level time studies were conducted, followed by work quality assessments. The manual method planted 7.23 ha/shift (Flatcrown) and 5.89 ha/shift (Kwambonambi) whilst the semi-mechanised method planted 4.72 ha/shift (Flatcrown) and 3.19 ha/shift (Kwambonambi). The manual system was 50 to 60% more productive (plants/PMH) than the semi-mechanised system. Higher worker efficiency 30 - 40% was observed at the Flatcrown site, which was characterized by level terrain and low slash presence compared to the Kwambonambi site, which had a gentle (< 20%) terrain and medium residue presence. Planting quality was conducted according to planting specifications and not significantly different between the two systems, although the study suggests that the proportion of good quality plantings could be somewhat higher for the manual system.

Precision: New and digital

New Developments In Winch-Assist Technology
Rien Visser, Karl Stampfer

Analyzing Harvesting Removals of Cut-To-Length Thinning Operations In British Columbia
Mathew Sloan, Kalle Kärhä

2 Different Methods of Point Cloud Classification For Dtm Creation and Their Affect On The Amount of Forest Road Earthwork
Mihael Lovrinčević, Ivica Papa, Andreja Đuka, Tibor Pentek

Utilization of Digital Technology and Mocap Systems In Workload and Ergonomic Risk Analysis
Eva Abramuszkinová Pavlíková, Martin Röhrich

Scots Pine (Pinus Sylvestris) and Silver Birch (Betula Pendula) Bark Thickness Comparison To Bark Algorithms Used In Stanford 2010 Forest Machine Standard
Janis Magaznieks, Mareks Millers

New Developments In Winch-Assist Technology

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ABSTRACT

Winch-assist technology is now a well-established system to support forest harvesting activities on steep slopes. In the European alpine area the most common system format is a winch integrated on the forwarder or harvester to extend their operating range. In North America and the Southern hemisphere typically a winch mounted on a separate machine at the top supporting felling and shovelling work of a machine on the slope provides greater flexibility, especially in the larger plantation forests. More recently, the success and availability of both systems have seen them expand to applications such as winch-assist skidder extraction. However innovative companies and logging contractors have continued to develop the use of aspects of winch assist capability. For example, in New Zealand shovelling to pre-bunch ahead of fully mechanized cable yarder extraction is proving to be highly productive. In addition to updating new developments, this presentation will show the latest applications including examples of greatly increasing the productivity of older yarders through life skyline support, simplified rigging through tail-hold bridling, as well as applications on wet swampy terrain. Where possible, this information will be supported by productivity and utilisation values based on successful case studies.

Analyzing Harvesting Removals of Cut-To-Length Thinning Operations In British Columbia

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ABSTRACT

The aim of this thesis project is to evaluate harvesting systems in British Columbia (Canada) and Finland and determine the potential for cut-to-length systems in Central and Northern British Columbia. As the province of British Columbia's (BC) delegation visited Joensuu, Finland there has been much discussion regarding the potential for newer logging machinery that produces less fuel and creates a more sustainable future. In order to evaluate the efficiency of the current harvesting systems, a combination of both literature and data provided for the study by PONSSE in Canada opened clear suggestions for future actions to be made by the forest sector. The peer-reviewed articles focused on the interior and northern British Columbia and statements made by the government of British Columbia were included to help define current systems such as: Commercial Thinning (CT), partial cutting, clear-cutting, compared to first thinning, secondary thinning, and final cut.

The research and data analysis made showed that current harvesting systems are not positively contributing to the overall wealth of the forest, and despite incentives for managers to cut early there may be greater incentive to practice a Finnish style of thinning that would yield more over the long-term. Additionally, the current view of forests in British Columbia and Finland are on opposite ends of the same log. In fact, Finnish foresters operate with a limited mindset, meaning that they operate with the idea that forests are a limited resource and must be treated with careful decision-making, conversely, British Columbian managers tend to view the forest as an unlimited resource that could afford the heavy rate of cutting. With the current state of forests in British Columbia, there is large incentive to turn the wheel and begin developing a new system, or a modern take on an old one.

The volume at which the province of British Columbia is currently cutting is far larger than Finland and the alarming rate has made way for the suggested use of PONSSE equipment. Not only could implementing Finnish type of harvesting system to a Canadian context add value to the ecological, social and economic value over the long-term, it could help reduce fire risk and give British Columbian foresters back the choice to watch their seedlings grow. The project discusses the data analysis of the PONSSE Scorpion used on harvesting sites and help determine the volume at which cuts have been made and how feasible the equipment is in a Canadian context. The abilities of the Scorpion allow for more value-added wood to be produced, and with the benefit of CTL methods of harvesting there is clear future for the use of this equipment in British Columbian forests.

2 Different Methods of Point Cloud Classification For Dtm Creation and Their Affect On The Amount of Forest Road Earthwork

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ABSTRACT

Forest roads are permanent forest infrastructure that enables modern and sustainable forestry to fulfill all management goals in a timely and optimal manner. Optimum execution of management goals is extremely important in today's challenging and changing conditions. One such condition is a bark beetle attack, that is, the salvage logging that follows the attack. Increasing forest road accessibility of such areas makes it easier to carry out intensive silviculture work that follows the rehabilitation of the infected area. This research analyzed the usability of digital terrain models when designing forest roads in an area where salvage logging was carried out. The salvage logging in the study area was performed in 2017 after a bark-beetle (Ips typographus) out-break. In this study, digital terrain models (DTMs) were generated based on georeferenced aerial photographs taken by an unmanned aerial vehicle (UAV). When photogrammetric processing was carried out in Pix4d software (v.4.8.4), automatic and manual point cloud classification was used. The generated DTMs were used during the further design phase in the RoadEng10 software. Horizontally and vertically identically routes of forest roads on each of the generated DTM were designed and the quantities required for the road substructure construction for each profile were computed. The calculated earthwork volumes were used in further statistical analyses.

Utilization of Digital Technology and Mocap Systems In Workload and Ergonomic Risk Analysis

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ABSTRACT

Forest work, wood processing or work in arboriculture is a mixture of manual and motor work alongside the integration of cutting-edge machinery and techniques. These methods pose ergonomic and safety challenges to workers, including the risk of musculoskeletal injuries, exposure to harmful factors, and the physical strain of operating in diverse terrains. Maintaining a balance between body stability, strength, and cognition while operating chainsaws or manual equipment demands constant dynamic adjustment of the body's posture in a difficult environment, placing additional strain on the neuro-skeletal system. Our recently published study of arboricultural work confirmed that there is a difference concerning blood pressure between physical workloads, associated with tree felling, tree climbing, or chainsaw maintenance, and cognitive workloads, such as supervision or observation. The study has shown that blood pressure was reasonably higher for activities that involved a cognitive workload. [DOI:https://doi.org/10.1016/j.heliyon.2024.e26264]. The objective of our Workload and Ergonomic Risk Study is to recognize the possible impact of high workloads during chainsaw operation and manual handling activities on total workload and energy consumption in alignment with the maturity of the workers and the ability to eliminate ergonomic and workload-related risks. The digital MoCap (Motion Capture systems) with IMU units (Inertial Measurement Units) and different wireless technologies to measure physiological signals (heart rate, breathing pattern, and oxygen saturation in the bloodstream) to identify possible risks, were used. The participants were two forest workers (experienced and less experienced) and four firefighters operating a chainsaw while dealing with disaster situations e.g. removing fallen trees (two experienced, two less experienced). Five groups of activities have been tested on all participants - initial physiological and Gait analysis measurements before the work, a defined set of physical power load exercises to simulate work activities, chainsaw cutting and manual handling measurements, and physiological measurements 10 min after the work activities. The Gait analysis for basic postural stability and movement analysis, analysis of the physiological data before, during, and after working activity, and Ergonomic Risk analysis. The final analysis focused on the total workload, energy consumption, ability to lower the ergonomic risks, the level of ability to properly manage given tasks and to apply given working instructions, safety, and ergonomic rules. Results showed that the lack of experience and ability to properly follow working instructions and rules correlated with a higher total workload and lower ability to balance body load and stability in diverse terrains on a safe level and eliminate possible safety risks (presented on a higher load on one leg, back and spine, and upper arms). The study has shown important points that need to be taken into consideration for future digital models and analytical tools for forestry ergonomics and workload risk analysis. This includes detailed analysis for manual and motor work, assessment of different work-related physical strains, ergonomic analysis

for small and large muscle groups, evaluation of terrain impact on worker biomechanics, and impact of the neurocognitive and stress-related loads.

Scots Pine (Pinus Sylvestris) and Silver Birch (Betula Pendula) Bark Thickness Comparison To Bark Algorithms Used In Stanford 2010 Forest Machine Standard

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ABSTRACT

The diameter of round timber, starting from the forest inventory and ending with the measurement of the timber before processing is usually measured with bark, but the calculation of the volume of wood is usually based on the diameter without bark, which has a greater economic value. For such cases, local or regional algorithms for estimating bark double thickness and volume have been developed and adapted for many tree species. The volume of the bark is on average 8% of the volume of round timber. Timber accounting using harvester data is used, firstly, to settle with service providers, and secondly, to prepare round timber in exactly the required sizes for further processing companies. Certain countries also use the volume measured by the harvester in transactions between timber buyers and sellers. There are several conditions for the accurate measurement of timber, and one of the most important is the appropriate algorithms for calculating the double thickness of the bark. The volume of the bark in different parts of the trunk can vary from 3-15%, as well as the thickness of the bark at the end of the trunk can reach 4 cm. To ensure the accuracy of diameter and length measurements, the harvester is regularly calibrated, while to accurately calculate the volume of round timber without bark, the appropriate bark reduction algorithms for each region must be used. In Latvia, from 2019-2021, a large-scale study was conducted to find out the accuracy of existing bark algorithms included in StanforD2010 for the most economically important tree species in Latvia - Scots pine, Norway spruce, Silver birch, aspen, oak, ash, and black alder. A total of 215 sample plots were created by measuring the assortments of the selected sample trees with the 1-meter step measurement method, which is adopted as the most accurate measurement method in Latvia. In the study, the variation of the double thickness of the bark was evaluated for each tree species depending on the growth region, the type of cut, the quality (tree height at certain age) and the place in the trunk. In Latvian conditions, the double thickness of the bark of Scots pine varies on average from 21 mm in the root part (first log) to 4 - 5 mm in the top part of the trunk. In comparison with linear algorithms (Zacco, 1974), a difference of 11 mm is found in the root part (first log). The double thickness of Silver birch bark varies on average from 22 mm in the root part (first log) to 10 - 12 mm in the top part of the trunk. Compared to the linear algorithms (Zacco, 1974), a difference of 4 - 5 mm is found in the root part (first log). Compared to the algorithm developed by "Skogforsk" in 2004 for pine, this difference is insignificant. Before starting work with the harvester, it is important to make sure of the double thickness algorithms set in the software, because they significantly affect the results of the calculated volume.

Impacts: Extracting timber again

Classifying Forest Roads Using Geometric Features Detected With The Mobile Proximal Sensing Platform Roadsens
Helle Ross Gobakken, Mostafa Hoseini, Stephan Hoffmann, Jan Bjerketvedt, Johannes Rahlf, Rasmus Astrup

Bearing Capacity of Forest Roads On Poor-Bearing Road Subgrades Reinforced With Timber Rollers and Willow Brushwood Mats
Grzegorz Trzciński, Tadeusz Moskalik

Slippage and Rut Formation With Two Types of Flotation Bogie Tracks
Lorenz Breinig, Henrik Brokmeier, Bastian Hinte, Bastian Sönchen, Dirk Jaeger

Assessing Soil Erosion Potential At Harvest Sites Using High-Resolution Drone Imagery, Deep Learning, and Geographic Information Systems
Manisha Parajuli, Tom Gallagher, Richard Cristan, Marissa Jo Daniel, Dana Mitchell, Timothy McDonald, Arjun Rijal

Evaluation of The Damages On Wood Raw Material and Residual Stands of Sustainable Timber Harvesting In Turkey
Saliha Ünver, Ebru Bilici, H. Hulusi Acar

Classifying Forest Roads Using Geometric Features Detected With The Mobile Proximal Sensing Platform Roadsens

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ABSTRACT

Sustainable forest management requires a well-planned and maintained forest road network to provide access to remote timber areas and for other management purposes. In Norway, most forest roads were built over 30 years ago, following partly outdated traffic requirements, and frequently being subjected to wear from transportation and deterioration of water-bound surfaces. To ensure traffic safety, mitigation of environmental impacts such as road-induced surface water channeling, and to avoid cost-intensive repairs, up-to-date information of the current technical condition and deterioration of the roads is essential. This information is often lacking and existing road databases are incomplete due to the main assessment methods conducted being manual, which are time-consuming and expensive. An alternative solution could be the use of remote sensing techniques such as Airborne Laser Scanning or aerial imagery. However, these alternatives have restrictions. Airborne Laser Scanning lacks frequent updates and the necessary point density for functional road classification, while aerial imagery, despite its frequent updates proves inefficient in forest areas with dense canopy coverage. Thus, proximal sensing technologies implemented through operational vehicle traffic on forest roads offer new opportunities to collect multiple road-related data in frequent updating intervals, at a much lower cost. The study presents an application of the proximal sensing platform RoadSens for technical road classification. The data products generated by RoadSens along with the 3D point cloud of the road include longitudinal and cross-sectional characteristics in a relatively high spatial resolution. Five different case study regions in Southern and Eastern Norway have been used to demonstrate the application of the platform. The extracted geometric features are integrated into a classification scheme, following the national standards for technical rural road classification (class 1-8), to determine the surveyed road's technical standard. The classification will be done road-wise based on the applicable cross sections with detected road

geometry to determine if the criteria are fulfilled, such as road width, ditch depth, and side-fall, set for the distinct technical class of the road standard. If sections of the road deviate from the standard it will be determined if the deviation leads to the entire road being degraded or if they can be accepted for the area. The goal of the study is to find a way to classify forest roads based on detected road geometry, as well as identify the roads most common limitations based on the national standards. This study is part of the Norwegian SmartForest project, where RoadSens is forming a component of the ForestSens cloud service family. Further developments of RoadSens will include an end-user application not requiring in-depth knowledge on data handling, processing, and interpretation. Where the output data will automatically show up as simple and readable results for the user in question. In summary, this study offers a novel approach to forest road classification that aims to overcome the limitations of traditional methods and remotely sensed techniques and provide a cost-effective and efficient solution to assess the technical condition of forest roads.

Bearing Capacity of Forest Roads On Poor-Bearing Road Subgrades Reinforced With Timber Rollers and Willow Brushwood Mats

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ABSTRACT

Clay and silt loam soils are weak road surfaces that require reinforcement, in order to obtain the load-bearing parameters of the entire road structure to allow transport related to forest management. It concerns especially the transport of round wood by heavy-duty vehicles, regardless of weather conditions. The research was carried out on a forest road on the territory of the State Forests in Poland, in the Brzeziny Forest District, where eight test sections with a total length of 422 m were made with different pavement structures on a weak-bearing soil substrate (clay, silt loam). The pavement structure was designed using crushed aggregates 0/31.5 mm and sand-gravel mix, sand-gravel mix 0/63 mm, 400 g·m-2 geotextile, on a sub-base reinforced with wood rollers (pine or oak) and willow mats. A reference road section without road base reinforcement was carried out only with the profiling of the existing pavement and a new layer of aggregate. The bearing capacity of the pavement was determined based on the static strain modulus ME determined by measuring with a VSS MN·m-2 plate, the dynamic deformation modulus Evd MN·m-2 obtained from lightweight deflectometer measurements. The compacted state of the pavement was determined by the strain index I0. It has been shown that pavements made of crushed aggregate and common gravel on timber roller substructure are characterized by good bearing capacity parameters, where the average values of secondary modulus of strain are above 130 MN·m-2. Pavements on weak-bearing soils reinforced with willow brushwood mats have low bearing capacity parameters, with averages of $26.09 \leq MEII \leq 53.93$ and $22.1 \leq Evd \leq 39.1$ MN·m-2.

Slippage and Rut Formation With Two Types of Flotation Bogie Tracks

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ABSTRACT

Machines with bogie axles dominate among wheeled machines in cut-to-length harvesting systems, and it is common to equip these machines with bogie tracks to enhance mobility and mitigate soil disturbance. Flotation bogie tracks are specifically designed to reduce contact pressure and thus soil compaction and rut formation on soils of low bearing capacity. Two types of flotation bogie tracks (Olofsfors Magnum and Olofsfors CoverX) differing mainly in the shape of the track pads were assessed with regard to slippage and rut formation in a field experiment. On a forest site, an 8-wheeled forwarder with a nominal payload of 14 metric tons was driven in three configurations: with bogie tracks of either type mounted throughout as well as with bare tires as a reference. Terrain was flat, but each configuration was also tested at adverse inclinations of 10% and 20% simulated by braking the forwarder with a defined braking force from a winch. For each setting of configuration and inclination, the forwarder was driven in eight consecutive passes over the same track. Wheel and travel speeds were measured over a defined distance during travel to determine slippage, and rut depth was measured at fixed locations with a laser scanner after each pass. Observed slippage was considerably lower for the CoverX than for the Magnum track at all levels of inclination, while the difference in slippage between the CoverX track and bare tires was most pronounced at 20% inclination. Slippage was higher for the Magnum track than for bare tires at 0% and 10% inclination. Rut formation was most pronounced for bare tires at all levels of inclination. The CoverX track was found more effective in reducing rut depth than the Magnum track, especially after a higher number of machine passes. These observations support the efficacy of flotation bogie tracks in mitigating soil disturbance and suggest a marked impact of track-pad design.

Assessing Soil Erosion Potential At Harvest Sites Using High-Resolution Drone Imagery, Deep Learning, and Geographic Information Systems

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ABSTRACT

Conventional methods for estimating soil erosion from a harvest site involve on-the-ground surveys that are time-consuming and labor-intensive. With the advancement of technology in forestry, we aimed to use drone technology to estimate soil erosion from a harvest site. This study presents an innovative approach to estimating soil erosion within harvest sites through the integration of high-resolution imagery, deep learning techniques, and geographic information systems (GIS). Conducted across ten distinct harvest sites in Alabama, using deep learning, we first performed a drone orthomosaic map classification of harvest sites into five categories, including roads, skid trails, landings, Streamside Management Zones (SMZs), and clear-cut areas, to assess soil erosion potential respective to each category. Rainfall data were downloaded from the National Oceanic and Atmospheric Administration (NOAA) Climate Data Online website, soil erodibility factors data were assessed from the UC Davis soil survey website, the slope data were assessed from drone-derived Digital Elevation Models (DEMs), and crop management factors for each site were derived from the field survey in line with the Universal Soil Loss Equation (USLE) Forest guidelines. The potential soil erosion rate from each site was estimated using Revised USLE (RUSLE) in ArcGIS Pro. The study highlights the effectiveness of combining high-resolution drone imagery with advanced computational techniques to enhance the accuracy and efficiency of soil erosion estimation in forestry practices.

Evaluation of The Damages On Wood Raw Material and Residual Stands of Sustainable Timber Harvesting In Turkey

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ABSTRACT

Nowadays, wood raw material is the most demanded although many materials such as steel and plastic can be used as raw materials in the timber industry. This situation has increased the pressure on forests and highlighted the importance of sustainable timber harvesting. The main reasons for the inability to produce wood from forests in the quantity or quality required by the industry can be listed as the amount or quality losses of wood raw material during harvesting and the damage to the remaining stand (trees, seedlings, etc.). Approximately 15% of the industrial demand for wood materials in Turkey is imported from other countries, as the annual production from Turkish forests does not meet the required quantity, quality, and specifications. In addition, although 10% of the wood raw material in forests is classified as Class I, 5.0% as Class II, and 85.0% as Class III, in practice, only 0.5% is Class I, 3.5% is Class II, and 95.0% is Class III logs can be produced. This situation is due to the damage caused to the wood raw material during harvesting (such as breakage, cracking, and splitting) or the damage caused to the trees produced during previous harvesting activities (such as breakage, and injury). Minimizing the damage to the remaining stand and providing wood raw material with the required characteristics for the industry in the present and future can only be achieved by correctly implementing sustainable harvesting activities. In this context, the effects of sustainable timber harvesting activities on the forest ecosystem are being evaluated in this study.

Ergonomics: Noise, friction and vibrations

An Ergonomic Evaluation For Afforestation Works With The Help of Risk Analysis Method
Mehmet Eker, Fatma Gamze Korkmaz, H. Hulusi Acar

Determining Friction of Safety Web Lashings For Load Securing In Round Wood Transportation
Juergen Richter, Christoph Haas, Christoph Huber

Using Noise Dosimeter Data and Machine Learning For Working Operation Detection
Anton Poje, Rok Petrovčič, Luka Pajek

Levels of Vibration Exposure In Cross-Cutting Operations By Chainsaw: Are They Affected By A Wrong Height of Chain Depth Gauge?
Francesco Neri, Cristiano Foderi, Andrea Laschi, Riccardo Paoloni, Enrico Marchi, Fabio Fabiano

What Can Forest Workers do Differently - Defining Countermeasures For Forest Accidents Through Counterfactuals of Causal Models
Anna Saranti, Ferdinand Hönigsberger, Seyedehanahid Naghibzadehjalali, Karl Stampfer, Andreas Holzinger

An Ergonomic Evaluation For Afforestation Works With The Help of Risk Analysis Method

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ABSTRACT

In terms of sustainability of forest resources, areas that do not have economic and ecological added value but can form forests are afforested using the primary tree species of the region through planting. Afforestation activities carried out within the scope of a national mobilization in Türkiye have been continuing for many years and benefit from a large number of workforce. It has been determined that an ergonomic-oriented evaluation is necessary in terms of the technical and economic sustainability of these activities, which are carried out with labor-intensive physical power in difficult terrain conditions and open to various environmental effects. The aim of this study is to evaluate forest afforestation works, workers and working conditions in terms of occupational health and safety. By performing a simple job analysis, the work steps in afforestation works were revealed, the workers were observed and data and information were collected along with field observations. For this purpose, risk analyzes (5x5 matrix method) were made with the help of field observations and risk checklists. Survey and interview methods were also used to evaluate working conditions, work performed and employees. As result, it has been determined that nearly 70% of those working in afforestation works are women, that female workforce participation focuses on the sapling planting phase, that the working posture required by sapling planting causes stress and strain that requires ergonomic regulation, and that short-term but constantly repetitive movements cause workers' complaints. Although physical, ergonomic and psychological risk factors predominate, it has been determined that sapling planting works can be in the category of less hazardous and light-heavy work.

Determining Friction of Safety Web Lashings For Load Securing In Round Wood Transportation

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ABSTRACT

In round wood transportation the load is usually secured sideways by stanchions and gets piled up with a crowned shape with a maximum of 25% of the width to the end wall. It is additionally tied down by a safety lashing, using web lashings, but chain- or rope-lashings are also permitted. The downforce is applied onto the load through the lashing by a suitable tensioning device e.g. a ratchet. This raises the friction between vehicle and load as well as the friction between single logs and thus reduces the chance of slipping. Frictional losses occur with every deflection of the lashing on round wood and reduce the preloading force on the opposite side of the tensioning device. Currently this effect is covered by a safety coefficient, but these frictional losses may vary highly depending on characteristics of lashings and logs. To determine the frictional coefficient in static friction, we compare safety web lashings, specified by standard EN 12195-2, of different manufacturers with a lashing capacity LC of 2500 daN and a standard tension force STF of 500 N. These were tested on different wood species (Norway Spruce and European Beech), with and without bark using different wrapping angles from 0 to 100°. A test stand for frictional performance of ropes and cables was adapted to gather data on the frictional behavior of safety web lashings on round wood. This presentation deals with the influence of logs in different conditions on the frictional performance of different web lashing materials. Furthermore the conclusions and guidelines for securing loads will be discussed.

