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PERFORMANCE OF A LIEBHERR 451-13 HANDLER IN LOG MOVING AND PILING OPERATIONS

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HIGHLIGHTS

- Cycle time, fuel consumption and productivity depend on movement distance in log handling operations.
- Time and fuel consumption models are linear in relation to average movement distance.
- Productivity decreases sharply in the models as a function of average movement distance.

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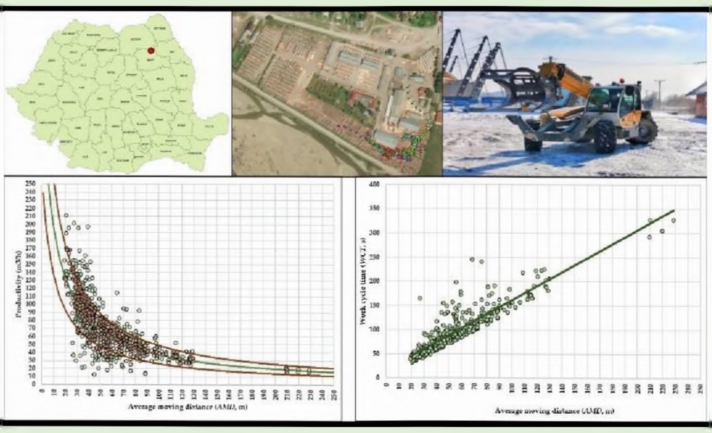
GRAPHICAL ABSTRACT



ABSTRACT

Performance assessment studies are essential in forest operations for optimizing larger systems, setting working rates, evaluating environmental performance and cost control. Studies on log handling operations are rare in the existing literature. This study evaluates the operational performance in terms of time, fuel consumption and productivity for a Liebherr 451-13 log handler in a wood storage facility. For coniferous logs of 4 m in length, a movement distance ranging from 30 to 500 m, a mean payload of 2.28 logs per turn averaging 1.68 m^3, net efficiency and productivity were estimated at 0.016 h/m^3 and 61.66 m^3/h, respectively. Systematically sampled GPS (Global Positioning System) speed was used to estimate the movement speed and distance which were then used to model time, fuel consumption and productivity as functions of the average movement distance. The developed models characterize the productivity functions of the observed operations and provide hints on potential improvements. Planning carefully the operations in terms of machine's operational coverage has the potential of improving the productivity and unit fuel consumption.

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1. INTRODUCTION

Evaluation of time and fuel consumption as well as of productivity is an essential component of forest operations research because it provides informed grounds and the data needed for optimization, work rate setting, cost control and environmental accounting; typically, it is implemented in the form of time and motion studies which account for production outputs and fuel use in operations [1]. Since the use of updated technology is a driver of sustainability in operations [2], an important application of time and motion studies is that of evaluating the performance of newly introduced or significantly changed equipment, technologies or methods of work, with the aim of characterizing their behavior in known or new operational environments. On the other hand, keeping records on the performance of operations in various setups is important for both practical and scientific applications.

The scientific literature is abundant in studies reporting on the performance of operations developed in the forests. As examples, review studies have collected a significant body of knowledge on the operational performance of motor-manual felling [3], skidding [4,5] and cable yarding [6], as well as on the share of partly and fully mechanized working methods in forest operations [7]. On the other hand, availability of data on the performance of log handling operations implemented in wood storage facilities is scarce, particularly for new generation equipment.

In Romania, for instance, there are work rates developed in the past for the Romanian-made front loaders (IFRON), which set the productivity and time consumption rates in wood sorting and grading facilities by considering factors such as the condition of the ground (paved/unpaved), species (broadleaved/coniferous), thickness of the logs (less or more than 16 cm) and the movement distance as categories [8]. Similar factors are considered to set the fuel consumption rates for operations implemented in wood storage facilities by Romanian-made front loaders [9], and both, or similar rate setting standards are currently used by the National Forest Administration – RNP Romsilva to set work rates, fuel consumption and to make payments.