Using Noise Dosimeter Data and Machine Learning For Working Operation Detection

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ABSTRACT

Since data collection on site is very time-consuming and costly, the aim of the study was to determine how accurately parts of the working time and working operations of chainsaw felling can be determined using noise dosimeter data and machine learning. For the study, a noise dosimeter and a video camera were used to record the felling of 53 spruce trees with a DBH of 8 to 72 cm. The time study and noise data were divided into a training set (27 trees) and a test set (26 trees) and analysed in the software Orange using the three machine learning methods Random Forest, Neural Network and Decision Tree. The results showed that the Random Forest method was most successful in classifying parts of the working time and operations. The effective and operating time of the chainsaw were determined with 96.0 % and 99.4 % accuracy, the main and auxiliary productive time with 92.0 % and 65.7 % accuracy and the sub-phases of felling and timber production with 84.1 % and 94.9 % accuracy. The highest accuracy in determining the work operations was observed in the case of notch- cutting and delimbing (80.3% and 89.5%, respectively), while the lowest accuracy was found for stump debarking, butt trimming and crosscutting (7.6% to 14.0%). The results show great potential for predicting time study data using machine learning.

Levels of Vibration Exposure In Cross-Cutting Operations By Chainsaw: Are They Affected By A Wrong Height of Chain Depth Gauge?

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ABSTRACT

Despite the introduction of high mechanization levels in forest operations, the use of chainsaws is still very common in many countries and many other activities, such as pruning operation, gardening and agriculture are performed using this tool, which is very dangerous. Indeed, chainsaw use exposes workers to many hazards such as noise, exhaust fumes, hand-arm vibrations (HAV), wood dust, cutting wounds, and workload. This research is focused on the vibration exposure and how it is influenced by the quality and efficiency in saw chain maintenance. In fact, while its sharpening must be performed according to the manufacturer instructions, in working conditions it is very common to find important errors in terms of sharpening angle and lowering the depth gauge. These problems could have negative consequences on cutting efficiency and chainsaw lifespan. But the most important, considering workers' safety, an excessive lowering of the depth gauge often causes a considerable increase in vibration exposure and an increased probability of kickback. Despite the safety recommendations and the increasing efforts to improve the professional level of forest workers, many of them continue operating the bad habit to lower the depth gauge of the chains under the manufacturer recommended level. Why they apply this wrong strategy? Because they are certain to obtain a higher cutting efficiency in this way, not considering the cons of this bad behaviour. For this reason, the aim of this study is to evaluate, during operations with chainsaw, the variations of both the vibrations transmitted to the operator and the cutting efficiency at different levels of depth gauge lowering (correct and excessive levels). The study was performed on European beech and Silver fir squared beams during cross-cutting operations using the same chain type (cutting teeth profile) modified at 3 different level of the depth gauge (0.65 - 1.0 - 1.3

mm). Results showed that for both species the vibration exposure increase was higher moving from 0.65 mm to 1 mm in comparison to the variation recorded moving from 1 to 1.3 mm. This increase was higher in beech than in fir, confirming the higher the basal density of wood, the higher the effects of bad habits in lowering the depth gauge. The measured daily exposures resulted significantly higher than the limits established by Italian Regulation (limit of 5 m/s2 and the daily action value of 2.5 m/s2) when the depth gauge lowering exceed the recommended level of 0.65 mm. On the contrary, applying the recommended level the exposure to vibrations resulted within the law limits for both the wood species considered. Looking at the cutting efficiency, it increased on fir only moving from 0.65 mm 1 mm, while between 1 mm and 1.3 mm no significant improvements were recorded.

What Can Forest Workers do Differently - Defining Countermeasures For Forest Accidents Through Counterfactuals of Causal Models

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ABSTRACT

The use of artificial intelligence (AI) in the investigation of occupational accidents in forestry represents a significant departure from conventional statistical approaches and provides a holistic analysis by considering multiple variables simultaneously rather than isolating individual factors. Machine learning (ML) algorithms such as decision trees (DT), random forests (RF), neural networks (NN) and tabular prior-fitted networks (TabPFN) are proving to be particularly efficient in predicting fatalities and the duration of sickness absence following forestry accidents, both in terms of time and resources. However, the explanatory power of these models is limited to extensive, complicated rules and enumerations of critical factors ordered by their relative importance. This limitation compromises their usefulness in providing comprehensive guidance for the daily decision-making processes of forestry workers.

In contrast, structural causal models (SCM) encode the dependencies between the key variables that contribute to an accident, taking into account human expertise (prior knowledge) and contextual understanding from occupational accident data sets. AI guides the computation of the functional relationships expressed by the causal dependencies, thereby being able to answer fundamental questions about the relative strength of each contributing factor with evidential reasoning. The ability to answer counterfactual questions and reasoning about alternative scenarios that are only slightly different from the original scenario, that led to a serious accident, provides forest workers with concrete suggestions on what they can do differently to avoid a fatal accident or reduce the severity of the accident. This solution is by definition better interpretable and in the realm of Actionable Explainable AI (AxAI) with the human (domain expert) in-the-loop (HITL) since the distilled insights from the counterfactual explanations define the countermeasures for accident prevention.

Operations: Powertrains, fuel and gas emissions

Tree: Transition To Efficient Electrified Forestry Transport
Gunnar Svenson, Anna Pernestål

Comparing Fuel Consumption During Timber Forwarding With and Without Traction-Assist Winch
Ferdinand Hönigsberger, Lukas Fuchs, Lukas Wedam, Thomas Holzfeind, Christian Kanzian, Christoph Gollob, Karl Stampfer

Evaluation of Post-Fire Salvage Logging Operations In Terms of Environmental Damages and The Timber Industry's Needs
Saliha Ünver, Yetkin Usta, H. Hulusi Acar

Reducing Greenhouse Gas Emissions With Liquefied Biogas (lbg) Powered Timber Truck Vehicle In Long-Distance Transportation of Industrial Roundwood
Sami Huuskonen, Kalle Kärhä, Jouni Karjalainen

Tree: Transition To Efficient Electrified Forestry Transport

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ABSTRACT

The transition to electric heavy road transport in forestry is to a great extent a system change. It is not just about replacing diesel with electrically powered vehicles, but it is required that the entire system around transport and electricity supply be developed and adapted, a development in which many of the steps must be synchronized. TREE is a project where system innovation can take place through the many parties working together and jointly creating the desired development. TREE is a project that runs over three years, and which will realize solutions for the electrification of heavy transport in an extensive system demonstration, spread over seven different locations in Sweden. The solutions that will be demonstrated include 12 battery electric timber and chip trucks with a gross vehicle weight of 64-90+ tons, mobile energy hubs, e-trailer (with battery and driven axle), advanced route planning and developed business models. The seven locations are spread from the north to the south of Sweden, representing a great variety in transport conditions. The locations will be hubs for knowledge building, research and innovation in vehicle technology innovation, electricity and charging, transport planning, business models, and system understanding. The project will also build knowledge about the impact of policies and environmental factors, as well as produce an industry-wide roadmap for transition to electrified heavy road transport. In the project, which is led by Skogforsk (Forestry Research Institute of Sweden), there are actors who represent different roles in the value chain; forest companies, logistics companies, haulage companies, loading companies, technology companies, and universities. The project's overall goal is to contribute to 50% of forestry's new trucks being electrified by 2030 and is run with support from the R&D program FFI (Vehicle Strategic Research and Innovation) at Vinnova (Sweden's Innovation Agency) and the Swedish Energy Agency. This presentation will report the barriers and opportunities regarding the electrification of heavy transport that we have identified and will address in the project, the structure of the project, as well as details regarding, for example, the vehicles that will be put into operation in 2024.

Comparing Fuel Consumption During Timber Forwarding With and Without Traction-Assist Winch

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ABSTRACT

Nearly 20 years ago, the first traction-assist winches were introduced to the market. This enabled an expansion of fully mechanized harvesting operations to steeper slopes. Concurrently, both productivity and occupational safety in steep terrain could be improved. The operating principle of traction-assist winches is to transfer driving and braking forces from the machine to the winch cable and thereby significantly reducing slippage during driving in inclined terrain. In numerous cases this has shown to minimize rut formation. On the contrary, little research has been conducted on the impact of using a traction-assist winch on the fuel and time consumption. Therefore, this study aims to investigate how the deployment of a T-WINCH 10.2 as traction assistance affects overall fuel and time consumption during extraction using a Komatsu 875. For the field test, two neighboring skid trails were selected, which had only minor terrain variations and were accessible also without a traction-assist winch. The average slope of the trails was 39%. The skid trails were driven on multiple times by an experienced machine operator, both with and without the winch assistance, loaded and unloaded. The experiments were conducted according to a predefined test procedure to randomize uncontrollable influences. The data was collected using CAN-BUS loggers to capture machine data from the forwarder and winch. The accuracy of this data was validated beforehand through refueling tests. It was found, that the fuel consumption derived from the CAN-BUS data deviated by less than 1% from the values determined

through weighing. Thus, it can be concluded that the fuel consumption obtained from the CAN-BUS data is reliably determined. The data analysis revealed an average fuel consumption of 21.9 l/h (Komatsu 875: 15.89 l/h; T-Winch: 6.01 l/h) for the forwarder using the winch assistance. For the forwarder without assistance, the average fuel consumption was 18.45 l/h. Thus, the average additional consumption per hour when using the winch was 3.45 l/h (+18.7%). In addition to its impact on fuel consumption, the winch also affects the work cycle time. An average time saving of 8.5% per load was observed, with the most significant time reductions occurring travel loaded uphill, representing a saving of 29.4%. In the overall result, and focusing on cubic meters extracted, an average consumption of 0.28 l/m3 was observed, resulting in an increased overall consumption of 10.8%. In conclusion it was shown, that even though the use of the T-Winch results in a reduction in fuel and time consumption of the Komatsu 875, this savings cannot compensate for the additional consumption caused by the winch itself. Ecological influences of traction-assist winch usage, which can also manifest positively, were not considered in this study.

Evaluation of Post-Fire Salvage Logging Operations In Terms of Environmental Damages and The Timber Industry's Needs

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ABSTRACT

Salvage logging practices generally aim to recover trees damaged by various natural disasters such as forest fires, floods, storms, disease, and insect outbreaks to the industry by minimizing the loss of economic value. Wildland fires are the main natural phenomena that significantly affect both the wood industry economically and the forest ecosystem environmentally. These practices may reduce the economic value of fire-damaged trees, change the type of wood produced (logs, poles, industrial wood, firewood, etc.), or cause direct or indirect environmental damage to the forest ecosystem. Post-fire management is usually based on the felling and extracting activities that have been damaged as quickly as possible. However, there are various concerns about both meeting the expectations of the industry and the minimizing of environmental damage associated with post-fire applications. Salvage logging practices should be planned by considering the expectations of the industry and environmental impacts, determining the damage levels on the trees, and deciding the harvesting time and the harvest techniques to be used. In this study, it was aimed to plan for post-fire salvage logging considering the needs of the industry and to assess the potential environmental impacts.

Reducing Greenhouse Gas Emissions With Liquefied Biogas (lbg) Powered Timber Truck Vehicle In Long-Distance Transportation of Industrial Roundwood

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ABSTRACT

The European Union is committed to decreasing greenhouse gas (GHG) emissions by 55% by 2030 compared to 1990. Furthermore by 2030, the goal is to increase the share of renewable energy to 24% in the transportation sector. Methane can be used in road transportation to replace fossil oil-based fuels. Heavy-duty long-distance truck vehicles can use liquefied natural gas (LNG) or liquefied biogas (LBG). The second LBG-powered timber truck vehicle in Europe started hauling for Metsähallitus in northern Finland in summer 2022. The LBG timber truck configuration consists of a Volvo FH LNG 460 truck tractor and trailer. The maximum gross vehicle weight (GVW) allowed of this configuration is 69 tonnes.

University of Eastern Finland and Metsähallitus are investigating the energy efficiency and GHG emissions of the LBG timber truck configuration in a long-term follow-up study that began in January 2023 and ended in December 2023. In the study, the reference vehicle was a normal diesel-powered Scania R660 timber truck configuration with maximum GVW of 76 tonnes. The LBG vehicle transported 553 payloads and the reference vehicle 676 payloads during the study. CO2 emissions were calculated with well-to-wheels (WTW) method, i.e., emissions generated throughout the entire lifecycle of fuel were determined according to fuel consumed and using emission factors based on the ISO 14083 standard.

Based on preliminary results, the WTW emissions of a laden LBG vehicle averaged 49.3% lower than those of the reference vehicle applying a measure of kg CO2 100 km-1 and 46.1% lower with the measure of kg CO2 tkm-1. With empty vehicle, the WTW emissions of LBG vehicle averaged 48.7% lower than those of the reference vehicle. The preliminary results of the study revealed that biogas can significantly reduce particularly WTW emissions in the long-distance transportation of industrial roundwood.

Logistics: Roads, logistics and supply chains

Blockchain Prototype In The Forest Supply Chain
Lukas Stopfer

Optimization of Techno-Economic Wood Procurement From Renewable Forests For Offsetting The Needs of Industry Against Those of The Environment
Teijo Palander

Timberport - Central Installation For Intermodal Roundwood Logistics
Hans-Ulrich Dietz, Julia Kemmerer, Florian Winter

A Sensor Solution For Automated Measurements of Forest Roads
Mostafa Hoseini, Helle Ross Gobakken, Stephan Hoffmann, Csongor Horvath, Johannes Rahlf, Jan Bjerketvedt, Stefano Puliti, Rasmus Astrup

Assessment of Risks By Making Some Environmental Measurements In The Wood and Furniture Industry
Hafiz Hulusi Acar, Tolga Barisik

Blockchain Prototype In The Forest Supply Chain

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ABSTRACT

Blockchain technology has the potential to revolutionise the forestry industry by providing a transparent and secure way to track and verify the origin and movement of forest products. By enabling the secure tracking of forest products, blockchain can improve the forestry industry. Supply chain transactions can be recorded in a decentralised 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 CO_2. However, there are challenges, including ensuring accurate data and engaging stakeholders. However, it is important to note that the implementation of blockchain technology in the forest industry is still in its early stages and there are challenges to overcome, including ensuring the accuracy of data recorded on the blockchain and engaging all relevant actors in the supply chain. The joint project "Blockchain Technology as a Driver for the Digitalisation of Forestry" specifies the potential, develops the technical requirements and determines the potential and acceptance of market participants 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. At the same time, the follow-up project to implement a prototype blockchain application in the timber supply chain will show first results, opportunities and challenges. 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 forest-wood chain will be explained and classified.

Optimization of Techno-Economic Wood Procurement From Renewable Forests For Offsetting The Needs of Industry Against Those of The Environment

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ABSTRACT

The importance of the security of wood supply has been emphasized in recent years due to the environmental issues and changes in operating environments. Thanks to resiliency in wood procurement, organizations with decentralized plants may be able to quickly adapt to the changing needs of society toward Industry 5.0. The main aim of this study was to increase the sustainability of these plants' wood procurement by modeling and optimizing it for determining the company's profitable wood procurement region while keeping the forests renewable. The sustainability of wood procurement was assessed by considering the additional costs caused through the EEAP mechanism if the carbon sink of the forest worsened due to wood procurement in the area. The supply chains were compared so that the sawmill managers could adopt the best wood value chains to their own and customers' mills. The results showed that updating the procurement strategy would be necessary. The sawmill managers should purchase wood more by themselves from a larger procurement area than the current one instead of using delivering purchases of wood. The Techno-Economic Wood Payment Ability Model was a useful part of the DSS in guiding wood buyers toward environmentally sustainable wood procurement by increasing the share of renewable forests.

Timberport - Central Installation For Intermodal Roundwood Logistics

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ABSTRACT

The accumulation of forest damage in the main tree species due to climate change, a declining number of employees at truck transport companies and the need to reduce carbon emissions while increasing resource efficiency in the timber supply chain are leading to ongoing efforts to significantly increase the share of roundwood by rail transport for long-distance sales. The current federal government in Germany has set the ambitious target of increasing rail freight transport to 25 per cent by 2030. The basic concept for optimising intermodal timber logistics is the identification of supply areas and the implementation of logistics hubs, known as Timberports. In a recently finalised R&D project with the acronym "VEHIT", solutions for intermodal transport logistics were investigated in a showcase in Bavaria in order to promote roundwood transport by rail. Joint partners in R&D project funded by the German Federal Ministry of Food and Agriculture have been DB Cargo Logistics, the German rail service company and Bayerische Staatsforsten (BaySF) as well as associated forest owners and timber marketing associations. Prerequisite for a systematic shift of truck volumes to rail is a high and stable volume of roundwood by bundling and smoothing seasonal fluctuations in demand through the temporary storage of supply volumes as well as levelling seasonal fluctuations in demand by temporarily storing supply volumes, buffering and targeted volume control in the event of calamities, and continuous timber removal out of the forest. On the other hand, ensuring the supply of railwagons and its efficient use by the logistics service provider are elementary components for optimising transport by rail. Various business models were developed for the establishment and ongoing operation of Timberports and then analysed from an economic perspective. These Timberports are characterised by a commensurate loading infrastructure, additional storage capacities and possibly add-on services. In a site analysis, suitable locations were identified for the project region that have the potential to continuously supply Timberports with roundwood. These Timberports were then integrated into the systemic communication and information technology process in roundwood logistics of the partners involved. A summary of the most important operating and business models will be presented. By creating storage areas at the Timberports, efficient whole train transport can also be realised and transport and organisational costs can be reduced through regularly scheduled train runs.

A Sensor Solution For Automated Measurements of Forest Roads

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ABSTRACT

This presentation outlines conceptual design and technical aspects of a recently developed sensor solution for the automated measurement and analysis of forest roads' geometric features. Forest roads play a pivotal role within the forest infrastructure, serving multifaceted socio-economic functions that span from facilitating forest management and operational activities to providing different ecosystem services. Given their significance, regular assessments of forest roads conditions are necessitated, driven by the dynamic nature of their usage patterns and the varying stresses they endure over different seasons. The RoadSens system, developed as part of the SmartForest project, offers an end-to-end solution comprised of two main components: an integrated proximity sensing platform and edge- or cloud-based data processing software. This system utilizes advanced technology, including a stereo camera for 3D perception of the road and a Global Navigation Satellite System (GNSS) module for georeferencing of measurements and longitudinal road geometric features. With a data handling engine capable of recording and processing data streams from the stereo camera at 30 or 60Hz and GNSS at 10Hz, RoadSens provides a practical monitoring tool for retrieving detailed information about forest road

conditions. Moreover, the platform's flexibility allows it to leverage cloud infrastructure for efficient post-processing tasks, enhancing its overall performance and usability. The primary data product provided by the system comprises information derived from the longitudinal profile, such as horizontal and vertical road curvatures, slope measurements, and cross-sectional details obtained at predefined intervals. These cross-section parameters include the road width, center point, side-slopes, and pertinent information regarding ditches, including their location, depth, and distance from the road's edge based on their visibility in the camera. The detailed data products generated by RoadSens have the potential to significantly improve the capture and documentation of road geometry with high spatial resolution, thereby addressing a key challenge in remote sensing approaches for evaluating forest roads. In conclusion, the RoadSens system presents a promising advancement in the automated measurement and analysis of forest road geometry, offering relevant and timely information for forest management and maintenance operations.

Assessment of Risks By Making Some Environmental Measurements In The Wood and Furniture Industry

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ABSTRACT

This research is a study conducted to instill occupational health and safety awareness among employees in order to ensure more efficient occupational health and safety in a business that produces wooden furniture. For this purpose, it is aimed to prevent work accidents, occupational diseases and injuries by predicting the risks that may occur due to work accidents, occupational diseases and injuries that occur in the enterprise. Because of the structure of wooden furniture, the machining process is commonly used, and occupational disorders are frequently noticed in workers who are exposed to noise, vibration, and dust for extended periods of time. Many quantitative and qualitative methods are utilized in risk assessment, and this study used the Failure Modes and Effects (FMEA) risk analysis method to ensure the preliminary identification of occupational diseases, work accidents, and injuries. Measurements were taken one by one using the essential devices to learn the values of dust, noise, temperature, vibration, and light in the workplace. The measurement results were statistically modeled and interpreted. Additionally, flaws in the working environment were discussed in conjunction with the measurements taken. It is a study conducted to establish a healthier and safer working environment for employees, to assure employee comfort, and to contribute to greater work efficiency. The findings of this study were determined to be relevant to existing workplaces and similar businesses.

Operations: Young forests, debarking heads and forest management

The Effect of Cutting Technique On The Mortality and Resprouting Vigour of Hybrid Poplar Stumps
Benno Eberhard, Natascia Magagnotti, Barnabáš Kovacs, Julija Konstantinavičienė, Raffaele Spinelli

Use of Harvesters With Debarking Head In Temperate Forests
Erwin Ulrich, Philippe Ruch, Xavier Montagny, Nina Bonche, Didier Pischedda, Stefan Wittkopf, Andrea Hauck, Joachim Heppelmann, Caroline Bennemann, Armand Clopeau

Debarking In Whole-Tree Cable Yarding Operations As A Measure For Bark Beetle Management
Franz Holzleitner, Stephan Böhm, Elias Amerhauser, Christian Kanzian

Exploring Forest Management Practices: Insights From Individual Forest Owners In South Savo, Finland
Jyri Mulari, Mika Aalto, Tapio Ranta

Leveraging Machine Data For Optimized Forest Management
Janine Schweier, Marc Werder, Elisa Plozza, Barbara Schneider, Stefan Holm

The Effect of Cutting Technique On The Mortality and Resprouting Vigour of Hybrid Poplar Stumps

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ABSTRACT

Short rotation coppice is a modern industrial crop and its profitability depends on the mechanization of all management operations. Once the crop is mature, trees can be felled with a variety of machines, but shears represent the most effective solution. However, shears can inflict a certain degree of stump damage, which has raised concerns about stump mortality and re-sprouting vigour - both crucial to coppice regeneration. This study compared the mortality and resprouting vigour of stumps cut with shears and with chainsaws – the latter representing the control treatment. Measurements were taken on 6 compartments on 5 sites. On each compartment, 10 sample plots were established, each consisting of two parallel row segments containing 10 live stumps each (e.g. 20 stumps per sample plot). One row segment was cut with a shear-type felling head, the other with a chainsaw-type felling head. One year after cutting, researchers determined for each stump the following parameters: diameter of the stump, number of live shoots, diameter and height of the 5 tallest shoots. Data were pooled into a structured database and statistically analyzed using R open software. Clone selection and site fertility had a very strong effect on stump mortality and resprouting vigor – the former possibly more dependent on clone, the latter on site fertility. Cutting technique had no effect on stump survival and a very small effect on resprouting vigor, which was represented by a consistently larger number of shoots on stumps cut with shears. The data also suggested that the five dominant shoots sprouted after shear cutting might not grow as fast as those sprouted after chainsaw cutting, but the statistics were inconclusive in that regard. If so, a likely explanation could be found in the harder competition resulting from the larger number of shoots; that would reduce the growth potential of dominant individuals on less fertile sites.

Use of Harvesters With Debarking Head In Temperate Forests

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ABSTRACT

Debarking helps to reduce the populations of sub-cortical pests (e.g. bark beetles) during heavy infestations, in order to prevent their spread. In the long term, debarking allows the nutrients contained in the bark to be returned to the soil. Compared with wood, the concentration of major elements contained in bark is up to 25 times higher. On moderately poor sites, this will make it possible to produce wood without having to amend or fertilize several times, and even without having to adapt the harvesting method. On very poor sites, this could limit the sometimes-restrictive harvesting recommendations for

small trees. The study allowed to test the debarking technique using logging machines equipped with a specific kit based on the experience acquired in Germany. 4 test logging operations were carried out in the north-east quarter on France in 2021 and 2022 in fir and spruce stands. These trials made it possible to determine the main characteristics of this new technique: productivity, debarking rate, reliability of length measurement, machine settings, etc. Integrated in-stand debarking with a harvester is a technique that is worth developing. It requires only limited investment and does not compete with the use of bark in sawmills, since it will only be used on limited surfaces or in the event of health crisis.

Debarking In Whole-Tree Cable Yarding Operations As A Measure For Bark Beetle Management

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ABSTRACT

Bark beetle calamities, which are mainly triggered by climatic impacts such as storms, temperature stress or even snow breakage, are increasingly affecting the roundwood supply in mountainous regions. This leads to unscheduled volumes and oversupply which challenges the responsible participants along the supply chain. Transportation and storage capacities of processed logs reach their limits. Interim storage facilities can support the supply chain and ease the tense market situation. However, storage of roundwood close to or in the forest must meet phytosanitary requirements. For this reason, immediate debarking at the forest road during processing can serve as a technical measure to effectively reduce the breeding potential for bark beetles to reduce the risk of mass propagations and could have a positive effect on the wood quality development after harvest. The aim of this contribution is to present the results of an ongoing research project that aims to evaluate integrated processor debarking at the forest road during whole tree cable yarding operations. During field experiments the truck mounted tower yarder Konrad Mounty 5000 was equipped with a Konrad Woody H60 processing unit. The processor was equipped with special designed feed-rollers combined with adapted pressure-settings of the delimbing knives. The observed harvesting operations took place in spruce dominated stands, each covering cable lines with and without integrated debarking as treatment- and control groups. The harvesting operations were recorded by two video cameras. Tree data and terrain information were linked to the video data during post-processing. Using structure from motion technique, debarking-quality was examined on the basis of remaining bark surface on 24 randomly selected logs per variant. Subsequently, the breeding-potential of the remaining bark strips was evaluated. Therefore the logs were stored near a wood yard and analyzed weekly regarding wood- and bark breeding insects. Additionally, probes were taken weekly from the same logs to monitor the development of blue-stain in the sapwood, caused by fungi. The results to present will focus on the additional effort for integrated debarking during processing. Furthermore, the debarking quality will be assessed with regards to a phytosanitary effect and a positive effect on wood quality development after harvest.

Exploring Forest Management Practices: Insights From Individual Forest Owners In South Savo, Finland

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ABSTRACT

This study presents the results of a 2022 survey of forest management practices among private forest owners in South Savo, Finland. The survey received responses from 715 of 3000 distributed questionnaires, with a focus on young forest harvesting and the boom-corridor method. The survey respondents were predominantly aged 45 to 65 (50%), with 36 percent over 65 and a smaller proportion under 45. (15 %). The majority were males (73 %). The most common occupational status was retired (38%), recognizing the role of forestry in retirement. Farmers accounted for 12 percent, with other entrepreneurs accounting for 11 percent, reflecting the region's link between forest ownership and agriculture. In terms of education, 9 percent had a primary education, 46% had a secondary education, and 43% had a higher education. Respondents' high levels of education may have an impact on their forest management practices and attitudes toward alternative methods such as boom-corridor and continuous cover forestry. Forestry was identified as the primary goal for 70% of respondents, emphasizing the significance of effective forest management. However, it is important to note that thinning young forests is frequently a loss-making operation for the forest owner. The findings revealed mixed feelings toward the boom-corridor method, with curiosity balanced by skepticism. The survey also revealed a keen interest in alternative forest management strategies, such as continuous cover forestry. A significant correlation (0.5) was discovered between interest in the boom-corridor method and continuous cover forestry. This implies that forest owners see the boom-corridor method as a viable option for transitioning from even-aged to uneven-aged forests. Disappointments were reported in the energy wood trade, particularly in terms of pricing, payment terms, and schedules, echoing previous research. Some respondents had a general concern about directing wood primarily for industrial use, but price was most frequently cited as the deciding factor for where the wood is sold. Forest owners who actively manage their forests are more aware of the importance of logging and are more likely to trade wood. These findings add to the ongoing discussion about sustainable forest management practices by providing valuable insights into the perspectives and preferences of individual forest owners in Finland. They emphasize the complexities of sustainable forest management practices and the need for additional research and discussion on these topics.

Leveraging Machine Data For Optimized Forest Management

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ABSTRACT

To enable data exchange between machines and users, as well as among machines, the international data standard StanForD was developed in the 1980s. The current version, StanForD2010, was introduced in 2011 and is based on XML. The most crucial data for harvesting performance is stored in hpr (harvested production), fpr (forwarded production), and mom (operational monitoring) files. Most commonly collected data include machine operating hours and distance traveled; performance; work cycles including start and end times, as well as the duration of specific subtasks; data on felled trees, processed logs and loaded wood; real-time machine positions with recorded location coordinates; fuel consumption; information on the machine's operational status, and details about performed maintenance activities. An open-use model was developed that can read those data and present it in a user-friendly way allowing real-time monitoring and control of machinery. Most importantly, the data enable obtaining key production metrics that can be further utilized in business calculations and logistics. Maintenance planning is supported, and operational processes are optimized. Consequently, data from logging machines contribute to enhancing efficiency, productivity, and sustainability in forestry. The presentation will demonstrate possibilities and limitations of the tool by using demonstration cases.

Operations: Planting, tending and guillotine cutting head

An Innovative Truck-Mounted Cable Yarder Capable of Positioning The Tower In Sloping Conditions
Federico Bertone, Marco Manzone

An Operational Compromise For Forest Tending In Protected Areas
Natascia Magagnotti, Benno Eberhard, Raffaele Spinelli

Productivity of Forest Restoration With Small-Scale Technologies
Matevž Mihelič, Natascia Magagnotti, Raffaele Spinelli

Mill-Logger Relationships and Timber Procurement Practices In The Us South
Joe Conrad, Puneet Dwivedi

The Efficiency of A Crawler Excavator With A Guillotine Cutting Head In The Harvesting of Energy Wood In Estonian Conditions
Marek Irdla; Allar Padari; Ahto Kangur; Peeter Muiste

An Innovative Truck-Mounted Cable Yarder Capable of Positioning The Tower In Sloping Conditions

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ABSTRACT

The transition from ground-based harvesting systems to cable-based timber extraction is necessary for gradients from 20% to 40%, depending on factors like surface roughness and slope length. For operating on slope up to 40%, the use of cable yarders is the most widespread production method in the Alps, particularly in countries, where cable cranes are manufactured, such as Austria, Switzerland, and Italy. In Italy, about 45% of the forests are characterized by slopes higher than 41% and considering only the Alpine Regions, they have a steep terrain rate higher than the national average. However, cable yarders need of flat landing for place them and for processing and stacking material. Sometimes, placing the machine in a flat location is not possible. The aim of the research was to design and analyse the performance of a self-propelled cable yarder capable of tackling existing forestry roads and being able to quickly install it on any slope. The base machine of the cable yarder is a small off-road truck, and the cable yarder is installed on roll-off system that permit to remove it and change the base machine or change the possible activity of the base machine (wood transport, wood chipping…). The tower is able to tilt ±50° compared to the orthogonal of the frame, guaranteeing its verticality in different working conditions. The use of this machine reduces the time needed for set-up by around 50%, enabling an increase in productivity of 20% if compared with standard cable yarders. Excellent results were also obtained in the positioning of the cable yarder on steep slopes, where the experimental tests carried out showed reduced cable crane set-up times in the face of modest earthmoving works. It was only necessary to carry out a slight levelling of the ground with a surface area of approximately 1 m2 in order to place a support of logs to support the base of the tower. This outcome guarantees the possibility of being able to work on forest stands in disadvantaged stationary situations, even by small forestry companies that do not always have the investments necessary to purchase specific machinery and expensive equipment.

An Operational Compromise For Forest Tending In Protected Areas

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ABSTRACT

The integration of draught animals with modern forest machines may offer an innovative solution to forest tending in protected areas. With this new system, machine traffic is constrained on pre-designated access corridors set 50 m apart, while trees are cut with chainsaws and dragged to the corridor's edge by draught horses. The operation presented in this study included one chainsaw operator, two draught horses with their driver, an excavator-based processor with its driver and a helper equipped with a chainsaw for knocking off forks and large branches, and a light forwarder (7 t) with his driver. That operation achieved a productivity in excess of 4 m3 over bark per scheduled hour (including delays). Harvesting cost was estimated at 53 € m-3, which was between 15% and 30% cheaper than the traditional alternatives. What is more, the new system increased labor and horse productivity by a factor 2 and 7, respectively; that can effectively counteract the increasingly severe shortage of men and animals.

Productivity of Forest Restoration With Small-Scale Technologies

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ABSTRACT

The research delineates the various forest interventions implemented on small-scale forests (< 2 ha) by seven crews under the management of the Forest Service in Verona, Italy. These interventions aimed to restore degraded forests. Data spanning 17 years and covering 340 worksites were collected from the operational records of these crews. They were analyzed to assess operational performance and identify medium-term trends in intervention types and efficiencies.

Primarily, the crews were entrusted with aiding forest owners in carrying out unprofitable interventions that would otherwise have been neglected. The majority of such interventions involved thinning (or salvage) operations in softwood plantations and the transformation of abandoned beech and mixwood coppice stands into high forests. Over time, thinning in softwood areas became predominant, and the conversion of coppice stands was discontinued altogether after 2014.

The duration needed for felling and processing varied significantly, ranging from 15 to over 80 worker days per hectare, contingent upon stand and operation types. Productivity levels fluctuated between 1 and 8 cubic meters per worker day. The median values for fuel consumption (chainsaws only) averaged 0.4 liters per cubic meter or 38 liters per hectare.

Mill-Logger Relationships and Timber Procurement Practices In The Us South

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ABSTRACT

Thousands of independent logging businesses are the critical link in the wood supply chain that harvests timber from public and private forests and delivers it to forest products mills. Logging businesses in the region have been struggling with losses of businesses and workers, low profitability, aging business owners and equipment operators, and insufficient recruitment of new owners and equipment operators. Timber procurement practices by forest products mills can have a major impact on the profitability of logging businesses, yet timber procurement practices are seldom studied. We conducted a mail survey of 654 forest products mills in six states in the US South to document timber procurement practices and assess the relationship between logging businesses and forest products mills. Ninety-five mills responded, yielding an adjusted response rate of 16%, which is similar to other surveys of this population. Pulp mills relied on an average of 85 logging businesses to supply their facility with timber compared to 30 for softwood sawmills. Pulp mills and softwood sawmills purchased the largest percentage of their raw material from wood dealers with whom they held a contract, followed by gatewood purchases, and purchases directly from logging businesses. Wood dealers serve as "middlemen" and purchase timber from landowners and market it to mills but may not own timber harvesting equipment. Gatewood refers to timber purchased "at the mill gate" that was not under a supply contract prior to its delivery. Eighty-nine percent of mills reported that the number of logging businesses in their area declined in the past five years and 76% expected further declines in the next five years. The majority of mills were satisfied with the operational efficiency and reliability of logging businesses but fewer than half were satisfied with the innovativeness and financial stability of logging businesses. Fewer than 40% of mills perceived that new logging businesses understood logging costs and conducted market research before investing in their business. This and other research suggest that improved communication and coordination between mills and logging businesses would improve the viability of logging businesses in the region.

The Efficiency of A Crawler Excavator With A Guillotine Cutting Head In The Harvesting of Energy Wood In Estonian Conditions

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ABSTRACT

One of the key objectives of the still valid Estonian national energy and climate plan 2030 is the reduction of GHG emission in Estonia by 80% by 2030. But now, to contribute the goals of the European Green Deal, Estonian Government has declared the commitment to reach climate neutral by 2050. Achieving the targets, the use of wood fuels should increase. In this study, the procurement of energy wood with crawler excavators equipped with guillotine-type cutting heads is documented. The crawler excavators examined in the study were the Doosan DX160LC and the Komatsu PC170LC, both of which utilized the same type of guillotine cutting head, namely the MTM SKOPRION 3010. Both crawler excavators were brand new at the commencement of the work, and the study was conducted over 3500 working hours for each machine. The average fuel consumption was calculated in liters per working hour, ranging from 9.1 l/h for the Doosan to 11 l/h for the Komatsu. The difference in fuel consumption was undoubtedly influenced by the weight disparity between the machines; the Doosan weighing 16 tons and the Komatsu weighing 20 tons. Productivity for the machines was 21 ml3/h per working hour for the Doosan and 18 ml3/h for the Komatsu. This disparity may also be attributed to the experience levels of the machine operators. The work was primarily carried out in the clearing of overgrown properties, and the tree species to be felled included gray alder, silver birch, aspen, black alder, spruce, and pine.

Impacts: Soil, water and nutrients

Disturbances To The Forest Soil of Ground-Based Logging and Related Recovery Time: Insights From Central European and Mediterranean Beech Forests
Francesco Latterini, Paweł Horodecki, Marcin K. Dyderski, Rachele Venanzi, Rodolfo Picchio, Andrzej M. Jagodziński

Assessment of Soil Parameters In Response To Repeated Wheeling
Julian Grünberg, Franz Holzleitner, Maximilian Behringer, Christoph Gollob, Ralf Kraßnitzer, Christoph Haas, Klaus Katzensteiner, Boris Rewald, Lisa Gasser, Barbara Kitzler, Armin Hofbauer, Christian Scheidl, Marcus Froemel, Martin Kühmaier

An Approach To Balance Nutrient Exports and Nutrient Recycling In The Future - Quantification of Element Contents In Different Wood Chip Size Fractions
Markus Riebler, Katharina Wendel

Comparing Water Quality Best Management Practice Implementation and Estimated Erosion From Conventional and Wood Pellet Harvesting Operations In The Southeastern U.s.
Hannah Bays, Chad Bolding, Joseph Conrad, Holly Munro, Scott Barrett, Alicia Peduzzi

The Relevance of Criteria and Indicators For Sustainable Timber Harvesting From The Perspective of Different Stakeholders
Martin Kühmaier, Julian Grünberg, Thomas Schranz

Ruth Depth Prediction In Boreal Forest Based On Open-Source Data and Machine Learning
Son Cao, Omid Abdi, Jori Uusitalo

Disturbances To The Forest Soil of Ground-Based Logging and Related Recovery Time: Insights From Central European and Mediterranean Beech Forests

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ABSTRACT

Understanding and mitigating the environmental concerns related to ground-based logging is one of the key aspects of sustainable forest management and a fundamental issue for achieving the goals of the newest European strategies in terms of forests, soil and biodiversity. On the other hand, studies dealing with a holistic assessment of the disturbances that ground-based logging can imply to the soils of beech forests are missing. Furthermore, there is a clear knowledge gap concerning the recovery time that forest soils need to return to the pre-harvesting conditions. The assessment of environmental impacts, with a particular reference to soil disturbance, related to ground-based timber extraction in Mediterranean and Central European beech forests is properly the main goal of the project AIMSUSFOR, which I am currently managing in the framework of my Marie Curie Grant at the Institute of Dendrology of the Polish Academy of Sciences. 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, as well as litter decomposition rate, related to ground-based timber extraction in shelterwood interventions in beech forests. This presentation reports the overall results of the project which is going to finish on 30/06/2024. We found that in the framework of Mediterranean forestry, characterised by a medium-mechanisation level, soil physicochemical features and microarthropods biodiversity are strongly impacted by ground-based logging, but a 10-year period is enough to let the forest soil recover. Data concerning Polish study areas and litter decmposition rates in both Poland and Italy are still under analysis, and will be presented for the first time in the conference.

Assessment of Soil Parameters In Response To Repeated Wheeling

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ABSTRACT

Within the wood supply chain, timber harvesting plays a crucial role, especially with the growing importance of the bioeconomy. The increased utilization of efficient, fully mechanized harvesting systems, however, raises concerns regarding their potential negative impacts on soil health and functions, particularly on and in the vicinity of skid trails. This study focused on the effects of repeated wheeling by a fully mechanized timber harvesting system on various soil properties in a mixed stand dominated by Picea abies located in Upper Austria. The study site is located on Stagnic Cambisol formed on silty Molasse sediments, partly covered with Pleistocene gravel and loess deposits. To assess these logging effects, we utilized four portable wheel load scales to estimate the surface contact pressure per single wheel of both empty and loaded machinery for each pass. Soil rutting was evaluated using terrestrial laser scanning and Structure from Motion (photogrammetry). Penetration resistance was measured using an Eijkelkamp Penetrologger. Both were assessed before and after the harvester passed, twice during forwarding and after extraction was completed. Undisturbed soil cores for the determination of soil moisture content, bulk density, total porosity, and C/N ratio were sampled initially, after the harvester pass, and after the final pass of the forwarder (twelve loaded passes). Control measurements and samplings were performed before the harvest for comparison purposes. Preliminary findings indicate a minimal incidence of soil rutting, with more pronounced effects observed on skid trails with higher clay content. The peak of penetration resistance occurred at a soil depth ranging between 5 and 10 cm. The harvester pass exhibited a comparable effect (2.4 MPa; control = 1.2 MPa) to the cumulative passes of the forwarder (3.7 MPa). Further laboratory examinations on bulk density and C/N ratio are expected to confirm these observations. Consequently, the low soil moisture content of 10 Vol.–% during timber harvesting contributes positively to soil stability at the end of a pronounced drought period. The preliminary results emphasize the strong impact of the initial pass of the harvester.

An Approach To Balance Nutrient Exports and Nutrient Recycling In The Future - Quantification of Element Contents In Different Wood Chip Size Fractions

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ABSTRACT

In recent years, continuing bark beetle calamities led to high supply of low-quality raw wood chips. To meet the specifically demanding quality requirements of small-scale combustion systems these fuels must be processed technically. During the screening process, fines, needles and bark particles are removed, as they would otherwise have a negative effect on combustion (e.g. higher emissions and ash content). However, screening residues contain a higher proportion of nutrients and organic ingredients compared to their volume. At present, these residues are mainly composted or incinerated in large-scale heat and power plants and are there for permanently unavailable for forest sites. The Bavarian State Institute of Forestry investigates whether screening residues could be redeployed to forest sites as a natural "fertilizer" or buffer to mitigate nutrient exports due to harvesting operations. Thus far, the state of knowledge does not provide data on overall quantity or proportional nutrient content in wood chip screen residues for respective sieve sizes. Therefore, a new method for measuring the distribution of nutrients in different particle fractions was developed. 30 samples of wood chip screening residues as well as their source raw material (if available and retraceable) were collected to provide an overview of current practices of the Bavarian market. Based on EN ISO 17827-2 for particle size distribution in wood chip samples, the standardised sieve sizes were adapted to the dominant particle sizes in residues and source material. Two further sieve fractions (1 mm – 3,15 mm and < 1 mm) we installed below the standard fine fraction (< 3.15 mm). A first, statistical analysis of the proportional occurrence of particle sizes showed a prevalent inclination towards smaller fractions in the source raw material (8 mm – 16 mm at 30 %, 16 mm - 31,5 mm at 22 %). The most used sieving sizes known from a former case study were 10-12 mm, 5 mm and 18-20 mm. At present, all samples have been compartmentalised in the predefined particle sizes (according to EN ISO 17827-2) and will be milled to analysis grain size (< 63 µm) for the elemental analysis by a benchtop XRF spectrometer. Of particular interest is the fraction containing the highest amounts of essential nutrients, which are crucial for tree growth and the forest ecosystem, such as N, Mg, Mn, P, etc. This allows to determine an optimal sieve size for nutrient availability and forest growth and guidelines for future nutrient-optimised wood chip supply could be developed.

This new method could help to derive a nutrient-optimal wood chip screen size for different wood chip assortments and support wood chip suppliers in determining which screen sizes are most advantageous for nutrient recycling to buffer nutrient exports from forest ecosystems.

Comparing Water Quality Best Management Practice Implementation and Estimated Erosion From Conventional and Wood Pellet Harvesting Operations In The Southeastern U.S.

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ABSTRACT

Wood pellet feedstock sourced from the southeastern U.S. has become an important renewable fuel for energy production in Europe. Concerns associated with pellet feedstock harvesting operations include increased removal of woody debris compared to conventional harvests, and the ability to adequately protect water quality using conventional forestry best management practices (BMPs). Decades of research have documented the effectiveness of properly implemented BMPs at protecting water quality and aquatic systems during forest operations. In contrast, limited research has been directed at BMP efficacy associated with biomass harvesting and essentially none has addressed wood pellet harvests specifically. To better understand how existing BMPs protect water quality during biomass harvests, we evaluated 51 recent (<1-yr) operational harvests in the southeastern U.S. and assessed predicted soil erosion and BMP implementation on conventional and wood pellet feedstock harvests. BMP implementation was scored using state BMP audit questionnaires and erosion was estimated using the Universal Soil Loss Equation (USLE). Results will determine if there is rational for specific guidelines on wood pellet feedstock operations, or if conventional BMPs are sufficient to meet forest sustainability goals.

The Relevance of Criteria and Indicators For Sustainable Timber Harvesting From The Perspective of Different Stakeholders

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ABSTRACT

This study presents findings from a systematic literature review covering the years 2017 to 2022, focusing on sustainable timber harvesting operations. Out of 423 selected studies emphasizing the impact of timber harvesting technology, 33 criteria were identified as relevant for evaluating sustainability. To assess the importance of these criteria, an online survey was conducted among Austrian stakeholders between April and May 2023, with 599 participants solicited and a response rate of 48%.

The survey respondents, primarily male (94%) with an average age of 47 years and an average work experience of 20 years, held responsibilities in various aspects of timber harvesting operations, including planning (80%), execution (36%), controlling (77%), analysis (57%), or consulting (46%). Predominantly utilized harvesting machines included chainsaws (97%), tractors with winches (93%), cable yarders (76%), harvesters (73%), forwarders (69%), skidders (57%), tractors with trailers (51%), and manual or animal-assisted timber extraction (49%).

Across all stakeholder groups, critical criteria identified for sustainable timber harvesting operations encompassed work hazards, residual stand damage, timber quality loss due to poor work performance, biomass regeneration, water erosion, noise exposure, soil rutting, physical workload, working conditions, and vibration exposure. While productivity, cost, and fuel consumption were not considered critical by most stakeholders, they were considered highly relevant by research institutions and harvesting companies, likely due to their use in scientific comparisons and economic considerations. Similarly, criteria related to machine-soil interaction, such as machine trafficability, soil rutting, and compaction, were prioritized by most stakeholders but received comparatively less emphasis from administration authorities and harvesting companies. Research institutions are particularly interested in minimizing impacts on humans. Notably, differing stakeholder preferences were observed due to the focus on different machines, leading to varied assessments of criterion relevance. The identified stakeholder preferences will be used to develop of a decision support model for sustainable timber harvesting in mountain forests, using these criteria as input parameters.