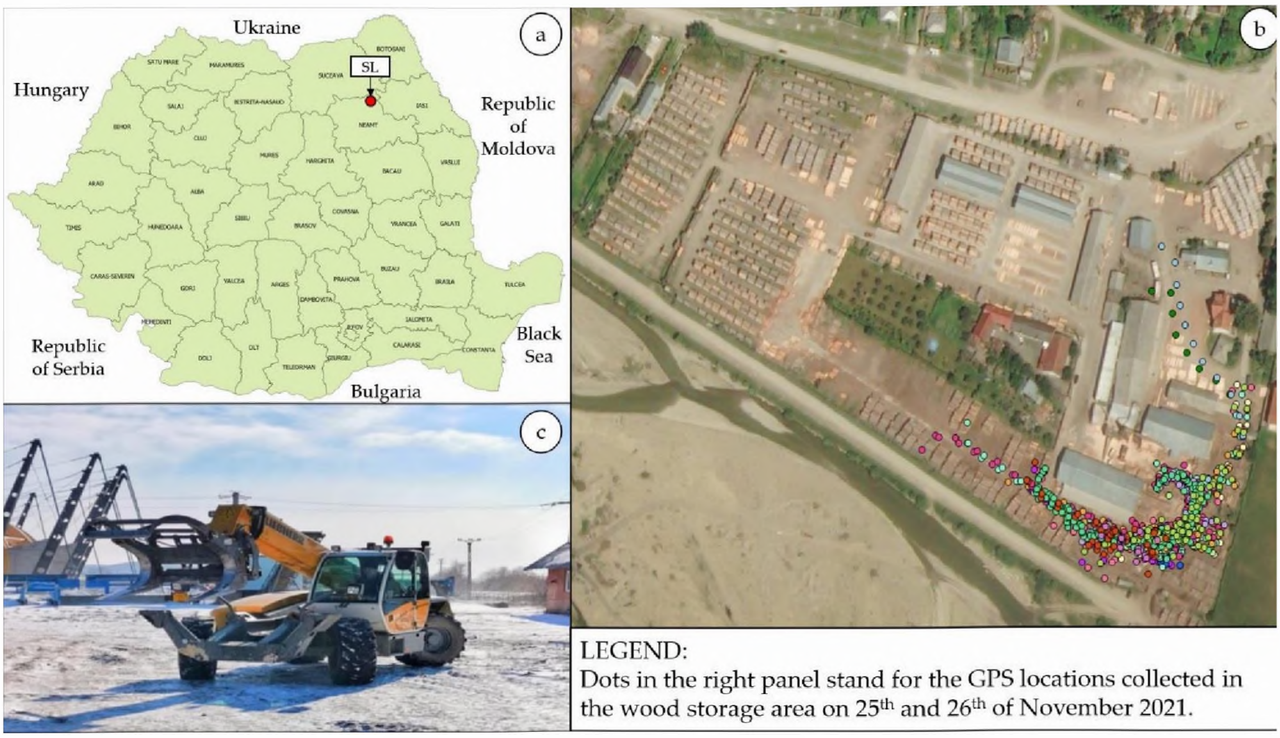
However, the machine fleet has been continuously upgraded in all the working places by purchasing significantly changed technology, while the working methods have changed to reflect the new configuration of the supply chain, in which the transportation of wood from the forest to the mills or to the storage facilities is dominantly done as wood assortments, particularly when dealing with coniferous wood. As such, the existing rate setting standards reflect only to a limited extent the way in which the log handling operations are currently implemented in wood storage facilities.

The goal of this study was to evaluate the operational performance of a new-generation log handler in moving, sorting and grading operations implemented for coniferous wood assortments in a wood storage facility. The first objective of the study was to characterize the structure of operational time consumption and to model the work cycle time as a function of log movement distance. The second objective of the study was to evaluate and model the fuel consumption as a function of operating distance. The third objective of the study was to evaluate and model efficiency and productivity of log handling operations by considering the information collected in the field as well as the data yielded by the models developed to characterize the time consumption.

2. MATERIALS AND METHODS

2.1. Study location

This study is based on data collected between 23 and 26 of November 2021 in a wood storage facility located in Neamţ County of Romania (**Figure 1a**). The wood storage facility is managed by Târgu Neamţ Forest District of the Neamţ Forest Directorate, which is one of the county-level forest directorates of the National Forest Administration (RNP Romsilva), being located near the Târgu Neamţ City. It is composed of several wood storage and processing facilities, the main of which is the wood sawmilling facility which is designed to saw logs with diameters in range of 20 and 80 cm and lengths of 3 to 6 meters. Typically, the logs are supplied to the storage facility from the surrounding forests; the processing operations are dominated in the facility by coniferous logs (99% spruce and fir), while broadleaved logs such as beech represent less than 1% of the inputs.



LEGEND:
Dots in the right panel stand for the GPS locations collected in the wood storage area on 25th and 26th of November 2021.

Figure 1. Study location and machine description: a – study location at the national level, b – wood storage facility, c – machine taken into study. Source: maps are designed in QGis based on freely available thematic layers and Bing ® aerial imagery.

As a general work organization, the logs are unloaded and piled by taking into consideration their diameter and length category (typically between 24 and 80 cm in diameter and 3 and 4 m in length). In this study, the length of the logs varied between 3 and 8 m, with the latter accounting for few logs which were crosscut to obtain logs of 4 m, which was the dominant length of the logs as observed in the field. Also, the internal log transportation distances varied between ca. 30 and 500 m, depending on the pile used to move them to the sawmill or to other locations within the storage facility. During the data collection activities, the air temperature was relatively low, varying between 5 and 7 °C and the condition of the ground was good.

2.2. Machine description

The machine taken into study was a Liebherr 451-13 telescopic handler (**Figure 1c**) equipped with a 74 kW John Deere, four-cylinder water-cooled diesel engine having a displacement of 4.5 l. The maximum moving speed is of 25 km/h and the machine was equipped with a four-wheel drive. Lifting capacity depends on the distance and height at which the payload is lifted from the ground, varying between 1 and 5 tons. The machine was equipped with a specialized grapple (**Figure 1c**) for log handling and transportation and it was operated by an experienced worker who was assisted in operations by the manager of the wood storage facility.