Ruth Depth Prediction In Boreal Forest Based On Open-Source Data and Machine Learning

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ABSTRACT

One of the major concerns in modern forestry revolves around the environmental impacts stemming from machine trafficking, especially in terms of rutting and compaction. Extensive research efforts in recent years have explored the relationship between soil properties and bearing capacity of forest soils across various types, including fine-grained forest, mid-grained forest, and peatland forests. While significant strides have been made in hydrological modelling of forest soils, models that overlook soil properties tend to poorly predict water content and trafficability. Despite a general understanding of the causes of rutting, the development of suitable predictive models and operational procedures to anticipate and visualize the probability of rutting for forest machine operators prior to operations remains a significant challenge. The Forest Centre of Finland (Metsäkeskus) conducts annual inventories at roughly 100 thinning sites with a specialized post-harvest quality control method. The method involves inventorying all trees within 5-10 circular plots. Additionally, rut depth measurements are taken along the closest logging trail. With precise knowledge of the of the tree plots and rut inventory lines, we complemented the field data with all relevant information sourced from various open-source portals. These data include topography factors, permanent soil attributes (soil texture, etc.), non-permanent soil factors (including the depth-to-water index, timing of operations, snowfall, precipitation, etc.), as well as the distance to ditches or ditch density. We selected 40 sites with a normal distribution across Finnish forest, comprising 420 sample plots and 425 rut measurement points for our investigation. Subsequently, we overlaid a hexagonal tessellation, each cell measuring 100 sq.m, onto the selected sites. Rut depth (the target variable) values and predictor variables (e.g., topography, soil characteristics, non-permanent soil attributes, and hydrology) were aggregated within the cells of the tessellation. We then utilized approximately 420 cell-samples, encompassing all variables including the target and predictors, to train a Random Forest regression model with optimal parameters for predicting rut depth. Our findings demonstrate the efficacy of the trained Random Forest model in predicting soil rut depth, emphasizing the importance of comprehending the dynamic interplay between soil rutting and its determining factors for fostering sustainable forest management practices. In this presentation we will show how different data structures were created and combined, along with the introduction of our trained machine learning-based models designed to predicts probabilities of rut depths in both mineral and peaty forest soils. We will discuss the appropriateness of the modes developed in assisting forest machine operators in planning and execution of daily operations.

Precision: Timber measurement, gross volume and bucking

Analysis of The Influence of Reference Dimensions On The Estimation of Gross Volume of Stacked Roundwood: A Case Study In Poland
Karol Tomczak, Felipe de Miguel-Diez, Jakub Matysiak, Marta Pędzik, Marek Szychta, Arkadiusz Tomczak, Tomasz Jelonek

Assessment of Felling Technique, Based On Stump Dimensions and Individual Logger Characteristics
Luka Pajek, Anton Poje

Timber Measurement and Conversion Factors: A Comparison Between Harvester, Optoelectronic Log-By-Log, Section-Wise Manual and Photo-Optical Measurements As Well As Log Truck Load Scans For Volume Assessment
Ferréol Berendt, Iman Bajalan, Felipe de Miguel Diez, Tobias Cremer

Time Consumption and Costs of Mechanized Felling and Processing of Deciduous Trees With The Waratah H 415 Harvester Head With Top-Saw
Benjamin Engler, Julian Burger, Gwendolin Hartmann, Thomas Purfürst

Improving Hardwood Bucking Techniques In Cut-To-Length Harvesting Operations In Eastern Canada
Caroline Bennemann, Eric R. Labelle, Jean-Martin Lussier

Uav-Enabled Deformation Classification and Earthworks Assessment For Sustainable Wood Extraction Management
Evangelia Siafali, Petros Tsioras

Analysis of The Influence of Reference Dimensions On The Estimation of Gross Volume of Stacked Roundwood: A Case Study In Poland

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ABSTRACT

Currently, a wide spectrum of solutions can be found on the technology market which uses photo-optical measurement methods for estimating the gross volume of roundwood stacks based on pixel recognition, stereoscopy, and LiDAR sensors. Therefore, the digital systems for roundwood measurements can be classified into two groups: 1) applications that require the use of a reference and 2) systems and applications that do not require the use of a reference. A reference is defined as a permanently or temporarily applied reference pattern on the front (and/or rear) side of the stack. Depending on the software considered in this study, a reference ranges from at least half a meter long to the width of the entire stack. The main aim of this study consisted of analyzing the influence of the: reference length on the gross volume of roundwood stacks. The following hypotheses based on this study (i) different volumes were obtained when using selected reference lengths; (ii) resulting differences were not significant from statical and practical points of view. A total of 30 pine industrial roundwood stacks were measured. Each stack was measured using the Timbeter app four times. For each measurement, a different reference length was used: 1 m, 3 m, 5 m and the width of the entire stack (W). The results showed that no statistically significant difference in volume within the tested reference length was observed. The highest volume was obtained for a 3m length reference. Compared to other results, the

resulting volume for that length was higher by approximately 0.2 m^3 (st) (o.b.) compared to other results using the other considered reference lengths. From a practical point of view, the results of this study are crucial for the dedicated consumption time when using photo-optical measurement methods which require references.

Assessment of Felling Technique, Based On Stump Dimensions and Individual Logger Characteristics

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ABSTRACT

In Slovenia, professional loggers are required to hold a national professional logger's qualification awarded by the National Centre for Vocational Training. The main purpose of these standards is to demonstrate a logger's ability to fell a tree safely. In our study, we measured the dimensions of each logger's stump. We also measured their personal characteristics and habits using pre-designed questionnaires. Twenty-five loggers were examined, each felling 5 trees, and one logger fell 8 trees. Prior to felling, each logger completed a questionnaire, detailing their personal characteristics and daily habits. The stumps were measured using eight different parameters, including the angle of the notch, lenght of top and bottom cuts, height and width on right and left side of the hinge and diameter of the stump. 60 % of the stumps had a correct notch angle between 35-45°. Notch angle is not statistically correlated with stump diameter. 77 stumps had the correct size of the bottom cut, which must be 1/6 to 1/3 of the stump diameter. Out of 128 felled trees, 110 stumps had a hinge and 18 had no hinge. The size of the hinge has a positive correlation with the diameter of the stump. The average width of the hinge measured 9 % of the stump diameter, whereas the prescribed width should be at least 10 %. The correct height of the hinge should be 1/10 of the stump diameter according to the standards. Our results showed that 67 % of all trees had the correct height of the hinge. Out of 25 loggers, 10 do not have breakfast before work, while the remaining 15 have breakfast every day. The amount of liquid consumed in summer is significantly different from that in winter (p=>0.001). According to our survey, 73 % of all loggers reported feeling tired after work every day. In addition, 43 % of them also feel tired in the morning before work, while 52 % do not feel tired and 5 % feel tired occasionally. 48 % of loggers described themselves as introverted, observant, pessimist (phlegmatic person), 32 % as extroverted, narrative, optimist (sanguinee person), 12 % as extroverted, hardworking, optimist (colerik person) and 8 % as introverted, thinker, pessimist (melanholic person).

Timber Measurement and Conversion Factors: A Comparison Between Harvester, Optoelectronic Log-By-Log, Section-Wise Manual and Photo-Optical Measurements As Well As Log Truck Load Scans For Volume Assessment

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ABSTRACT

From an economic standpoint, accurate timber measurement is of utmost importance. Besides being used for billing purposes, an accurate assessment of the quality and quantity of wood, along with predicting product yields, holds significance for optimizing the timber supply chain. In Germany, different timber measurement systems are used depending on the assortments or products. Whereas high quality timber is often measured at the sawmill gate logwise, the volume of timber assortments destined to the wood panel or pulp industry is mostly estimated in wood piles manually or photo-optically at the forest road side. Through conversion factors, which relate the gross and net volumes, net timber volume can thereby be estimated quickly based on the measured gross volume of the pile. However, the commonly used conversion factors for Scots pine in Germany are not based on scientific findings and are therefore controversially discussed. This study therefore aimed to evaluate the accuracy of conversion factors by comparing different measurement systems i) harvester measurement, ii) optoelectronic log-by-log measurement at sawmill gate, iii) section-wise manual wood pile measurement, iv) photo-optical wood pile measurement and v) log truck load scan measurements for five different assortments including OSB, MDF, LAK, LAS 3 m-length, and LAS 5 m-length. The analysis was conducted using 56 wood piles in Northeastern Germany, a region where Scots pine is the dominant tree species with a proportion of 70 % of the forest area. The total gross volume of these wood piles was approximately 4,000 m³ (st). The average of the resulting conversion factors ranged between 0.57 and 0.62 for higher quality assortments, varying from a minimum of 0.51 to a maximum of 0.66. The results revealed significant differences in both net timber volume measurements and gross wood pile volume measurements, across all assortments. Notably, a significant difference was observed between harvester and log-by-log measurements, especially for the 3 m-length assortments. Concerning the truck load scans for gross volume estimation of industrial timber assortments, the comparison with the section-wise manual wood pile measurement highlighted noticeable differences.

Time Consumption and Costs of Mechanized Felling and Processing of Deciduous Trees With The Waratah H 415 Harvester Head With Top-Saw

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ABSTRACT

For large parts of Europe and in particular for Germany, the proportion of deciduous tree species, including the standing volume, stand age and diameter of trees, is significantly increasing (compare third National Forest Inventory). Harvesting deciduous trees with modern harvester is extremely challenging and less intensively studied in terms of time consumption, costs and yield. It has furthermore a strong impact on occupational safety due to hazards such as falling dead branches. The present work was carried out in October 2023 in Homberg/Effze, Germany. A regeneration thinning was done in a 95-year-old mixed forest stand, dominated by deciduous trees, in specific European beech (Fagus sylvatica), European ash (Fraxinus excelsior), sessile oak (Quercus petraea) and sycamore maple (Acer pseudoplatanus). We performed a time work study to investigated the time consumption and costs of tree felling and processing with a harvester HSM 405 H2 8 WD equipped with a harvester head Waratah R415/1000 with top-saw. In total 115 runs were analyzed and 591 logs were count. Using the top-saw resulted in a higher yield of 0.63 m3solid or 33% per harvested deciduous tree. The time consumption was slightly lower (-5%) using the top-saw compared to not using it and instead changing the grip of the harvester head. Both, higher yield and lower time consumption, resulted in 18.7% lower harvesting costs when using the top-saw compared to the costs without using the top-saw.

Improving Hardwood Bucking Techniques In Cut-To-Length Harvesting Operations In Eastern Canada

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ABSTRACT

One of the most complex working steps during hardwood harvesting operations is bucking. It is particularly demanding in trees with complex architecture and with diverse product specifications. Since bucking has a high potential of influencing value yield, astute bucking decisions are essential to reach an efficient use of the wood resource, while ensuring profitable harvesting. In softwood operations, the automatization of bucking can increase wood utilization and monetary value, whereas this is not possible yet in hardwoods.

A research initiative was undertaken to first characterize northern hardwoods of Acadian forests based on stand, site and tree attributes and understand which of those attributes influence volume recovery. In a second part, the focus was set on the increase of value recovery during harvesting operations.

To understand factors influencing product recovery in hardwoods, a characterization of Acadian forests in New Brunswick, Canada, was performed. The analysis was based on more than 250,000 trees inventoried between 2012 and 2021. Besides tree dimensions (DBH and height), results indicated the strong influence of site factors on product recovery.

In a second phase, the evaluation of actual bucking as compared to a bucking considered as optimal is mandatory. Therefore, a bucking optimizer, BuckR, based on dynamic programming was developed in R. Bucking was considered as optimal when reaching a maximum in monetary value generated at tree-level. Based on a taper model for each tree and the product specifications, all possible product permutations were calculated and finally the optimal cross-cutting sequence for each tree identified. Within the BuckR optimizer, tree taper was calculated based on diameter height combinations and the Canadian national taper model with parameters adjusted to the study trees.

The objective was, in a first step, to evaluate hardwood bucking when considering the main stem until the first branch. We expected larger differences between actual bucking and the optimized solution when product specifications are more intricate. Therefore, bucking of more than 300 sugar maple, red maple, yellow birch, and white birch trees harvested in Acadian forests of New Brunswick, Canada were investigated, and initial results will be presented.

Uav-Enabled Deformation Classification and Earthworks Assessment For Sustainable Wood Extraction Management

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ABSTRACT

Human activities such as wood extraction exert a notable impact along the trails and forest roads in the form of soil degradation. The objective of this research was to create a Deformation Classification Model for a multi-use trail surface. Additionally, the study aimed to compute sediment deposition and produce a flood hazard map in a region with partial forest cover. The eBee X mapping Unmanned Aerial Vehicle (UAV) equipped with the senseFly S.O.D.A. 3D camera and Real-Time Kinematic (RTK) technology surveyed the study area spanning 149 ha in Northern Greece from an altitude of 120 m and achieved a high spatial resolution of 2.6 cm. The specific configuration of fixed-wing equipment eliminates the need for ground control points, compared to previous, in most cases polycopter-based, terrain deformation research. Employing the same methodology, two distinct classifications were applied, utilizing the Digital Surface Model (DSM) and Digital Elevation Model (DEM) for analysis. The Geolocation Errors and Statistics for Bundle Block Adjustment exhibited a high level of accuracy in the model, with the mean values for each of the three directions (X, Y, Z) being 0.000023 m, −0.000044 m, and 0.000177 m, respectively. The standard deviation of the error in each direction was 0.022535 m, 0.019567 m, and 0.020261 m, respectively. In addition, the Root Mean Square (RMS) error was estimated to be 0.022535 m, 0.019567 m, and 0.020262 m, respectively. Furthermore, a total of 20 and 30 altitude categories were defined at a 4 cm spatial resolution, each assigned specific ranges of values, respectively. The area of each altitude category was quantified in square meters (m^2), while the volume of each category was measured in cubic meters (m^3). Creating a Deformation Classification Model for trail or forest road decks, along with calculating earthworks and generating a flood hazards map, presents an effective approach that can offer valuable assistance to forest managers in the planning and maintenance of trails and forest roads.

Wildfires: Wildfire, calorific value and machinery fleet

Estimation of Spanish Forest Machinery Pool: Types, Number, and Brands of Spanish Forest Machines
Eduardo Tolosana

Small and Light Machinery To Prevent Wildfire Risk In Mediterranean Forests
Martino Rogai, Gerard Alcoverro, Gianni Picchi

Evaluation of Changes On Forest Road Network Using Uav Photogrammetry In Areas Affected By Forest Fires
Hakan Durgun, Mehmet Eker

Productivity and Particle Size Distribution In Chipping (over)seasoned Poplar Biomass
Branko Ursić, Andreja Đuka, Dominik Falamić, Dinko Vusić

The Portuguese Forest Harvesting Machinery Fleet
Pedro Britto, José Luis Carvalho, Susana Morais, Pedro Silva, Paulo Machado, Alexandra Marques

Forwardsens: A Conceptual Flexible Sensor Solution Integrated Into Forestsens To Track Forwarder Loads Independent of Equipment Manufacturer's On-Board Systems and Fleet Management Solutions
Stephan Hoffmann, Mostafa Hoseini, Marian Schönauer, Rasmus Astrup

Estimation of Spanish Forest Machinery Pool: Types, Number, and Brands of Spanish Forest Machines

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ABSTRACT

In Spain, there not exist an official record about forest machines, so it is not possible to precisely know the number of the different forest machine types. As those are relevant data for forest planning, a survey among all the forest machines manufacturers and dealers in Spain has been performed in 2022, giving a reasonable estimation of the forest machines number, classified by their type (skidders, forwarders, adapted farm tractors, several kinds of forest harvesters and feller-bunchers – wheeled or tracked dedicated forest harvesters and felling and harvesting heads mounted on excavators -). The number of machines from the different domestic manufacturers or imported brands have also been assessed. After the last published estimation at the beginning of 21st century, a very strong increase in CTL forest machines has been detected – from 250 to more than 1,2 thousand forwarders and a slightly greater number of different types of wood harvesters, coming from 150 machines at 2000 - along with a decrease in skidders and adapted farm tractors. The number of biomass bundlers – around one hundred, most of them fabricated by Iberian manufacturers - is remarkable. As annual wood fellings follow a slightly growing trend, it is expectable that the forest machinery pool will keep on growing, still following a slower rhythm.

Small and Light Machinery To Prevent Wildfire Risk In Mediterranean Forests

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ABSTRACT

The mitigation of wildfires impact on ecosystem services and human assets can be achieved by reducing the spread rate and the intensity of the fire front. As wildfires scatter through a landscape where vegetation is available for combustion, a key strategy to reduce fire intensity and fire perimeter growth is to limit the biomass available for combustion by means of the management of vegetation fuels. Typically, these forest works are non-productive operations with negative economic results, often supported by public subsidies that aim to secure the largest area possible. The study focuses on the feasibility of small and light innovative machinery to prevent wildfire risk in Mediterranean fire-prone areas, where a mix of selective and from-below thinning was used as a preventive silvicultural method to modify the load and the arrangement of both live and dead fuels. Besides reducing wildfire risk, it also aimed at promoting the growth of the most promising trees, increasing the forest value and resilience in the long term. The focus of the study is to compare the cost and productivity of the proposed system with the current preventive silviculture treatments, mainly based on manual work. To reach our goals we used an innovative combined machine performing a double function: felling-processing as a harvester and fuel extraction as a forwarder. This double function makes forest work very flexible and minimises relocation costs also thanks to its minimal size. The study took place in the region of Catalonia, Spain, during the fall months of 2023, the site chosen was a Pinus halepensis forest naturally regenerated after a wildfire and ready for first thinning to prevent risk from fuel accumulation. Three different plots have been selected to evaluate the productivity and costs of a small-scale harvester/forwarder machine in first thinning. The mean DBH and tree density of the first plot were 16.9 cm and 1697 tree/ha, the second counts 10.35 cm and 3338 tree/ha, and the third 5.92 cm and 9620 tree/ha. The productivity of the machine varied according to the development of the vegetation, impacting the cost per hectare and in two cases becoming advantageous compared to the traditional method. The costs of the interventions per hectare of the first plot, where the quality of the wood was greater, were 64% and 52% compared to the second and the third, without including the products obtained. Timber biomass, often left on the ground with manual operations, was extracted providing a yield of 50.5, 61.2 and 27 tons per hectare respectively in the first, second and third plot. The value of this product can be used to further improve the economic balance of the preventive silviculture, allowing to secure a larger area with the same funding

Evaluation of Changes On Forest Road Network Using Uav Photogrammetry In Areas Affected By Forest Fires

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ABSTRACT

Because of the effects of global climate change as well as the hot and dry summers typical of the Mediterranean environment, forest fires have become an inevitable reality in Turkey's southern and western coastal districts. Forest roads are essential for the transportation of harvested goods from burned areas after a fire, as well as for the movement of people and vehicles during a fire. During forest fires, temporary roads may be built in a hasty and improvised manner to contain the fire and then to remove forest products from the area. Accordingly, the density and distribution of forest roads in burnt areas may vary. This study used satellite photos to digitize the forest road network in the Bucak area of Burdur province, in Mediterranean region of southwest Turkey, prior to the 2021 forest fire. UAV photogrammetry was then used to digitize the post-fire situation, which was the outcome of the products being evacuated from the region following the fire. This made it possible to measure how the forest road network in the research region changed both before and after the fire. This study also highlights how effective realistic remote sensing techniques, like UAVs, are at detecting post-fire changes in forest areas.

Productivity and Particle Size Distribution In Chipping (over)seasoned Poplar Biomass

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ABSTRACT

The research aimed to investigate the influence of knife sharpness on chipping productivity and wood chips quality regarding particle size distribution. The research was conducted in Croatian lowland forests where wood chips were produced from tree residues using the Albach Diamant 2000 drum chipper. The time study was used to determine time consumption, and sampling of wood chips was done according to EN ISO 18135:2017. Particle size distribution was determined according to the EN ISO 17827-1:2016. The highest share in wood chips produced had 34 months of air-dried poplar biomass (80%); the rest was narrowed-leaf ash, American ash, and other hardwood biomass. During the nine working days, wood chips were produced with 60 truckloads or 1 670.1 t (average moisture content was 27.57±2.47%). In total, 33 samples were taken for laboratory analysis for particle size distribution determination. The production rate, on average, was 1.35 min/t of effective time or 2.20 min/t, including all delays. Productivity (min/t) showed no statistically significant dependence on cumulative chipped wood chip mass (denoting knife wear). The highest share in particle size distribution was in the diameter class 16-31,5 mm. The share of fines fraction (< 3.15 mm) was negatively correlated with cumulative produced mass. Despite the unexpected absence of a significant relation between cumulative produced wood chip mass and chipper productivity as well as between particle size distribution and knife worn, the research opened new questions regarding the differences in cut surfaces between wood chips produced with sharp and worn knives. During particle size distribution determination, evident differences in cut surfaces of coarse wood chip particles were noticed. Wood chips produced with sharp knives had clean surfaces in contrast to wood chips produced with worn knives with a hog fuel-like shape with distinctive torn surfaces.

The Portuguese Forest Harvesting Machinery Fleet

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ABSTRACT

The knowledge on the Portuguese forest harvesting machinery fleet is of fundamental importance for forest companies and machinery suppliers in order to support decision-making about the forest harvesting machinery market and potential new investments for the sector. Timber harvesting in Portugal has an annual production arround twelve milions cubic meters, mainly based on Pinus and Eucaliptus plantations. However, there is a lack of general information about the characteristic of the Portuguese forest harvester machinery fleet, used to produce these figures. Most of the forest operations in Portugal are performed by smal to medium third-party companies and, with a huge heterogeneity of forest harvesting machine types and ages. This research aims to fulfil the gap on lacking knowledge of forest harvesting fleet in Portugal. Therefore, data was gathered from two main groups: a) Machinery suppliers and; b) Owners of forest machinery and third-party companies. For group “a” it was performed a survey where it was identified the number and age of commercialized forest machinery in the last years. For the group “b” it was gathered information about the company size, machinery type, brand, and machinery age. In total, five questionaries were applied to the companies of group "a" and over hundert and twenty questionaries were applied to the companies of group “b”. Preliminary results indicated that there are over one thousand third-party companies working with forest operations and harvesting in Portugal. Most of these companies (74%) are small companies with an annual production up to five thousand cubic meter of timber per year. By the other size, only 7 % of the companies (with an annual production over twenty thousand cubic meters each), are responsible for about 50 % of the total timber production in Portugal. Additionally, circa of 60 % of forest harvester fleet has more than five years old. In conclusion, there is great potential for modernizing the fleet of forestry machines in Portugal.

However, there is also a great challenge because this modernization has to contemplate small to medium size companies.

Forwardsens: A Conceptual Flexible Sensor Solution Integrated Into Forestsens To Track Forwarder Loads Independent of Equipment Manufacturer's On-Board Systems and Fleet Management Solutions

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ABSTRACT

Real-time information about work progress with respect to production output and product location is required for efficient timber supply chains. Within fully-mechanized timber operations, the productivity of the harvester can be well monitored through the harvester protocol, providing information on the assortment, log volume and numbers, as well as the geolocation of pre-bunched logs at enabled on-board GPS. This information already supports the forwarder routing and beyond can support logistical processes if integrated into a machine specific operation management solution such as John Deere's TimberMatic. However, such solutions are manufacturer specific and from the landing difficult to further integrate into overall logistic systems of third parties, creating information cut-offs, causing difficulties and delays in trucking and mill production planning. ForwardSens is a proximity sensor as an extension to the RoadSens platform developed within the SmartForest project. The platforms share similar hardware components, i.e., stereo-camera, GNSS receiver and antenna, a communication module, and a GPU-powered edge computer. ForwardSens utilizes the stereo-camera to capture images with depth map and point clouds which are geo-referenced using the data stream of the GNSS receiver. A YOLOv8-based computer vision model is trained and used to detect objects of interest, e.g., the logs and forwarder tracks. The 3D points associated with the objects are derived from the point clouds based on the model output masks and further processed for geometric analysis and mapping purposes. For the validation of the functionality of ForwardSens, an empirical study will be conducted in spring 2024 at an operational site in the communal forest of Oslo/Norway. It is scheduled to monitor the timber extraction conducted by a forwarder during a cut-to-length operation over two consecutive days. The ForwardSens platform will be attached on various positions on the machine (e.g. cabin roof, behind windshield, etc.) to draw conclusions about the influence of common limitations of optical detection systems (view angle, sunlight deflections and dirt aggregation) on the visibility of the working area and objects. Since it is a pilot trial, the extraction cycles will be limited to a single assortment of one length, with data of interest being log number and diameter. The captured loads will be processed by the customized cloud application and compared with the manual counted and scaled logs of every individual load at the

roadside landing. The accuracy between the computer vision-based load description and the manual measurements should proof the applicability of optical sensors to support the information flow among logistical processes.

Digitalization: Accuracy, remote sensing and robots have talent

Accuracy and Suitability of Photogrammetry and Lidar-Based Methods To Estimate The Log Volume
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Intra- and Inter-Rater Reliability In Log Volume Estimation Based On Lidar Data and Shape Reconstruction Algorithms: A Case Study On Poplar Logs
Gabriel Osei Forkuo, Stelian Alexandru Borz

Automating A Mini Crawling Tractor: Designing An Autonomous Controller For The "Pfanzelt Moritz"
Steffan Lloyd, Csongor Horvath, Stephan Hoffman, Rasmus Astrup

Augmented Reality In Forestry: Transforming Forest Operations With Hololens 2
Thomas Purfürst, Felipe de Miguel-Diez

Forest Robots Got Talent! New Technologies Support The Automation In Reforestation of Clear-Cutting Areas
Marek Szychta, Jarosław Mac, Florian Adamczyk, Karol Tomczak, Krzysztof Koszela; Paweł Tylek

Estimation of Tree Centroids Based On Terrestrial Laser Scan Data
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Accuracy and Suitability of Photogrammetry and Lidar-Based Methods To Estimate The Log Volume

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ABSTRACT

Estimation of log volume is still carried out in several countries using analogue instruments and traditional methods. During the purchasing phase, the accuracy of the log volume measurement process plays a key role, as the cost of purchasing this raw material represents between 60% and 85% of the final production cost. Miscalculations in volume estimation can lead to dramatic losses for the purchasing companies or forest owners. In several European countries, logs destined for sawmills because of their high quality, long lengths and high midpoint diameters are transported to landings or forest roads sides to be measured by the staff of the involved stakeholders. At this point, the volume of each log is estimated based on the diameters and length measured, using analogue tools and formulas traditionally used in each region, such as the Huber or Smalian formulas. Recent studies have demonstrated the high accuracy of lidar-based methods for estimating the volume of logs as their volume was measured using a xylometer which is deemed as the most accurate method for that purpose. In addition, these developed lidar-based methods bring further advantages that lead to the optimisation of the measurement process, such as transparency increase, lower time consumption and comfort for the staff responsible for carrying out the measurements in the forest. The aim of this study is to compare the accuracy and suitability of selected recently developed methods for estimating the volume of logs in the forest. Lidar and photogrammetry-based methods were selected for this study, being collected the data using 1) UAVs, 2) iPhone with ViDoc RTK device, 3) GeoSLAM ZEB HORIZON and 4) GoPro Hero11 camera supported in a Zhiyun Crane M3 gimbal. For this study, 87 oak logs (Quercus robur L.) were prepared and measured in the forest district located in Chorin (Brandenburg, Germany). Their length

ranged from 3.34m to 11.82m and their midpoint diameter from 47cm to 94cm. The accuracy of the selected methods will be evaluated based on the volume estimated using traditional methods. Specifically, Root-Mean-Square Error and Mean Bias Error will be calculated to compare the results provided by each method and evaluate the accuracy. The suitability of each method will be assessed based on the time required to estimate the volume of each log and the reliability of the obtained results.

Intra- and Inter-Rater Reliability In Log Volume Estimation Based On Lidar Data and Shape Reconstruction Algorithms: A Case Study On Poplar Logs

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ABSTRACT

Reliable log volume data is crucial in the wood supply chain. A promising technology used lately to source log volume data is based on LiDAR sensing. Several interpolation algorithms have been developed to extract generic volume data from LiDAR point clouds, such as the Poisson interpolation and Random Sampling and Consensus (RANSAC). Some tests have checked the accuracy of LiDAR estimates by comparative studies. As a common methodological approach, point clouds require several post-processing tasks to get useful data. These include segmentation, removing noise and assigning normals, and are followed by shape reconstruction by dedicated algorithms. Although this procedure has been used quite frequently, and several papers have pointed out the accuracy limits of single comparative experiments, no paper has addressed the intra- and inter-rater reliability of these procedures. This raises two important questions, namely: (i) Would the same person processing the same data by the use of same procedures come to the same results? and (ii) How much would the results deviate when different persons will process the same data using the same procedures? A set of 432 poplar logs arranged at the ground at about 1 m each other was scanned by a professional mobile LiDAR scanner (Z) as groups, then the first 418 logs of the initial data set were scanned individually by an iPhone-compatible scanning app (3D). Then the data was assigned for processing to two researchers (R1 and R2) who used a protocol to process the point clouds twice (A1 and A2), by repeating the same steps each time, which included calculation of volume by Poisson interpolation (P), and reconstruction of cylinders (Ci) and cones by (Co) by RANSAC algorithm. Intra- and inter-rater agreement was evaluated by several metrics, out of which the mean absolute error (MAE) was retained here for comparison. For inter-rating experiment, when working with Z data, four comparisons were in place for each volume extraction algorithm. MAE ranged from 0.051 to 0.060 m3 (P), from 0.123 to 0.130 m3 (Ci), and from 0.123 to 0.221 m3 (Co); for the same algorithms but when working with 3D data, MAE ranged from 0.029 to 0.045, 0.093 to 0.109, and from 0.081 to 0.095 m3, respectively. For the intra-rater experiment with the Z data, the MAE returned values of 0.024 and 0.064 for P, 0.090 and 0.142 for Ci, and 0.091 and 0.141 for Co. In the same experiment, but for the 3D data, the values of MAE were of 0.016 and 0.026 for P, 0.088 and 0.101 for Ci, and 0.067 and 0.139 for Co. All of these suggest that there are important differences in volume estimates brought by the raters when repeating the experiment as individuals, or by different persons running the experiment on the same data. This has implications for the use of the data and makes a good point to find ways for automating the whole process to get better in data consistency.

Automating A Mini Crawling Tractor: Designing An Autonomous Controller For The "Pfanzelt Moritz"

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ABSTRACT

Remote controlled mini crawling tractors have become an important component of modern forestry operations, thanks to their efficiency, ease of use, and low environmental impact. These machines are often used in thinning, log skidding, or site preparation, while more recent innovations have demonstrated their utility in more complex tasks such as planting and felling. For small forest owners, mini tractors can play a crucial role, as the use of conventional large-scale forestry equipment is uneconomical, rendering small-scale forestry infeasible.

This presentation outlines our mechanical, electrical, and software design for an autonomous control system tailored for the Moritz mini crawling tractor. Our proposed system integrates a central GPU-powered real-time edge computer running ROS2, which collects data from an extensive sensor suite. A 3D LiDAR system will enable precise self-localization and mapping, allowing the machine to detect trees and obstacles in its environment and track its position and velocity with high accuracy. Ground-oriented stereo cameras mounted at the front of the system support local navigation and obstacle avoidance. Additionally, these cameras will enable future image-based AI algorithms to intelligently detect and classify objects in the machine's environment, further improving its decision-making and autonomy. Additionally, a GNSS system will ensure precise positioning under GPS coverage, while IMU's improve localization and monitor for potentially hazardous conditions such as tilting or sudden accelerations. Finally, a communication module will enable the device to be programmed and controlled remotely, while also relaying data back to a central system.

Our aim is to significantly reduce the need for human intervention in forestry operations, increasing efficiency and safety, while reducing costs. Future directions of this work will explore how to effectively utilize this platform's sensing and computing capabilities for fully autonomous forestry operations, such as sowing, mulching, or soil preparation within designated areas.

Augmented Reality In Forestry: Transforming Forest Operations With Hololens 2

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ABSTRACT

The integration of Augmented Reality (AR) in forest operations marks a significant leap forward in how forestry management tasks are planned and executed, with the Microsoft HoloLens 2 being at the forefront of this technological advancement of optical AR. This paper aims to explore the application of HoloLens 2 in enhancing the planning and realization of forest operations, bridging the gap between virtual planning and physical execution. The study investigates the device's capability to overlay digital information onto the real world, allowing forest managers and operators to visualize forest landscapes, tree positions, and potential hazards in real-time, thereby enabling more informed decision-making processes.

We conducted a series of field experiments to evaluate the effectiveness of the HoloLens 2 in various forestry operations, including timber harvesting, site preparation, and reforestation. The results indicate that AR technology significantly improves the accuracy and efficiency of these operations. The use of HoloLens 2 facilitates a better understanding of the terrain, assists in identifying the optimal routes for machinery, and supports the precision placement of seedlings. Moreover, the technology promotes safety by highlighting areas of concern directly within the operator's field of view, reducing the risk of accidents.

This presentation also discusses the technical challenges encountered during the implementation of AR in forest operations, such as the limitations in field of view, battery life, the need for robust GNSS integration and data quality for precise location tracking in dense forest environments. We propose potential solutions and future directions for research to overcome these challenges, emphasizing the importance of continuous improvement in AR technology tailored to forestry applications.

The study embeds the AR results in the overall concept of the Extended Reality Lab at the University of Freiburg and presents the development of high-precision standardised single-tree-based digital twins of forests.

In conclusion, the application of HoloLens 2 in forest operations presents a promising avenue for enhancing the efficiency, accuracy, and safety of forestry practices. By leveraging AR technology, forestry professionals can achieve a seamless integration of digital information with the physical environment, leading to more sustainable and effective forest management strategies.

Forest Robots Got Talent! New Technologies Support The Automation In Reforestation of Clear-Cutting Areas

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ABSTRACT

Nowadays reforestation of clear-cutting areas and afforestation of abandoned lands are very important both from ecological and wood production points of view. On the other hand, being a forest worker is no longer attractive labour. Improvement of work through digitalization or mechanization of the most time-consuming and simple activities is contributing to significant growth in the forestry sector. Recently it has become important to use innovative solutions to automate these activities. The main idea of this work is to present solutions for the running systems of self-propelled forestry machines and their ability to overcome terrain obstacles. New solutions of adaptive running gears for forestry and agricultural robots was presents. The results of simulation studies carried out on selected virtual models and the results of tests of selected prototypes in operational conditions will be shown. In addition, the possibilities of using non-contact sensors and overhead data acquisition techniques to help automate the movement of forestry machinery in difficult terrain will be discussed, with an emphasis on the use of AI technologies. The capabilities of artificial intelligence solutions laboratories for working machinery, operating within the framework of the European AgrifoodTEF project, will also be demonstrated. Finally, development directions and legal and regulatory challenges for emerging new solutions will be presented.

Estimation of Tree Centroids Based On Terrestrial Laser Scan Data

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ABSTRACT

Timber harvesting is one of the most dangerous activities in forest management, resulting in a significant number of fatal accidents every year. One of the main causes of such accidents is the incorrect determination of the felling direction and inclination of the tree. A precise forecast of the felling direction makes it possible to fell a tree in a controlled manner to avoid damage to residual stand and natural regeneration and to prevent accidents. Accurate estimation of the inclination of a tree requires skilled knowledge of tree anatomy and experience, but human error and misjudgment can never be completely eliminated. Innovative technologies as for example laser scanning can be used to provide additional support for timber harvesting planning and to minimize the risk of misjudgment. The use of Terrestrial Laser Scans (TLS) is very well suited for the detailed visualization of scanned trees. In our case, several stationary scanning processes were carried out for each individual tree resulting in individual point clouds, which represent a digital twin of the trees. Quantitative structural models (QSM) are often used to accurately estimate the biomass or volume. A very reliable way of calculating structural models from individual trees is "TreeQSM", an algorithm that is integrated into the "MATLAB" operating programme. The algorithm re-constructs the tree structure using adapted cylinders that correspond to the diameters of the individual tree segments. The statistical programming language R can then be used to query the coordinates and radii of the individual cylinders. The start and end coordinates of the cylinders are averaged in order to determine the centers of the cylinders which are used to calculate the lever arm distances. Since the dimensions of each cylinder are known, the volumes can be computed. This allows the calculation of the weight of each individual cylinder, taking the relative density into account. These numbers can then be used to derive the actual position of the tree centroid using the sum of the singular cylinder resultants. The new developed method makes it possible to determine the inclination of a tree very precisely and the force required to fell the tree in a certain direction can be derived from this. The choice of felling direction influences the productivity of timber harvesting and has an impact on the remaining stand. Therefore, a careful planning of the felling layout with the

appropriate felling direction is essential to ensure the cost efficiency and working safety of timber harvesting. In order to test the practicality of this approach, the results of the calculations are compared with the estimations of forestry workers.

Precision: IBC, 3D and TLS

Intelligent Boom Control System On Forwarder - Inexperienced Operator Benefits More
Dawid Grabowski, Jennifer Kowalska, Mariusz Bembenek, Piotr Mederski

Productivity Assessment of A Loader By Using Drone Captured Images
Halit Büyüksallı, Ebru Bilici, Abdullah Emin Akay

Productivity and Quality Issues In Young Stand Mechanized Tending In Latvia: A Case Study
Kristaps Makovskis, Toms Artūrs Štāls, Rūdolfs Fabiāns, Dagnija Lazdiņa

Monitoring of Cable Corridors and Anchor Tree Dimensions In Cable Yarding Using Personal Laser Scanning
Christoph Gollob, Ralf Kraßnitzer, Tim Ritter, Valentin Sarkleti, Andreas Tockner, Martin Kühmaier, Christian Kanzian, Ferdinand Hönigsberger, Karl Stampfer, Arne Nothdurft

3d Reconstruction of Uneven-Aged Natural Forest In Single Tree Scale
Hadi Bayati, Akbar Najafi

Audit Forest Roads Using A Combination of Methods
Anastasia Stergiadou, Georgios Kolkos, Maria Chatzigeorgiou, Dimitrios Moutsopoulos, Dimitrios Kelesakis, Nikolaos Grammalidis, Emmanouel Tsiros, Apostolos Karteris

Intelligent Boom Control System On Forwarder - Inexperienced Operator Benefits More

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ABSTRACT

Loading and unloading are crucial oprational time categories influencing forwarder productivity. Intelligent boom control (IBC) system, which was implemented in 2013 in forwarder John Deere, aims at shortening time of loading and unloading, resulting in higer productivity of extracting. Productivity of forwarder depends also on operator experience, with obvious relation that more experienced one will perform higher productivity. The objective of presented research was to find out how much time can be saved when using IBC system with particular attention to inexperienced and experienced operator. The research was carried out on John Deere 1510G forwarder in two scenarios: 1) in controlled conditions (CC), where the same logs were distributed twice along forwarder passage and were collected twice: once with IBC on and once with IBC off; 2) in typical stand conditions (SC), where logs from one part of the plot were collected with IBC on and another part with no IBC. In scenario 2) in SC, two operators took part in the experiment: 1) inexperienced (IO), with nine months work on John Deer 1210E with no IBC and ten months work on John Deer 1510G, which was exuipped with IBC and used constatnly by the operator. Experienced operator (EO) had 15 years work experience on forwarders mainly, but also on harvesters, including 20 months on forwarder 1510G with IBC. The outcomes of the research show that IBC system brings the biggest benefit to an inexperienced operator. Namely, loading and unloading was faster by 3.5% and 14.4% respectively on CC, whereas in SC loading and unloading was accordingly faster by 17.7% and 21.7%. Whole extracting in SC was 16.7% faster when using IBC. In relation to EO, the research showed that IBC system impacts his work to lower degree: use of IBC system makes faster loading and unloading by 6.1% and 4.5%, respectively in SC, and by 4.3% in overall extracting process in SC.

Productivity Assessment of A Loader By Using Drone Captured Images

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ABSTRACT

The loading operation has an important function in the smooth execution of forest operation as it is a transition activity between timber extraction and long-distance timber hauling. Thus, it is crucial to estimate productivity of loading operation and determine the main factors effecting the productivity. The time study analysis is commonly used in productivity estimation of forest operations. Traditional time study analysis, usually done by utilizing time watch, requires two or more personnel who closely observe the logging operation and measure the logs at the landing. However, this field work can be dangerous since several equipment work and move around the operation site. In this study, the productivity of a loader was estimated based on video images which were taken with an "DJI Mavic Pro" model Unmanned Aerial Vehicle (UAV). The study was conducted in a Brutian pine stand located in Muğla Forest Enterprise Chief in the city of Muğla in Turkiye. It was found that the productivity of the loading operation was 25.52 m3/hour. The results indicated that there was a positive significant relationship between productivity and product diameter and volume.

Productivity and Quality Issues In Young Stand Mechanized Tending In Latvia: A Case Study

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ABSTRACT

Young stand tending is common practice in Latvia, where every year around 60,000 hectares are tended. The purpose of the tending is to create the desired composition of the tree species with a specified number of trees to provide them with sufficient growth space. Tending, where biomass is not collected is highly manual work, done with brush-cutters. Due to the lack of labor, which is a common problem in forestry, mechanized young stand tending is a solution to keep tending at the same intensity shortly. To compare mechanized young stand thinning productivity and quality, the study was done in 11 sites, where in 5 sites job was done when trees had leaves and in 6 sites in leafless state. In 5 sites trees were regenerated naturally and in 6 sites were planted. Work was done in 9-16 year old birch, spruce, and pine stands, where tree height was 5 – 8 meters. The tending was done without biomass collection and all felled trees were left on the ground. From the LIDAR data cloud, different sample plots regardless of tree density (high, average, and low) were installed in sites, where working productivity and tending quality were measured. As base machine was Malva 560.H4 and the cutting head was Risutec RII. The time spent during thinning was analyzed using the GPS tracker, which recorded base machine coordinates every second. Tending productivity was measured in 450m2 plots and tending quality in 100m2 plots. This study aimed to evaluate mechanized young stand tending without biomass collection productivity in different tree species, densities, leaf conditions (in autumn when trees and bushes have leaves, and winter time, when they are without leaves), and quality. Average mechanized tree tending in all sites was 10.7 hours ha-1, whereas, in areas with low tree density, it was 8.1 hours ha-1, with medium 10.3 hours ha-1, and with high tree density 13.6 hours ha-1. The average tending time in sites where the work was carried out in the leaf period (early autumn when the tree has leaves and heavy grass overgrown, which obstructed visibility and made the base machine move slower) was 13.1 hours ha-1, while in the leafless period (early winter) it was 8.7 hours ha-1. Average tending productivity in spruce sites was 12,6 hours ha-1, in birch sites 11,8 hours ha-1, and in pine sites 8,9 hours ha-1. In almost all sites, the number of trees left is less than optimally required, except for one site where it was significantly higher. Despite limited visibility from the machine cab, mechanized tending can ensure, that quality requirements are met by cutting trees with double tops, crookedness, and animal damage. Despite the

swinging and free movement of the cutting head, the bark abrasions and notches on the left tree bark are mostly small (4 x 5 cm) and will not affect the future growth of the trees. The growing conditions and stand density in the site usually are different, which must be considered when tending productivity is predicted in the site.

Monitoring of Cable Corridors and Anchor Tree Dimensions In Cable Yarding Using Personal Laser Scanning

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ABSTRACT

Cable yarding is one of the most relevant technologies that enables efficient and sustainable use of timber resources in mountainous areas. A traditional standing skyline setup in uphill operation with a tower yarder includes at least a skyline, a mainline and guylines with corresponding anchor trees. The planning for this setup is commonly done in advance based on crew experience and can be supported by using smart tools integrated into geographic information system. In practice, the actual exact location

of the tower yarder, the rope configurations and the position of the anchors are usually different compared to the planning situation. Exact cable corridor layouts as well as the dimensions of the anchor trees of cable yarding systems are difficult to record and are usually not documented.

The goal of this study was to automatically detect and measure the courses of the skylines and guylines of cable yarding systems using a mobile personal laser scanner (PLS). The cable corridors were selected in such a way that a broad variation in forest type (broadleaved, coniferous, and mixed), forest structure (one- or two layered) and silvicultural treatment was represented. The point clouds captured with a GeoSLAM ZEB Horizon (GeoSLAM Ltd. Nottingham, UK) personal laser scanner were classified, clustered and segmented in order to analyze the skyline and guylines independently of the rest of the 3D environment (terrain, trees, other vegetation, etc.). Region growing algorithms were used to segment and trace the cable corridor in the 3D point clouds. By tracking the guy lines, the anchor trees of the cable yarding system can also be automatically detected and measured (tree position, dbh, height). Subsequently, the geometries (corridor length, rope angle, mounting position of supports, skyline deflection) of the system can be reconstructed and documented on the basis of this data. A precise digital representation of the real cable yarding corridor configuration is created (digital twin). Manual segmentation of the cable corridors and manual measurements of the anchor trees served as reference data.

This study shows that such systems can provide important digital information for the planning, operation, supervision and documentation of timber extraction and serves as input data for more precise planning of future cable yarding operations.

3d Reconstruction of Uneven-Aged Natural Forest In Single Tree Scale

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ABSTRACT

The most important variable that are measured in forest inventory activities are DBH and the height of trees. These variables correlated with other variables (volume, etc) so measuring these is difficult. Acquiring correct and high accuracy information about forests with low prices and a user friendly devise is one of the forest inventory goals. Traditional measuring techniques are low accuracy, and time-consuming. Optical dendrometry was developed for solving this problem and filling this gap. Making 3D reconstruction of objects by using a hand-held digital camera via SfM-MVS (Structure from Motion with Multi-View Streophotogrammetry) technique is a relatively new photogrammetric approach that can be used in forest inventory. the aim of this study was the test potential of an uncalibrated hand-held digital camera with SfM-MVS technique in deciduous and uneven-aged forest environment conditions for the estimation of linear tree metric (DBH). Field data measurements were collected at the Faculty of Natural Resource, Tarbiat Modares University, Nur, Mazandaran, Iran. To this end, a Nikon digital SLR camera and AgiSoft PhotoScan software were used to capture the image and extract point cloud data from the study area with about 2400 m2 and a total of 35 trees. The results of the evaluation DBH estimated by SfM-MVS indicated that this technique has very good potential in trees DBH estimation. The linear relationship between DBH derived via traditional and SfM-MVS techniques was strong (R2=98 %). The RMSE% and Bias% of this technique in tree height estimation were 14.84% and -11.27% respectively. The percentage of omission, commission error, and overall accuracy of the SfM-MVS technique in 3D reconstrucion of all trees was 11.42%, 0%, and 88.57%, respectively.

Audit Forest Roads Using A Combination of Methods

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ABSTRACT

Gravel roads are the main forest and rural road network. Audit them is a yearly issue for the Greek Forest Service Offices and for Agriculture Service. To evaluate gravel road conditions with various conditions, surface materials and geometric features was the main task of this research. A well maintained and improved forest road can provide successful transportation to the forest and non-forest products by minimizing the possibility of reducing the product quality. In this study demonstrated the ability of combined methods such as: field forest road ride quality estimation, classification the ride quality per 100meter, set the standards for each ride quality classification, road segment condition monitoring, from very high-resolution multispectral satellite images using innovative semantic segmentation and classification based on deep learning, additional data collection by UAVs equipped with RGB cameras that can also provide accurate DSM information, manual inspection or other free sources. Since in most cases, such detection and monitoring procedures require manual and tedious procedures, the INFOROAD project (https://inforoad.karteco.gr/) (Project code: KMP6-0079153), implemented under the framework of the Action “Investment Plans of Innovation” of the Operational Program “Central Macedonia 2014 2020”, that is co-funded by the European Regional Development Fund and Greece”,

is developing an innovative methodology and tools for automated extraction, mapping and status monitoring of forest and rural road network, by combining remote sensing data with state-of-the-art deep learning approaches. Since only few data sets exists for forest and agricultural roads because of they are gravel roads that makes the research more challenging. Case-study area is chosen the peri-urban forest and rural area of Thessaloniki, which will be associating the needed dataset for the pilot application and will be produced for open access use in order to boost similar researches on the field. The stakeholders such as forest and agriculture authorities, wood and farming enterprises, etc. are the pillar of public and workers opinion about the necessity of that kind of tool such as INFOROAD project which will be performed by an online WebGIS - Geographical Information System platform. The expected impact of the research is to expand INFOROAD project, throughout the forestry and agricultural community, as its use will reduce resources for continuous inspection of road axes only from the field, while increasing the quality of the products that will use it the gravel road.

Workforce: Learning, audiovisuals and stumpage prices

Modelling Softwood Timber Flow From Forests To Sawmills Across The Road Network Using Hydrological Gis-Tools
Florian Renner, Herbert Borchert

Slovenian Case Study On Forest Roads Affected By Last Year's Torrential Floods
Jaša Saražin

Learning Curves of Harvester Operators In A Simulator Environment
Krzysztof Polowy, Dariusz Rutkowski

Consolidation of Forest Machine Gnss Tracks Into One Solid Logging Trail Line
Jori Uusitalo, Omid Abdi, Kaarlo Koivukoski, Son Cao

Evaluating Noise Propagation From Cross-Cutting Operations In Forest Environment
Salvatore Francesco Papandrea, Stefano Grigolato, Maria Cataldo, Giuseppe Zimbalatti, Andrea Proto

Determine The Passability of Skid Trails Using Sensors
Philipp Stein, Andreas Ligocki, Markus Wallner, Anja Krauth

Modelling Softwood Timber Flow From Forests To Sawmills Across The Road Network Using Hydrological Gis-Tools

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ABSTRACT

Roundwood for the timber industry is usually delivered from the place of origin in the forest to the consumer by truck. The costs of timber transportation make up a relatively large proportion of the raw material costs for the timber industry. By modeling the softwood timber flows, we wanted to understand where and how much timber volume from the forest reaches the roads and along which routes it ultimately reaches the sawmills. The motivation for this was making provisions for disasters. In the event of calamities, such as windthrows or bark beetle outbreaks, the volume of timber often exceeds the processing capacity of the industry, and the timber should then be stored temporarily. If possible, additional log storage yards should be set up outside the sawmills' immediate catchment areas. Hydrological GIS tools are used to assign the timber removals to the forest roads and to model the transportation of the timber via the roads along a cost gradient to the sawmills. Apart from the delineation of the catchment areas, the modeling also provides the technically available timber potential in the catchment area. In addition to the search for storage locations, the method also offers potential for the search for additional sawmill locations. The amount of wood transported can be tapped at any point on the road network. Therefore, the method can also support traffic and route planning.

Slovenian Case Study On Forest Roads Affected By Last Year's Torrential Floods

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ABSTRACT

In July and August 2023, Slovenia was hit by a large number of intense torrential storms, which together resulted in the largest natural disaster in Slovenia. In many places in northern Slovenia, local precipitation and river flows far exceeded the 100-year return periods. The Slovenia Forest Service reported that the storms damaged more than 2,000 km of forest roads, making the management of around 15% of Slovenia's forests temporarily impossible. The forest roads were damaged by debris flows, landslides or windbreak fallen trees. In the Koroška region, we investigated 10 cases of destruction of forest roads at the junctions with torrential streams and studied the possible causes. The size of the catchment areas of the observed bridging objects ranged from 2 to 72 ha. The common characteristics of the damaged roads were: (1) all were built before the year 2000; (2) in all cases, pipe culverts or bridges were clogged with debris or woody material; (3) in one case, a newly built filled slope of skid trail colapsed into the torrent, resulting in a masive debris flow downstream. Some cases could be solved by proper maintenance and larger dimensioning of the transverse structures, while others would only survive if they were reconstructed into dips or by slowing erosion processes upstream.

Learning Curves of Harvester Operators In A Simulator Environment

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ABSTRACT

Modern tree harvesters are highly productive but increasingly complex and costly pieces of equipment. Operator training places a considerable mental burden on the trainee due to high demands on motor skills, concentration and planning. Harvester simulators assist in the initial phase of training by allowing basic skills to be acquired in a safe and relatively inexpensive manner. The aim of the study was to analyze the learning curves of the trainees in order to determine the period during which most development takes place. This would allow estimation of the optimal time required for simulator training. In this study, 11 students (10 male, 1 female) were trained on a John Deere harvester simulator for a period of approximately 15 hours (each). After every 30 minutes of training, a simple test task was performed and recorded - a total of 28 test tasks for each student. The most valuable parameters for evaluation were: productivity (calculated from task completion time), crane tip travel distance, crane control, and number of simultaneous crane movements. In each case, a clear learning curve could be identified, despite high inter- and intra-person variability. Effective time showed a steady decrease during training with a group minimum at the 27th trial (1.25 min). Crane tip distance per tree dropped rapidly in the first 6-7 trials, followed by a more gradual decrease to reach a minimum of 23.8 m in the 16th and in the final trial. Crane control - a parameter describing the precision and smoothness of crane operation - showed a significant increase from an initial 0.63 to a maximum of 0.8 (in the 17th trial), after which it fluctuated around 0.76. A number of crane functions used simultaneously increased more rapidly from an initial value of 1.5 to reach almost a maximum value (1.8) already in the 10th test (the final maximum group average of 1.82 was reached in the 20th test). The individual curves for each trainee were highly variable, showing a wide range of values and shapes. In conclusion, the simulator is a valid and effective teaching tool for the initial training period, but it must be followed by hands-on practice. Most personal development occurs during the first phase of simulator training, which typically consists of up to 17 attempts or approximately 9-10 hours. However, it is not advisable to terminate the training at this point, as some increase in performance still takes place afterwards. It is important to consider significant inter-personal variability and tailor the duration of simulator training to individual needs.

Consolidation of Forest Machine Gnss Tracks Into One Solid Logging Trail Line

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ABSTRACT

In both RF- and CCF -based management practises in boreal forest, logging trails are not typically considered as permanent forest infrastructure. However, information of the positions of old logging trails (OLTs) can prove highly beneficial upon revisiting the forest, typically 20-30 years after the previous operation. In RF, operators may be encouraged to follow OLTs to maintain a suitable forest structure, while in CCF-based management, OLTs might be avoided, particularly if trails have disappeared due to tree regrowth. The number of machine passes within a segment of logging trail is also crucial information. Research across various forest biomes (boreal, temporal, tropical, etc.) show that the higher the total stress induced by machine traffic the more permanent damages it will cause. Hence, it is essential for forestry machines to manage total overload, especially in sensitive terrain conditions. Modern forest machines are now equipped with GNSS positioning system that continuously store the tracks of machine movements. These tracks are stored as a bunch of single points or converted into polylines. However, GNSS tracks may suffer from inaccuracies due to satellite visibility, terrain conditions, and space weather, resulting in positioning variations of 2-10 meters in forest environments. In this presentation, we demonstrate a system designed to consolidate GNSS tracks from harvesters and forwarders into a one solid logging trail line. We have developed a GIS-based approach that calculates the density of segments of logging trails (passes) as a raster layer, then it finds the cells with the highest density as the centre of logging trails. Finally, it digitizes lines through the centre of the cells as the final solid logging trails. The file can also be utilized to calculate the characteristics of logging-trail networks (intervals, density) or network efficiency factor (ideal network versus actualized network). We also aim to create a procedure that can interpret the number of machine passes within each logging trail segment. This information can aid operators, forest managers, and owners in visualizing machine traffic patterns, controlling access to consecutive machine trafficking, and assessing the need for soil rehabilitation activities.

Evaluating Noise Propagation From Cross-Cutting Operations In Forest Environment

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ABSTRACT

Technological innovation, industrial development and urbanisation have brought many important contributions and benefits to human life, but have also had some negative impacts on natural resources and ecosystems. One of these negative effects is anthropogenic noise pollution, which is an important element of environmental disturbance and a growing problem in our daily lives. Forestry operations often involve the use of equipment and machinery that can produce noise and represent a potential permanent or temporary disturbance to wildlife. In Italy there is currently a medium level of mechanisation in forestry, and the most commonly used equipment in forestry operations is the chainsaw, whose noise affects not only the operator but also the local wildlife. In fact, during felling, delimbing and cross-cutting operations, chainsaws of different power and size emit high and prolonged levels of noise that spread throughout the environment and the forest. The aim of the work was to carry out a first experimental approach to assess the range and intensity of the noise generated by different chainsaw models. The study was carried out in a forest in a sensitive area of the Sila National Park (southern Italy), where a pilot simulation of cross-cutting was tested on beech and Corsican pine logs. The simulation consisted of cutting discs of approximately 3 cm thickness from logs of approximately the same diameter. The cutting was carried out with 3 different chainsaw models of low, medium and high power. The assessment of noise exposure during cross-cutting was carried out using 26 sound dataloggers, which recorded the sound levels in a geometric pattern to assess the propagation of noise in the test area. Before and after each series of measurements, a field calibration was carried out with appropriate adjustments using a sound calibrator. Each data logger was mounted 2 metres above the ground and positioned at a distance noted by the operator. The test area, with the noise source in the middle, was divided into the 4 main directions. The measurements were carried out in a forest environment using an appropriately set up measurement system in order to recreate a realistic condition.

Determine The Passability of Skid Trails Using Sensors

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ABSTRACT

The passability of the skid trail determines whether and how well a harvester or forwarder can move there. If the machine has struggled, you will notice unsightly ruts that are related with soil compaction. The forester is rarely pleased about this. The culprit is quickly identified as too much moisture in the soil. Vehicles should therefore not be allowed to work on excessively damp ground. But how can this be achieved?

The operations planner usually has several areas that could be considered for the next location. He is interested in selecting the area with suitable soil conditions. He must therefore obtain knowledge of the moisture in the soil in all relevant areas and keep this knowledge up to date. The current procedure involves regularly visiting the areas in person and subjectively assessing their suitability. This process is very time-consuming and is to be improved/simplified/supported by the use of sensors.

The precise determination of soil moisture content is still problematic, even for high-quality/high-priced sensor technology, as soil properties involve a large number of parameters. This precision is not absolutely necessary for assessing the passability of skid trails. A rough measuring scale may be sufficient. With precise knowledge of the requirements of the sensors, material costs can be reduced to a minimum and their use can be more worthwhile overall.

In order to get the measured value from the sensors to the deployment planner, common wireless technology from the IoT area is used (LoRaWAN, NB-IoT, etc.) This may require the establishment of a local wireless network. The following points will be discussed in this presentation: • Listing of common sensory measurement parameters in the context of soil moisture and their physical measurement principles. Discussion of their suitability for the intended application • Pointing out of the possibilities for the constructive implementation of different sensor units. • Discussion of technologies for large-scale application (beating, drilling, shooting, robots, ...)

Impacts: Wood, stand damage and safe forest

Evaluation of Black Alder (Alnus Glutinosa) Wood Structure and Opportunities For Wider Use of Timber In Structural Elements
Ziedonis Miklašēvičs, Liena Poiša

How Will We Balance Production Forestry and Renewable Energy Systems In The Future?
Robert Keefe

Stand Damage After Thinning Operations: Does Size and Location of Damages Differ? A Comparison of Logging Operations
Christoph Haas, Juergen Richter, Christoph Huber

Effects of Timber Harvesting Methods On The Nutrient Supply of Forest Soils and Recommendation Tools
Elke Dr. Dietz, Stephan Rimmele, Makus Riebler, Herbert Dr. Borchert

Gridling Efficiency: Influential Factors In Managing Ailanthus Altissima Spread In Slovenia
Matevž Triplat, Urban Žitko, Martin Jež, Amina Gačo

Safe Forests – The Psychophysiological Interrelationship Between Working Conditions and Stress of Harvester and Forwarder Drivers
Vera Foisner, Christoph Haas, Arnulf Hartl, Christoph Huber

Evaluation of Black Alder (Alnus Glutinosa) Wood Structure and Opportunities For Wider Use of Timber In Structural Elements

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ABSTRACT

When greshly cut, black alder (Alnus glutinosa (L.), Gaertn.) timber presents a light orange colour and during air exposure it changes to red-orange. European alder tends to be light tan to reddish brown; color darkens and reddens with age. Large aggregate rays appear as accasional small streaks on the intensity of the colour that can be mistaken for defects in the wood. Heart colouring and heartwood herd rot are not clearly distinguishable from each other. Although the tree 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. the main goal of study is to work out the Alnus glutinosa roundwood, harvested in final felling methods: density - according to ISO-13061-2-2014; Compression strength paralel to the grain -according to ISO- 13061-17-2017; three point bending strength and modulus of elasticity - according to 13061-3(4)2014. The results of study whwre the strength properties of Alnus glunosa saund timber, timber coloures coused by fungi when strength parameters aren't signitificantly affected, early stage of rot, characterized by discolourred fibres and pathes in the wood, where the general texture and strength properties only start being affected were investigated would help for practical applications so that this wood species can be processed more efficiently for value -added products.

How Will We Balance Production Forestry and Renewable Energy Systems In The Future?

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ABSTRACT

Efforts to deliver climate-smart forestry have focused primarily on utilization of biomass residues or dedicated systems to produce bioenergy or manipulation of growth and yield to increase carbon uptake by forests. Woody biomass utilization to produce electricity, heat or biofuels has dominated forest operations and forest engineering research in the US for the last several decades. By comparison, very little attention has been paid to how operational planning, harvesting, and logistics may be impacted by the current, rapid transition to electrification of vehicles, equipment, and tools, or emphasis on other renewable energy systems. For example, solar and wind have received over $US 97 billion in investment recently as part of the US Bipartisan Infrastructure Law (BIL). How will we balance these energy systems, the conversion of transportation and equipment to electric or electric hybrid with sustainable forestry production? These new technologies may actually provide new opportunities for operational forestry to lead global efforts on climate and sustainability in ways that may simultaneously improve the profitability of our industry. A review of related literature and results of a nationwide US analysis of a new approach to integrated forestry and solar energy are presented.

Stand Damage After Thinning Operations: Does Size and Location of Damages Differ? A Comparison of Logging Operations

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ABSTRACT

Thinning operations are seen as a necessity to obtain stability, produce timber, derive income and promote adapted tree species in even-aged forests. In Austrian forests the highest number of machineries used in forestry are tractors with winches. Different yarder systems, used in combination with excavators with processor heads and with built-in processor units, represent the second most frequent owned machines. Harvester and forwarder are ranked third when numbers of owned machines were compared in 2020, even though in the last years the volume of extracted timber by forwarder increased. These three harvesting technologies were used in thinning operations of coniferous and deciduous dominated stands in central and eastern Austria: Data on damaged trees after a thinning with motor-manual felling and extraction of the timber by tractor with winch was collected at flat to low slope gradients in a coniferous dominated stand. A cable yarder in combination with an excavator was observed in middle steep terrain in beech stands. Data was also collected on residual stand damage after harvester and forwarder, at flat terrain in coniferous stand without traction aid winch and in steeper terrain in combination with a traction aid winch. After the harvesting operations damages on remaining trees were precisely examined by location on the tree, size, intensity and number of damages. The presentation deals with the comparison of various harvesting systems in thinning operations and its effect on the intensity and location of damages.

Effects of Timber Harvesting Methods On The Nutrient Supply of Forest Soils and Recommendation Tools

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ABSTRACT

Introduction Sustainability focuses more and more on cascade using of timber. In the last years especially, timber construction made big steps. Higher und bigger wooden houses are constructed. Besides, due to the transformation of the energy system in Germany the need of wood for combustion increased, too. On the other hand, the environmental requirements as nutrients and soil protection gains importance. It is often demanded to connect timber harvesting with nutrients sustainability. The effects on the nutrient balance should also be taken into account in situations that require rapid timber harvesting measures, such as windthrows and bark beetle outbreaks. To archive this the project “Nutrient saving Forestry” was conducted.

Methods and Material In the research project “Nutrient saving Forestry” a system to improve timber harvesting by focusing on nutrient protection was developed for Bavaria. It compares two different silvicultural systems, state-owned and large privately owned forests versus small privately owned forests. On top, different harvesting methods were considered. In the project course forest growth, nutrient requirements, site class, harvesting cycles (rotations period and frequency of thinning), deposition, water balance e.g., water regime, the equipment of soil with nutrients, soil chemistry and mineralogy, physical soil characteristics were included. These parameters were implied in modelling weathering rates and nutritional balances. Data were obtained from the “Bavarian Site Information System” (BaSIS) and for nutrient content of tree compartments all over Bavaria from different monitoring sources and projects. For modelling the weathering process the modelling program PROFILE 4.2. (Becker 1999, Sverdrup and Warfvinge 1993, Sverdrup et al. 1995) was used. The project focused on the supply with base, also on phosphorous.

Results Thus, for each region and each forest site in Bavaria, based on detailed high-resolution maps, the consequences of the different silvicultural systems, forest management and harvesting scenarios, their impact for the nutrient reservoir of the soil, the delivery of weathering is quantified. Alternative scenarios are shown, and recommendations for forest practitioners and decision makers are given.

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Gridling Efficiency: Influential Factors In Managing Ailanthus Altissima Spread In Slovenia

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ABSTRACT

The tree of heaven (Ailanthus altissima) is due to its rapid spread and negative impact on biodiversity on the list of invasive species that need to be eradicated or its spread controlled. This mechanical control, such as girdling, can lead to permanent solutions in the field of invasion biology. Previous studies have reported that girdling was more effective than felling a tree. The presented study aimed to analyze the productive times considering different factors at girdling Ailanthus altissima. Time studies were conducted to monitor worker time needed for bark girdling of Ailanthus altissima. This involved identifying 9 sites in the Slovenian Kras Region with a total area of 4 ha. Girdling was performed at 20 to 30 cm above the ground while avoiding herbicides and chainsaws. Such a method would contribute to the weakening of the trees. The effect of griddled tree characteristics, stand conditions, terrain conditions, and physical activity of examined workers were therefore investigated. Linear regression models were built to explain and predict productive time. Different field-collected and remotely sourced variables were used as independent predictor variables. Eight factors were identified as influencing as the model showed their statistical significance. It includes eight independent variables relating to tree characteristics (Diameter), terrain and stand characteristics (Relief, Basal area), preparation and work organization (walk distance, Tree marking), and worker characteristics (Age, Body weight, Metabolic equivalent). The productive time required to girdle a single tree is affected mainly by terrain conditions (e.g. is increased by 78.27 seconds if the relief of the work site changes from angular or convoluted compared to smooth to undulating). The study shows that under average conditions (taking the average values of the independent variables into account) the productive time required to ring a single tree and move to the next tree would be 2 minutes and 16 seconds in the case of favorable terrain and previously marked trees to be ringed; and up to 3 minutes and 53 seconds in the case of unfavourable terrain and unmarked trees to be ringed. Considering the area as a output, workers would spend 26 hours of productive time to ring trees over an area of one hectare. In summary, the chosen method of gridling to control the spread of invasive tree species is physically difficult and rather time-consuming. There is also the question of the effectiveness of the action taken with the chosen removal method using hand tools, as the effect has yet to be seen after the first growing season. In particular, the chainsaw girdling

method should be investigated because of possibly higher efficiency as well as the effectiveness of the measure.

Safe Forests – The Psychophysiological Interrelationship Between Working Conditions and Stress of Harvester and Forwarder Drivers

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ABSTRACT

The use of fully mechanized harvesting systems in Austria is of increasing importance, since the extraction of timber is rising, and the technological development of such machines allow them to operate in steep terrain. However, working in such challenging conditions leads to potential hazards and additional challenges. Those range from difficulties manoeuvring the machine through mountainous areas, over variable soil conditions, to the high level of physiological and psychological stress the drivers are facing. Furthermore, these factors can lead to high mental stress and strain, resulting in higher stand damage rates. The aim of the present work is to assess and analyse the working tasks of the machine to identify stressful work situations for both, harvester and forwarder drivers; to determine the psychophysiological response of these operators to environmental factors and slope gradient; and to evaluate the driver´s subjective stress and fatigue before and after a harvesting operation. Harvester and forwarder operators, with and without the use of traction aid winches, were examined during a work shift with a set of qualitative and quantitative methods. Sensor and video-based analysis of environmental and machine data, such as working tasks and slope gradient, was performed. Psychological measures (Questionnaires and Interviews) were taken, as well as time and space resolved physiological parameters, such as heart rate variability, galvanic skin response, emotion, and eye fixation duration in real time. First results suggest that the subjectively experienced stress and strain do not deviate from the norm for the most part, showing overall psychological wellbeing. Certain working tasks, e.g. driving forwards or manipulation on platform, were identified being stressful for the drivers, indicating a high mental workload. During these tasks a lower heart rate variability, a higher galvanic skin response, more negative than positive emotions, as well as a higher fixation duration were recorded.

Others

Contribution of Non-Timber Forest Products To Household Food Security: The Case of Yabelo Woreda, Borana Zone, Ethiopia
Ahmed Mohammed Abdulla

Mechanized Thinnings In Young Stands In North Rhine-Westphalia
Marian Schönauer, Marius Möller, Thilo Wagner, Dirk Jaeger

Semi-Mechanized Planting of Saplings: Pivotal Results On The Efficiency of A New Method
Marian Schönauer, Stephan Hoffmann, Lorenz Breinig, Thilo Wagner, Filippo Guerra, Dirk Jaeger

The Potential of Alternative Powertrains In Heavy Non-Road Machinery Operations
Jarkko Pesonen, Robert Prinz, Heikki Ovaskainen, Pertti Kauranen, Asko Poikela, Kalle Kärhä

Contribution of Non-Timber Forest Products To Household Food Security: The Case of Yabelo Woreda, Borana Zone, Ethiopia

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ABSTRACT

Livelihoods of the rural people of Ethiopia depend on agriculture. However, erratic nature of rain and prevalence of drought in the country make agricultural production a challenge. To counter this problem, use of the available forest resource for non-timber forest products production is the most promising option. Nevertheless, no systematic and rigorous analysis on contribution of the product to income and food security to households was made. This study, therefore, was conducted in the Yabello Woreda of Borana Zone, with the objectives of identifying determinants of household food security in the study area, to assess contribution of non-timber forest products to household food security, and to analyze the challenges in getting contribution from non-timber forest products to the rural household food security. The required data set for the study were gathered primarily through survey method from 160 randomly selected sample households both from non-timber forest products participants and non-participants (80 each). A purposive sampling procedure was used to select 2 PAs. Structured interview was used as data collection method. Supplementary, secondary data were collected from various sources. Household calorie consumption method of data collection was followed to determine food security status of sampled households. The data were analyzed using descriptive statistics like mean, standard deviation, percentage and frequency distribution. Univariate analysis such as t-test and Chi-square ($\chi 2$) tests were also used to compare characteristics of non-timber forest products participants and non-participants groups. The binary logistic regression model was run to establish whether and to what extent income from non-timber forest products (NTFPs) along with other variables influence food security status of households. Among 12 explanatory variables included in the logistic model, 3 of them were significant at less than 5 percent probability levels. In general, the empirical analysis, like many other similar studies, confirms that non-timber forest products production would have positive impact on income and food security of beneficiary households. Thus, the concerned GOs and NGOs should join hands to support the improvements of such non-timber forest products production.

Mechanized Thinnings In Young Stands In North Rhine-Westphalia

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ABSTRACT

Large stand openings, resulting from windthrows and bark beetle infestations in the last decades, have altered the forestry landscape in Germany. In North Rhine-Westphalia alone, approximately 50,000 hectares experienced windthrows due to the Kyrill storm in January 2007. Seventeen years after Kyrill, most of the stands regenerated by nature or planting. Some of these stands were tended meanwhile, at least on sites with high grow potential. Failure to implement these planned measures has led to the formation of dense, qualitatively mixed stands, where growth is not concentrated on selected dominant trees. These stands now urgently require thinning. In this research project, we will examine practical and economic aspects of thinning using harvesters on regenerated windthrow areas in North Rhine-Westphalia. Therefore, we conducted several time-and-motion studies on sites cleared after Kyrill. The main objective was to determine the productivity of fully mechanized harvesting in young stands (heights up to 13 m). Two configurations were tested: (1) A standard harvester and harvester head were used, and (2) the harvester was equipped with the John Deere Universal Multi-Tree Handling Device (MTH). Additionally, we aimed to assess the effect of previous tending on the harvester's productivity. Preliminary results show a different distribution of tree dimensions. The untreated stand exhibited smaller diameters at breast height (DBH) of 6.7±3.5, compared to the tended stand, with an average DBH of 8.5±4.8 cm. Currently, the time studies are being facilitated and will be ready for presentation at FORMEC 2024. The findings of this study will support decision making of forest land owners by providing information about the performance, costs, potential of the surveyed work systems in young stands in North Rhine-Westphalia.

Semi-Mechanized Planting of Saplings: Pivotal Results On The Efficiency of A New Method

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ABSTRACT

Large clear-cut areas as a consequence of drought and bark beetle infestations necessitate extensive replanting efforts in German forests, leading to an increased interest in efficient planting systems. In addition to manual planting, mechanized and semi-mechanized systems utilizing surplus forest machine capacities available after completion of salvage logging operations are likely required for timely reforestation of the clear-cut areas. A semi-mechanized system utilizing a standard forwarder with a grapple-actuated soil borer for both, the transport of planting material and the preparation of planting pits, combined with two workers carrying out manual planting, was investigated in a time-and-motion study. The frequency method was used after video recording of a planting operation that covered an area of approximately 1.2 hectares. A total of 815 alder saplings (Alnus glutinosa L.) with heights of 1.2–1.5 m were planted. Observed productivity was 93 saplings per system work hour (SWH). With additional placement of stakes for stabilizing the plants, the productivity decreased to 42 saplings per SWH. While directly comparable results were not found in the literature, available productivity figures of purely manual planting systems do not suggest an increased productivity of this semi-mechanized system. Considering ergonomics, however, forwarder utilization provides reduced workload not only in plant hole preparation but also with material transport and clearing of planting spots. Both the ergonomic aspects of the system and, in particular, the suitability of the soil borer for different soil textures should be further investigated.

The Potential of Alternative Powertrains In Heavy Non-Road Machinery Operations

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ABSTRACT

The European Union (EU) plays a crucial role in the global battle against climate change. The EU has a target to cut greenhouse gas (GHG) emissions by at least 55% below 1990 level by 2030. The effort sharing sector (ESS), i.e., sector outside the Emissions Trading System (ETS), comprises the emissions from transport, agriculture, residential heating, non-road machinery, waste management, F-gas emissions, and emissions from industry and energy consumption outside the ETS. In Finland, the total share of the emissions caused by non-road machinery (i.e., industrial machines (e.g. excavators, wheel loaders, forklifts), agricultural tractors and forest machines (harvesters and forwarders)), is around 10% of the total GHG emissions. Rising concern about the non-road machinery emissions has accelerated the development of alternative powertrains (i.e., hybrid, electric, hydrogen, biofuels, biogas) which can be feasible in high-power operations.

This literature review focused on studies on the alternative powertrains and fuels of non-road machinery based on their potential and future visions during the last 14 years. The goal was to evaluate different alternative powertrains based on previous research and highlight the possibilities and bottlenecks of each technology. A total of 122 studies were included in the literature review, of which 66% were from European countries and the rest (34%) from Asia, North and South America and Africa. In 67 studies, alternative powertrains were examined based on their feasibility and potential in non-road mobile machinery and 55 studies presented results on non-road machinery with conventional diesel engine. Different alternative powertrains were compared to diesel and the potential was evaluated based on emissions, energy efficiency and limitations in the implementation of powertrains or fuels.

The preliminary results showed that especially in forest machinery in the near future, hybrid technology has the best potential because it can be integrated to operate as a booster of conventional diesel engine, while reducing fuel consumption and CO_2 emissions. Correspondingly, in industrial machinery, full-electric powertrain has been found to be the most feasible powertrain due to extensive charging network and energy efficiency in short-term high-power operations. In agricultural machinery, the scope of the research has been in biofuel technology which have given promising results on emissions reduction and performance improvement.

Poster Presentations

Productivity During Selection Cutting: A Key Factor During Continuous Cover Forestry Operations In Nordic Boreal Forests
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Changes In Calorific Value of Pine Dead Wood Stored For 54 Months
Radosław Wąsik, Dariusz Kulak, Krzysztof Michalec, Arkadiusz Stańczykiewicz, Monika Gach

Digital Skills For Forest Education: The Foree Erasmus+ Project For The Integration of Digital Technologies In The Forest Training Sector
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Tree Species Classification of Young Energy Wood Forest Using Machine and Deep Learning
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Real-Time Traffic Load of Forest Road Network In A Suburban Forest
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Tracing The Timber From Forest To The Mill: An Application of The Surf Algorithm To Fingerprint Truckloads Based On Photographs Taken At Their Ends
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Can Log Geometry Be Used For Traceability Within The Forest Value Chain?
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Hybrid-Electric Self-Propelled Carriage - First Field Tests of The Second Prototype
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Technodiversity Light - A New Tool For The Practitioners
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Investigating Logging Wounds Severity After Thinning In Beech High Forests By Tomographical Analysis
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Evaluating An Innovatice Ict System To Monitor Small-Scale Forest Operations
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Preliminary Study On A Combined Roundwood Extraction system
Stanimir Stoilov, Maria Francesca Cataldo, Krasimir Petkov, Salvatore Francesco Papandrea, Georgi Georgiev Angelov, Giuseppe Zimbalatti, Andrea Rosario Proto

Time Consumption of Timber Harvesting and Forwarding In Terrain With Linear Unevenness
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Comparative Analysis of Small-Sized Logging Crews Using Cable-Grapple Skidders In Beech Stands
Petros Tsioras, Stanimir Stoilov, Pavel Nichev, Georghi Angelov, Marina Chavenetidou

Forest Misconceptions Among Young Students: Identification Through Enquiries and Production of Forest Learning Resources Accordingly
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Analysis of Influencing Factors On Stumpage Prices From Galician Auction Series Between 2011 and 2017
Eduardo Tolosana, Alejandro Pasamar

Biomass Collection From Salvage Logging of Young Plantations Affected By Wildfires and Pests Using The Fixteri Fx-15a Feller-Bundler
Eduardo Tolosana, Ruben Laina

Global Overview of Fuel Consumption and CO_2 Emissions In Fully Mechanized Ctl Logging Operations of Industrial Roundwood
Kalle Kärhä, Lars Eliasson, Martin Kühmaier, Raffaele Spinelli

Productivity During Selection Cutting: A Key Factor During Continuous Cover Forestry Operations In Nordic Boreal Forests

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ABSTRACT

Our two studies address the increasing interest in continuous cover forestry (CCF) in Sweden, where even-aged forestry (i.e. rotation forest management) traditionally dominates. The conversion of even-aged stands to uneven-aged ones through practices like selection cutting is expected to rise.

Despite this trend, there is a lack of current research on harvester productivity during selection cutting in Nordic conditions. During selection cutting, harvest intensity is crucial, because it influences volume growth and is instrumental in preserving forest ambience. The objective of our first study was to investigate the impact of harvest intensity on harvester productivity during selection cutting in Swedish boreal forests. The field study involved harvesting 14%, 28%, or 48% of a mature stand's basal area. Harvester productivity was primarily affected by piece size (stem volume). In selection cutting, piece size increases with decreasing harvest intensity, which boosts harvester productivity. Moreover, when fewer trees are harvested, we noted a subtle trend that harvester operators seem to have greater freedom in selecting the order of stems and their felling directions. This facilitation further increases productivity during lighter harvesting intensities.

Our second study focused on forwarding during CCF in Swedish boreal forests. Contemporary literature emphasizes that log concentration, the number of assortments, piece size, load size (capacity), slope, and extraction distance as the main factors affecting forwarding productivity. However, scientific knowledge on CCF in boreal forests, particularly the impact of remaining trees on forwarding productivity during selection cutting, is limited. Our second study's objective was to isolate the effect of remaining trees (i.e. stand density) on forwarding productivity in Swedish boreal forests. The results indicated that log concentration (log volume per 100 m distance of strip road) predominantly explained productivity, while other factors had at most minor effects. Importantly, stand density did not significantly affect forwarding productivity in our study. These findings raise a broader question: should productivity models for thinning and clearcut operations in Nordic boreal forests be distinct if remaining trees have no significant impact on forwarding productivity? While this study serves as a pilot with a small dataset, the results prompt further verification through larger datasets involving multiple operators and stands.

In summary, this research contributes to understanding harvester productivity and forwarding efficiency in the context of CCF in Nordic boreal forestry. These studies shed light on the potential need for nuanced productivity models in Nordic boreal CCF forest operations, especially regarding lighter harvesting intensities (≤20% of stand basal area), because lighter harvesting intensities seem to increase the relative competitiveness of selection cutting (i.e. CCF) versus clearcutting (i.e. even-aged forestry / rotation forest management) in Nordic boreal forests.

Changes In Calorific Value of Pine Dead Wood Stored For 54 Months

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ABSTRACT

The study was conducted in 2017-2021. The subject of the study was dead wood of pine, which was stored without shelter for a period of 54 months, at a depot located in the Spała Forest District. A pile of roundwood 124m wide and 3.2m high was laid from pine rollers 2.5m long (medium-sized assortment with the symbol S2a). A total of 620 m3 of wood was deposited in the pile. In three places of the pile about 50 m apart, so-called "measuring baskets" were placed (steel structures filled with wood). In each basket, three layers of test rollers were determined: the bottom (about 0.5 m from the ground), the middle (halfway up the pile) and the top (about 0.5 m from the top edge of the pile). Each layer included 7 test rollers of varying diameters. The field study consisted of measuring the weight (accurate to 0.1 kg), diameter (accurate to 1 mm) and length (accurate to 1 cm) of each test roller. Measurements were taken at the beginning of the experiment (trial 0), then 6, 9, 12, 15, 18, 24, 30, 36, 42, 48 and 54 months after the experiment was set up. During each trial, a disc 3-5 cm thick was cut from each test roller. The cut-off discs were used to determine the moisture content of the wood, calculate the oven dry density and determine the lower heating value (LHV) [J/g] and wood calorific value (WCV) (also called energy density by volume [GJ/m3]). In total, the lower heating value and wood calorific value of 471 wood samples collected during the 12 trials were analysed. In each trial, the characteristic was determined for at least 35 rollers. It was found that after 54 months of storage, the LHV of the pine wood remained practically unchanged. In fact, there was a minimal increase of about 1 % compared to the beginning of the experiment (trial 0). The slight increase in LHV should be explained by changes in the chemical composition of the tested wood, which was the subject of a separate study. After 54 months of experimentation, a decrease in the proportion of hemicelluloses, characterised by a lower gross calorific value, and an increase in the proportion of cellulose and lignin, with a higher gross calorific value, were found. The WCV after 54 months of the experiment was about 9 % lower compared to the beginning of the experiment, and these differences were statistically significant. This feature was strongly related to the wood density. The average value of wood density at the end of the experiment decreased by almost

10 % compared to the beginning of the experiment. The average LHV of the tested wood obtained at the end of the experiment significantly exceeded the normative (PN-EN ISO 17225:2014) minimum values reported for wood chips. This shows that dead wood of pine stored for a period of 4.5 years can be used as a full-value energy feedstock.

Digital Skills For Forest Education: The Foree Erasmus+ Project For The Integration of Digital Technologies In The Forest Training Sector

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ABSTRACT

Among the top priorities of the European Policy Agenda is the enhancement of digital skills and competencies for both work and life. Indeed, digital technologies improve methods of processing, storing, and transmitting information, contributing to the creation of knowledge and fostering progress. The forest education sector would enormously benefit from the integration of digital technologies. However, it's crucial first to identify the issues and opportunities of partial or total digitalization, to understand the role of digital technologies in the process of converting information into knowledge, skills, and competencies, and to define ways to support the form and content of the knowledge transfer process. The Erasmus+ project "FOREE - Digital skills for forest education" aimed to overcome the reservations of forestry teaching staff towards digital teaching through knowledge exchange and innovative approaches for the conceptualization and implementation of e-learning formats. It also aimed at further improving the skills of combining digital learning formats and contents with on-site teaching. Specifically, FOREE's objective was to develop a National guided pilot Train-the-Trainer (ToT) course and a MOOC on blended learning models to guide the transition of the European forestry education sector from purely classroom/field-based courses to a flexible hybrid education system through the complementary use of digital learning concepts, tools, and platforms, and their broad application in adult forestry training courses. Additionally, the project developed an online and free-access toolbox reporting information on the main digital tools and technologies regarding their applicability to the forest education sector, helping trainers to identify the best options for their teaching activities. The FOREE Erasmus+ project consortium involved five organizations from four European countries (Italy, Estonia, Germany, Austria), including three forest education centers, one university with excellence in blended learning models, and a cluster organization with competence in digital transformation. The project's results are scalable at the European level.

Tree Species Classification of Young Energy Wood Forest Using Machine and Deep Learning

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ABSTRACT

The government of Finland is actively promoting the utilization of forest wood for energy generation, leveraging the abundant wood fuels in young Finnish forests to replace fossil fuels in heat and power production. Therefore, robust assessments of forest resources and comprehensive classification of tree species within these ecosystems have become imperative. Our objective was to classify 3 tree species (Scots Pine, Norway Spruce, and Deciduous species) and forest floor using images from digital aerial photogrammetry (DAP) employing two machine learning methods i.e. random forest (RF) and extreme gradient boosting (xgboost) and one deep learning model i.e. convolutional neural network (CNN). The Deciduous species includes Silver Birch, White Birch, European Aspen, and other species.

A young private forest in Pieksämäki, Finland, was surveyed using a Sony RX1R II camera mounted on a GEODRONE X4L drone across 18 ha of three forest stands in spring and summer. Pix4D mapper processed the images into georeferenced digital maps with a DAP pixel resolution of 3.9 cm. Summer images were utilized for reference data due to deciduous tree detection limitations in spring. The total of 3615 tree species crowns (Pine: 1071, Spruce: 909, Deciduous: 1110) and forest floor (525) polygons were delineated manually for preparing reference data sets. Random forest and xgboost classifiers with hyperparameter grid search were implemented for tree species classification. In addition to this, a basic CNN was used for the classification. The convolutional layers within the CNN employ 3x3 kernels with ReLU activation, gradually increasing the number of output channels to capture hierarchical features from the input images, followed by max-pooling layers with a 2x2 kernel and stride 2 for down sampling. The dense layers consist of two fully connected layers, with the first layer having 512 units and ReLU activation, followed by an output layer with units equal to the number of classes for classification. The training and test images were divided into 80 % and 20 % respectively. The training of all models was conducted in Jupyter notebook (python) web interface utilizing the computational resources of the Puhti supercomputer, made available by the CSC–IT Centre for Science, Finland.

The result shows that the CNN outperformed two machine learning models. The overall accuracy of CNN was 91% (Pine: 91 %, Spruce: 94 %, Deciduous: 85 % and forest floor:97 %) achieved for the test sets. Similarly, random forest received an overall accuracy of 83 % (Pine:82 %, Spruce: 80 %, Decedious:83% and forest floor: 91 %) with optimum values of hyper parameters: n_estimators=50, max_depth=None, min_samples_split=2, min_samples_leaf=4 and max_features=None. Likewise, xgboost resulted an accuracy of 89 % (Pine:87 %, Spruce:86 %, Decedious:93 % and forest floor: 93%)

with hyper parameters: n_estimators=100, max_depth=3, subsample=0.8, colsample_bytree=0.8, learning_rate= 0.1, gamma= 0.1 and objective= multi:softmax.

In conclusion, the classification of young tree species benefitted significantly from the application of both machine learning and deep learning models. Across the models assessed, it was observed that deep learning, specifically the CNN, exhibited superior accuracy compared to traditional machine learning algorithms such as RF and xgboost.

Real-Time Traffic Load of Forest Road Network In A Suburban Forest

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ABSTRACT

Suburban forests belong to the category of ecosystems located in areas bordering areas of intense human activity (cities, factory areas, etc.), taking on important roles, such as protection from severe weather phenomena (floods), reduction of emitted pollutants, the production of oxygen, etc., while helping to improve the quality of life of residents and visitors. The aim of the research was the real-time measurement of the traffic load of vehicles passing through the forest areas, using special equipment and field measurements at the entrances of the Periastic Forest. The method used is that of measuring the traffic load (DTV)* at regular time intervals with use, on the forest road axis. The way of conducting the research, including all the necessary processes, from the selection of the point and the placement of the equipment, to its removal and the processing of the results, is thoroughly analyzed. The process is simplified by encouraging the use of the method in the forestry practice. Through the calculation of the traffic load, immediate conclusions are drawn about the users and the traffic in the peri-urban forest. The traffic load measurement device of the company MetroCount – Vehicle Classifier System was used and piezometric tires were applied to the device. The data was processed with the application MetroCount Traffic Executive v.5.0. Through the analysis of the traffic load data, the study aims to draw conclusions about the points of the forest where the number of users is located. By finding these points, as well as the reasons for their selection, a model of controlled guidance is proposed. The aim of the model is to strengthen the recreation areas of the forest, which receive the majority of visitors, and at the same time to temporarily remove them from parts that need protection. With the implementation of the model over time, all parts of the forest can receive a gentle regeneration and be able to support the number of visitors, offering them quality and safe development of sports and leisure activities. Finally, the measurement of the traffic load will also be a means of estimating the frequency of maintenance of the forest road network based on the intensity of its use over time, and this makes it a valuable tool in the Forestry Service.

Tracing The Timber From Forest To The Mill: An Application of The Surf Algorithm To Fingerprint Truckloads Based On Photographs Taken At Their Ends

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ABSTRACT

Traceability in the timber-based industries is a basic requirement to fulfil economic, social and legal requirements. Timber transport provides the link between timber harvesting and the mill. This process has significant economic consequences. In most cases, timber is transported with a waybill that lists the species, quantity, destination, and place of origin of the timber. As a consequence, the use of fake waybills to support the legitimacy of the timber's legal origin, and the conformity of the truckloads with the data from their waybills is difficult to check. Improving the traceability of timber is now achievable, thanks to the breakthroughs and advances in machine learning and computer vision that have changed the methods used in many scientific disciplines. The shape and arrangement of logs in the trucks could be important features for truckload fingerprinting and matching. Photographs taken at the truck end can be compared by the use of automatic machine learning and computer vision techniques. This study utilizes the SURF (Speeded Up Robust Features) algorithm to fingerprint and match photographs taken at the truck ends. It uses feature key point descriptors for extracting relevant information and photograph matching. Based on regions with notable variations in intensity, it identifies unique points in a photograph and uses effective, scale-invariant descriptors to characterize these significant locations. Strong matching between key points in different photographs is made possible by these descriptors, which gather details about the local photograph region surrounding each key point, and the result is a correlation metric which is a measure of the similarity between the key points descriptors. To evaluate the effectiveness of the algorithm, this study uses two data sets. The first dataset contained 39 photographs taken at the end of distinct trucks, and it was used as a reference data set. The same number of photographs were taken for the same trucks from a slightly different field of view, and they were used for comparison. Both datasets were extracted from video files and cropped to remove the background and to depict only the area with the logs in each photograph. Using the SURF algorithm implemented in Mathcad, the photographs taken on the same truck were pairwise compared, then the photographs from the first data set were compared with randomly picked photographs from the second dataset. In this second experiment, the photographs compared against those from the reference data set were picked so as to correspond each time to a different truck. As the main findings, comparison of photographs from different trucks produced a correlation metric close to 0, whereas those of the same truck produced a correlation metric with values of 0.1 to 0.6, producing this way a clear differentiation between the comparison outcomes. These findings clearly indicate the potential of the algorithm in fingerprinting and successfully matching the truckloads based on photographs taken at different points in the supply chain. Further work is needed to check how some important variations in scale and rotation of the photographs taken may influence the matching outcomes.

Calculation of Timber Volume Losses Incurred Due To Cross-Sectional Cuts During The Production By Harvesters

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ABSTRACT

This study focuses on actual losses incurred due to cross-sectional cuts during timber bucking by harvesters. The analysis was conducted at three selected plots. Out of 46 trees, 297 assortments were produced. Only assortments produced in accordance with specified standards were included in the analysis. For spruce samples, their actual length, middle diameter, and top diameter were measured. Dimensions were measured according to the "Recommended Rules for Measuring and Timber Bucking in the Czech Republic." Huber's formula was used to calculate the volume of produced assortments, which was modified to calculate the volume of cross-sectional cuts as well. The method of indirect measurement, which depends on a single variable R, i.e. the maximum radius of the cut after integration, was chosen as the basis for determining volume measurement errors. The unified cutting device of the harvesting head used for bucking the stem had a width of 7 mm. Due to this width, the diameter of the assortment at the cut location can be considered as the middle diameter simultaneously. The total volume of samples was estimated at 17.214 m^3, and the volume of cross-sectional cuts at 0.028 m^3. The timber loss due to cross-sectional cuts was thus calculated at 0.16 %. Analytical results indicate a clear positive correlation between the total cutting volume depending on the volume of the overall stem, as with each subsequent produced assortment, the cutting volume increases due to the thickness of the cut.

Saplings Extractor For Mechanized Planting

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ABSTRACT

Drought and the effects of insect pests have a huge impact on the landscape, the forests and their owners. Therefore, research and development of a cultivation machine that would be flexible, reliable and universally environmentally friendly, is a great opportunity to accelerate the change in tree species composition. And this is in favor of mixed forests with a higher proportion of deciduous trees, which are more resistant to weather fluctuations and climate change. The forestry technology market lacks logging and cultivation machinery, as well as adapters, that would be operationally and economically efficient, environmentally friendly, applicable in hard-to-reach terrains and affordable for small forest owners, greenness managers and entrepreneurs of cultivation machinery. For this reason, a small multi-purpose machine with high performance and flexibility for picking up and replanting of saplings in seedling forests on calamitous clearing areas, was developed at the Faculty of Forestry and Wood Technology of Mendel University in Brno. The extractor enables the use of the production potential of saplings in seedling forest stands, which are often very difficult to access and growing in heavy unprocessed soil with a high content of roots and stones. The saplings are picked up without significant damage and their replanting on calamity areas is carried out with minimization of rides and damages to the subsoil. This newly developed technology enables the rapid renewal of calamitous clearing areas, or its replenishment, with the help of saplings from seedling forest species, which are more resistant and stronger than the saplings grown in forest nurseries. A new prototype of a saplings extractor, which penetrates horizontally into the soil around the picked up sapling by pressure and rotational movements, and thus enables the collection of trees up to 250 cm in height with a large hemispherical ball of soil and root (diameter: 80 cm, depth: 40 - 50 cm) is manufactured by MISTRA s.r.o. The same technology is used to prepare a place for planting of saplings. The benefit of this extractor is that with its small dimensions (as mentioned above) and weight (approx. 750 kg) it enables one to gently pick up a sapling from seedling forest species, with a sufficient ball of soil and root even from hard-to-reach terrain. Testing of the new technology took place in cooperation with the engineering manufacturer MISTRA s.r.o. and the Faculty of Forestry and Wood Technology at Mendel University in Brno. This technique and technology has been filed for patent. It is a unique, hitherto unused technique and technology. The resulting solution from the manufacturer MISTRA s.r.o. offers the penetration of the tool into the soil by pressure and at the same time punching, which is a fundamental difference and shift in this technique. The tool is able to penetrate even heavy unprocessed soil, such as soil in forests, where are a lot of stones and coarse roots.

Scientific Audiovisuals - A Core Component of The Technodiversity Project: Harmonizing European Education In Forest Engineering By Implementing An E-Learning Platform To Support Adaptation and Evaluation of Forest Operations

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ABSTRACT

This year, the Technodiversity project - Harmonizing European education in forest engineering by implementing an e-learning platform to support adaptation and evaluation of forest operations - comes at the end of its implementation. Besides the dedicated e-learning platform, and Technodiversity booklet, which integrate a large body of knowledge and explanations for the master level students and for the industry, one of the important results of the project was the production of scientific audio-visuals aimed at exemplifying and explaining the main sub-processes relevant to forest operations, in a harmonized way of presentation. The project consortium has succeeded to produce a number of 47 high-quality-media scientific audio-visuals, accounting for a total duration of close to 5.4 hours. These files cover the main description of the processes by a functiogram, the typical work cycle as of the depicted sub-process, and an audio-visual representation of the action in each sub-process by integrating video, media and speech components. A full list of the audio-visuals will be available for watching on the YouTube, covering, among others, operations carried out with chainsaws, fellers, processors, harvesters, chippers, horse logging, farm tractors, cable skidders, grapple skidders, clambunk skidders, forwarders, sledge yarders, tower yarders, and processor tower yarders. The duration of the produced audio-visuals ranges from 3:59 to 11:19 minutes, averaging 6:52 minutes. This work presents the rationale behind the development, materials and methods used in the development, and structure of the audio-visuals.

Upsmart 5.0 – A Project Designed To Produce Tutorials On The Use of Advanced Methods In Forest Engineering Research

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ABSTRACT

This year, a Romanian financed project – UPSMART 5.0, financed by UEFISCDI – has started with the aim of producing tutorials on the use of advanced methods in forest engineering research. This project builds up on the experiences gained in several other projects such as Technodiversity (financed by Erasmus+), Hypercube 4.0 (financed by UEFISDI), and Sintetic (financed By Horizon Europe), as well as those coming from other smaller projects and needs. The aim is to produce high quality media tutorials on the most common methods used in forest engineering research, as well as to extend the portfolio of scientific tutorials in order to cover new research trends of the discipline. These tutorials are to be produced in two languages: English and Romanian. This work presents the current developments and the links to the developed tutorials with the aim to disseminate them to interested researchers and to support the development of scientific skills among young forest engineering researchers.

Development of A Receiver System For Sub-Meter Accurate Navigation In Real Time of Forestry Machines In Forest Operations – Results of A Practical Test

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ABSTRACT

The accurate positioning of vehicles and workers in the forest is a focal point of the forestry digitization processes. Digital harvest planning and positioning of forest machines with sub-meter accuracy and in real time is essential for sustainable, soil conserving, efficient and safe forest utilization. A forestry-oriented navigation system providing sub-meter accuracy can be applied to precisely plan and construct new skid trails, find and restore lost skid trails as well as mark individual trees and woodpiles. Additionally, transport routes can be optimized and monitored. In recent years, providing accurate positioning and navigation in the forest was identified a seminal development in optimizing the wood supply chain by research and the industry. Hence, commercial GNSS (Global Navigation Satellite System) receivers and RTK (Real Time Kinematic) base station rover systems have been released as an integrated technology for forestry operations. However, due to adverse conditions prevailing in the forest, e.g. signal attenuation, diffraction and poor signal-to-noise ratio, these approaches do not deliver the required sub-meter accuracy in real time. The development of a sub-meter navigation system and subsequent integration into a forestry vehicle are the main goals of the project "Sub-meter positioning in forestry under difficult Sat/Nav conditions", SuperNav for short. A specially modified GNSS antenna has been developed that compensates for the signal attenuation by flattening the directional characteristic. This enables better reception of weak satellite signals. The receiver has also been adapted to process signals under forest-specific conditions. The arrangement of several receiver-antenna combinations on the roof of the forestry vehicle is intended to reduce shadow-related signal loss. The GNSS data is then closely coupled with an IMU (Inertial Measurement Unit) and odometry sensors on

the basis of harvest-specific algorithms. The combination of these technologies complements the strengths of the individual components and ensures precise positioning in real time. The developed technology was tested in an extensive practical test and the machine positioning was checked on a terrestrially measured test course in the northern Black Forest.

Efficiency of Skidding of Timber Using A Forwarder Depending On The Type of Equipment

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ABSTRACT

Forwarders are specialized machines constructed and used mostly for extracting of timber under the CTL (Cut-To-Length) method. They are also sometimes used, after changing equipment, for skidding of long logs under the LL (Long-Length) method. The aim of this study was to determine the efficiency of skidding large-size timber. During the study, a Timberjack 1110D wheeled forwarder was used, in two types of construction 1) classic (with stanchions) and 2) with a clambunk. The significance of parameters affecting skidding efficiency were analyzed, which were used to determine multivariate regression equation models. The study was carried out in the Kobiór Forest District (Regional Directorate of State Forests in Katowice - Silesian voivodship in southern Poland), on a clear-cutting area, where the skidding distance was 200 m. During the study, 49 skidding cycles were recorded. Productivity in productive work time was calculated depending on how the machine was aggregated. More than 23% more long-logs can be loaded with the clambunk than with the stanchion version. The average load volume of the clambunk version was 7.79 cu.m. and that of the stanchion version was 6.19 cu.m. of solid wood. Consequently, skidding timber in the clambunk version was more efficient (only about 1.6 %) and the time consumption of this operation less (about 11 %) than skidding in the stanchion version. However, it should be emphasized that, primarily due to the high probability of increasing the machine's failure rate, long-log skidding with a forwarder in its classic version should not be practiced.

Can Log Geometry Be Used For Traceability Within The Forest Value Chain?

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ABSTRACT

Traceability in the forest sector has gained increasingly interest for ensuring sustainable management, compliance with regulations, and optimizing supply chain efficiency. Log geometry, if expressed in enough details, offers a multi-dimensional perspective on timber structure and can be used as a distinctive fingerprint that can potentially be utilized for traceability purposes. Furthermore, the size and quality of logs define 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 saw timber. In this study we will discuss the possibilities of utilizing different log features such as log length, taper and log diameter as a novel approach for timber traceability. By harnessing advanced data collection techniques and analytics, we aim to establish a comprehensive understanding of timber characteristics and quality attributes throughout the harvesting process. This integration allows for real-time monitoring and assessment of timber parameters, enabling stakeholders to make informed decisions regarding harvesting strategies and log utilization. In this study, sawlogs are followed from the forest to the sawmill and harvester stm-file information about length, diameter and taper are available. The logs are transported to a local sawmill where a stereo camera solution is installed on the log sorting facility. The picture frames and point clouds of the stereo camera are processed in a computer vision based pipeline to deliver taper, diameter and log length. These geometric features are evaluated and connected to the harvester data to identify individual logs.

Fast Lane: Survey and Status Assessment of Forest Roads Based On Airborne Data Combined With Field Records

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ABSTRACT

A properly constructed and well-maintained forest road network enables sustainable management of forests, both commercial forests and protection forests. Especially in steep and difficult terrain, the forest road network with all its functions plays a key role to ensure efficient forest management. This includes all impacts on the forest caused by the forest road network itself. Since the construction of forest roads is associated with considerable costs, regular maintenance or repair is also required during usage. This includes not only the technical trafficability by the transport vehicles, but also the functionality of culverts and lateral ditches, as well as the condition of the road structure itself with regard to load-bearing capacity. The aim of this study is to survey and assess an existing forest road network in steep terrain with a total length of 45 km covering 2,340 ha in central Austria in the limestone region. Various sources were available for developing a digital model of the forest road network. On the one hand, there is an orthophoto of the entire catchment area including a digital terrain model taken from an airplane. On the other hand, maps of the forest road network were also available from the forestry company. Furthermore, detailed drone flights with a laser scanner were carried out along selected road segments, to obtain very dense point clouds of the road to develop a digital map of an existing forest road structure. In addition, all culverts were specified onsite with their location and length, gradient, diameter, design and functionality. At the same time, the condition of the road network was also recorded on site by means of load-bearing capacity measurements and visual inspection using a previously defined survey method. The next step is to prepare the developed digital data set for detailed analyses such as water runoff and estimating maintenance needs or overall trafficability. However, the road network must not only be verified manually, but also using existing semi-automatically routines.

Hybrid-Electric Self-Propelled Carriage - First Field Tests of The Second Prototype

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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 2024, this new product is expected to achieve its market launch in 2025.

Technodiversity Light - A New Tool For The Practitioners

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ABSTRACT

TD stands for Techno-Diversity: the technological equivalent of biodiversity, where the multitude of technical options for forest harvesting becomes a mirror of the multitude of life forms in the natural environment. TD is also the name of a new tool for evaluating and choosing the most suitable harvesting system for each forest when silvicultural intervention is required. TD offers a universal, logical and transparent evaluation system that has the fundamental merit of simplifying communication between the various stakeholders: forest owner, forest doctor, user company and supervisory authority. The system consists of four main elements: 1 - a standardised chart describing any harvesting system, from fully manual to highly mechanised. 2 - an evaluation grid for the capacity of each system to operate under defined site accessibility conditions, and in particular terrain trafficability and the presence of access corridors or tracks. 3 - a scoring system applicable to each system for each accessibility condition. This system returns three values, respectively indicating the economic, environmental and social performance expected from that solution. 4 - finally, a multiplication factor for the scores, based on the weights given to the three dimensions of the operation, namely: economy, environment and society. The fundamental advantage of this system is not so much that it teaches which system works best to those who already know it, but rather that it makes the decision-making process transparent and allows the result to be explained to everyone. In addition, the chart for the description of harvesting systems makes it possible to overcome the possible (and frequent) misunderstandings that arise from incomplete communication or from a terminology that is not always clear to everyone. Once the system being discussed is described using simple icons placed on a standardised flow chart, it is much easier to understand each other and be sure that we are all talking about the same thing. This is especially important when working in a situation like forestry, where there are many stakeholders with different technical backgrounds and for whom there is often no common technical language.

Investigating Logging Wounds Severity After Thinning In Beech High Forests By Tomographical Analysis

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ABSTRACT

This research was carried out in the framework of the project AIMSUSFOR, related to a Marie Curie Grant currently ongoing at the Institute of Dendrology of the Polish Academy of Sciences. The goal of the project consists of investigating the environmental concerns related to logging operations in European beech forests. In this case, we focused on logging wounds occurred after thinning interventions in three different forest parcels located in Central Italy (Tuscany, Latium and Calabria regions). The three parcels were harvested 7-10 years ago, with motor-manual felling by chainsaw and extraction carried out by forestry-fitted farm tractor equipped with a winch. Logging severity was assessed by a Fakopp Arbotom 3D tomograph, and this represents the innovative aspect of the research. Despite numerous injuries were detected on the trees, tomographical analysis revealed low internal decay of wood, highlighting that the logging damages did not jeopardise the survival of the tree nor its mechanical stability.

Evaluating An Innovatice Ict System To Monitor Small-Scale Forest Operations

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ABSTRACT

This research was carried in the framework of the projects AGRIDIGIT and AGRITECH. The prototype was developed in AGRIDIGIT and tested within the activities of AGRITECH. A prototype of ICT system for monitoring forwarding operation in small-scale forestry interventions has been tested. This system is made up of a loading cell installed on the forwarding deck, a GNSS receiver and a smartphone app able to record the working times. The test was carried out in two forest parcels in Central Italy, after ground-based logging operations carried out by a forwarder in two oak coppices with standards. The ICT system was located into the cabin of the forwarder during the operations, thus recording the strip roads established by the forwarder. These tracks were converted into shapefile and uploaded on a high-precision handheld GNSS (Spectra SP20). Then an operator returned to the harvested parcels and located the recorded strip roads on the field, measuring the distance of the tracks from the really established trails. Average error was above 2 m. Generalized linear mixed effects models were used to investigate the influence of topographic features (elevation, slope and topographic position index) on the GNSS error, revealing that only site elevation significantly affected the positioning error.

Preliminary Study On A Combined Roundwood Extraction system

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ABSTRACT

Cable yarding is a highly appreciated and very efficient wood extraction method in areas that are difficult to access with ground-based extraction machines. Combining a tower yarder with other extraction machines, although known for a long time, is not often implemented. However, recently some combinations have been observed in forest operations. This study, conducted in a deciduous stand in Bulgaria, paid attention to the combination of a tractor-mounted tower yarder (Valentini V 400) with a clambunk skidder (Timberjack 1010D), aiming to examine the viability and improve the use and operational efficiency of the two-stage extraction system and to determine the time, log volume extracted per unit by the yarder and the clambunk, as well as the yarding and skidding costs. The research carried out the time-motion study and performed a regression analysis to identify those variables that are most likely to affect the duration of work elements and productivity. For cost analysis, the COST model was used. The knowledge of these parameters is useful to integrate the work of both machines to achieve economic and environmental efficiency of timber harvesting in deciduous forests included in the Natura 2000 network.

Time Consumption of Timber Harvesting and Forwarding In Terrain With Linear Unevenness

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ABSTRACT

Terrain roughness and local unevenness are included in the classifications of technological accessibility of an area, which are the starting point for functional (secondary) classifications. The aim of research was to determine the impact exerted on the time consumption of timber harvesting and forwarding by linear terrain unevenness remaining after soil preparation for planting in the form of trenches and ridges with a depth ranging from 0.2 m to 0.6 m. The research was conducted in pine stands in which early thinning was being carried out applying ten different types of harvesters, forwarders and agricultural tractors with forestry trailers. The share of main work time (MW) and complementary work time (CW) for harvesters amounted to approx. 50%, of which 35% was for delimbing and bucking, and 15% for tree felling. The times of forwarding and unloaded journeys amounted to 28% for forwarders and were shorter by approx. 17% as compared to forest trailers aggregated with agricultural tractors. The share of loading and unloading times amounted to approx. 50%. The lowest time consumption of timber harvesting and forwarding, approx. 30 min/m^3, was recorded for the variant with the SAMPO harvester and for forwarding with the FAO-FAR forest trailer or the VIMEK forwarder. Higher time consumption was noted especially in the case of harvesting in stands with deeper linear irregularities of the terrain. In the Eco Wood land accessibility classification applied in forest practice we propose use new factor, linear irregularities of terrain.

Comparative Analysis of Small-Sized Logging Crews Using Cable-Grapple Skidders In Beech Stands

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ABSTRACT

The transition from modified agricultural machinery to purpose-built forest machinery has become evident in the forest sector of many countries, driven by the need for enhanced productivity and a shortage of local forest workforce. The adoption of purpose-built forest machinery often coincides with a reduction in logging crew size, prompting new considerations regarding the productivity, costs, and ergonomics of the introduced harvesting systems. This study investigates two skidding systems utilizing the cable-grapple skidder Welte 115/5L, differing in work team size: one with one skidder operator and two chainsaw operators (WT3) and the other with one skidder operator and one chainsaw operator (WT2). Conducted in natural European beech forests in southern Bulgaria, the research focused on the group shelterwood system within the Natura 2000 network. Both WT3 and WT2 exhibited net skidding productivity of 9.96 m3/PMH over a mean skidding distance of 300 m and a mean winching distance of 20 m, outperforming conventional systems in the area. Despite this, there were notable differences in gross skidding productivity (8.64 m3/SMH for WT3 vs. 7.30 m3/SMH for WT2), affecting skidding cost (5.41 €/m3 for WT3 vs. 6.62 €/m3 for WT2) and unit production cost (EUR 9.33 €/m3 vs. 11.53 €/m3). This study emphasizes the effective utilization of the cable-grapple skidder by smaller teams, offering higher productivity, lower unit costs, and enhanced flexibility during piling—largely attributed to the inclusion of the knuckle-boom loader. In conclusion, WT3 emerges as a well-balanced choice for small logging crews, ensuring sustainable forest operations amid workforce challenges and demonstrating increased productivity compared to conventional logging crews in the area.

Forest Misconceptions Among Young Students: Identification Through Enquiries and Production of Forest Learning Resources Accordingly

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ABSTRACT

More than fifty groups of students from around fifteen secondary schools in Madrid region (Spain) have been surveyed in order to identify their opinions about forest management and forest fire issues. As, in former European studies, some relevant misconceptions in the public opinion have been detected, the enquiry objective was to identify the main wrong opinions spread among 13- and 16-years old students from an urban environment in the Region of the Country capital city, Madrid. The results have been analyzed statistically, the principal misconceptions were identified and compared between private and public schools, centers from the downtown and the surrounding suburbs and villages, students from different socio-economic levels and so on. Besides, in collaboration with two groups of secondary school students within the scope of a learning-service domestic project, dissemination materials about the related forest basic concepts have been produced and delivered through social networks to other students' collectives, and through professional associations to biology and geography secondary teachers. The evaluation of the results of this action is still in course, and the final results will be published when finished.

Analysis of Influencing Factors On Stumpage Prices From Galician Auction Series Between 2011 and 2017

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ABSTRACT

In this study, 1,183 standing timber auctions in Galicia between 2011 and 2017, published by the Galician Regional Government, have been analyzed. Updated annual average price series have been developed for industrial pulp or panel wood from eucalipt and conifer plantations, for conifer wood for packaging and construction sawmills and for conifer wood for quality large square sawntimber manufacture. The factors that affect those prices were identified and quantified. Four samples were analyzed using as separation criteria species, presence of damages, type of felling - selective vs. clearcut - and geographic procedence. Three of the samples were analyzed with GIS, adding factors such as slope, distances to roads and distance or time to the factories. The analysis of variance and multiple regression models fitted between the prices and the analyzed factors yielded determination coefficients between 37% and 54% and mean absolute errors between 3.1 and 5.3 €·m^{-3}. The predictors of the price of standing timber have been the presence of damage, type of felling, slope, distance or time to the factory, unit volume, percentage of sawmill destination and average distance to roads (some of them only in some of the studied samples).

Biomass Collection From Salvage Logging of Young Plantations Affected By Wildfires and Pests Using The Fixteri Fx-15a Feller-Bundler

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ABSTRACT

The Fixteri FX-15a feller-bundler equipped with a Nisula280E+ accumulator felling head has been timestudied, felling two Young Galician eucalypt plantations, one severely affected by Gonipterus pest and the other having been burnt a year and a half earlier. The monitoring methods were GPS, automatic recording of weights/time and work reports at shift scale, in addition to continuous timing in shorter periods. The productivity equations, through non-linear fitting of logarithmic models, identified the type of stand - burned or pest-affected - and the weight per tree as the main factors. Causes of lower productivity in the stand set on fire were the difficult handling and bundling, the less efficient collection and the greater heterogeneity (there were areas already partially harvested and others inaccessible). The detailed time-study concluded that the bundling process caused considerable waiting times for the felling head, and that the in the burned stand the bundling process was slower and moving times were longer. In no case was the positive income-cost balance reached, although in the mass attacked by Gonipterus it was reduced to -125 €·ha-1. According to the fitted curves cost per hectare vs. dry weight per tree, self-financing in the case of the pest-affected stand would be reached for more than 33 kg of dry matter per tree, while, in the burned stand, for more than 80 dry kg·tree-1, far from the observed range.

Global Overview of Fuel Consumption and CO_2 Emissions In Fully Mechanized Ctl Logging Operations of Industrial Roundwood

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ABSTRACT

The aim of this literature review was to bring together the most relevant and recent research information on the fuel consumption (L h^{-1} & L m^{-3}) and CO_2 emissions caused by the fully mechanized cut-to-length (CTL) logging machinery when applied to industrial roundwood. For that reason, the search was limited to papers published from the year 2000 onwards. A specific aim of this review was to describe the effect of different independent variables on fuel consumption in fully mechanized CTL logging operations. The final review included 83 study papers.

The review showed that the engine power of CTL forest machines accounts for most of the variance in the hourly fuel consumption of both harvesters and forwarders. We underline that the cubic-metre-based fuel consumption of CTL forest machines is correlated to the same factors that affect work productivity. Among all influencing factors, the average stem size, removal intensity and silvicultural treatment have the strongest effect on the fuel consumption per m^3 incurred with felling-processing, whereas forwarding distance, removal intensity and payload size are the main drivers of fuel consumption per m^3 as incurred with extraction. Further influencing factors are soil type (mineral soil or peatland), use of tracks, assortment type and machine size. Together with those factors, the role of the machine operator remains crucial and is dependent on two separate skills: the capacity to achieve high productivity, and that to apply fuel-saving driving techniques.

The easiest way to reduce the carbon footprint of CTL logging machines is to increase the productivity of the logging work, for example by giving machine operator-specific training to utilize more efficient work methods and economic energy-efficient driving techniques. Furthermore, several other measures to reduce the carbon footprint of CTL logging operations were discussed in this review. Finally, we recommend that all essential variables that have a significant impact on the productivity of logging work, fuel consumption and CO_2 emissions are reported in study papers in the future.