2.3. Work organization

The observed work tasks consisted of moving the logs from the piles in which they were stored to new piles either to feed the sawmill or to prepare the wood for further transportation. In both cases, the wood was sorted and graded, which included measurements. The time consumption and work elements considered in this study are described in **Table 1**.

Table 1. Description of time and work elements

Time & work element	Abbreviation	Description
Total time	*TT*	Total time observed during the field study, including delays caused by various reasons
Productive time	*PT*	Time in which productive tasks were observed. It excluded the delays caused by study and technical reasons, as well as meal time
Delay time	*DT*	Time spent to setup and take down the measurement devices as well as to make measurements, to have meals, and to solve technical problems
Delays caused by study	*SDT*	Time spent to setup and take down the measurement devices, as well as to make fuel and production measurements during which the work was interrupted
Meal time	*MT*	Time spent to have meals
Delays caused by technical reasons	*TDT*	Time spent to solve technical problems
Empty turn movement time	*ETMT*	Time spent during empty turn
Empty turn rear movement time	*ETRMT*	Time spent during empty turn by rear movement
Empty turn forward movement time	*ETFMT*	Time spent during empty turn by forward movement
Loading time	*LOADT*	Time spent to grab/take the logs from a pile
Loaded turn movement time	*LTMT*	Time spent during loaded turn
Loaded turn rear movement time	*LTRMT*	Time spent during loaded turn by rear movement
Loaded turn forward movement time	*LTFMT*	Time spent during loaded turn by forward movement
Unloading time	*UNLOADT*	Time spent to place the logs into a pile
Workplace cleaning time	*CLEANT*	Time spent to move small log ends

The organization of work was relatively simple, and it consisted from grabbing the logs from piles and delivering them to new, log-graded piles, which supposed empty turn on the machine, log loading, loaded turn and log unloading. In several cases, small ends of logs were moved to designated places to clear the workplace. Empty and loaded turns were made by moving the machine in both directions (forward and backward), therefore the study accounted for such movements. Breaking points of the work elements were based on accounting for that moments in which a specific event started to occur. As an example, loading was considered to start when the first maneuvers of the telehandler occurred, although the machine was still slowly moving towards a pile; each time, this occurred close to the piles from which the wood was taken. To forward and rear movements were given the starting and ending points at those moments in which one of the two ended.

2.4. Data collection

Data collection aimed at accounting for the time and fuel consumption, and for production measurement. Since measuring the distance was difficult by regular means, for each work cycle it was estimated based on the speed extracted from systematically collected GPS (Global Positioning System) locations by the means of a smartphone-based application. To do so, a smartphone was placed in the machine and measurements were taken in the last two days of observation by using the Geo Tracker app (version 5.1.5.2972), which is able to export .gpx files for use in external mapping software. To collect data on time consumption, a GoPro Hero 10 video camera was placed on the machine with the field of view oriented towards the front part so as to properly cover the operations done by the machine. The camera was powered by an external energy source (24000 mAh) and set to continuously collect video files at high resolution. Fuel consumption was measured by the refilling to full method [1,10,11] following the completion of a number of work cycles which varied between 7 and 13. It consisted of using hard polymer graded cylinders to determine the quantity of fuel consumed during the completion of the work cycles as mentioned above and the quantities determined by differences were noted in a field book along with the corresponding work cycles. The measurements were taken to the nearest 100 centiliters. Production was estimated at a work cycle resolution by noting the species and the number of logs transported between piles and by measuring the length and end diameters of each log. Diameter measurements were taken to the nearest centimeter while the log length measurements were taken to the nearest meter. The measurements on log biometrics were taken at the piles in which the logs were placed by the machine. At the office, Huber's formula was used to estimate the volume of each log, which was the used to account for the volume of each load and for the volume of production. Data describing the biometrics of each log and load, as well as the data on fuel consumption were noted in the field book. Video files were downloaded into a personal computer at the end of each observation day and the data collected by smartphone app was exported and stored as .gpx files. Data was collected from the field based on informed consent of the observed workers who agreed to participate in the study and who were instructed to work as usual.

2.5. Data processing and statistical analysis

2.5.1. Time consumption

Video files were analyzed in detail by running them in the free VLC Media Player software (Video LAN Organization, www.videolan.org). Time consumption for each work cycle was determined by observing the events and noting the starting and ending time of each work element as described in **Table 1**. Then, the duration of each time element was computed as the difference between the ending and starting time. The work of [1,12] was used as a guideline for the time consumption analysis. **Equations 1-3** describe the time elements included in a typical work cycle.

$$WCT\ [\mathrm{s}] = ETMT\ [\mathrm{s}] + LOADT\ [\mathrm{s}] + LTMT\ [\mathrm{s}] + UNLOADT\ [\mathrm{s}] \quad (1)$$

Where:

WCT - time spent to complete a work cycle, excluding delays; *ETMT* - time spent during empty turn in a work cycle, *LOADT* - time spent to grab the logs in a work cycle, *LTMT* - time spent during loaded turn to move the logs in a work cycle, and *UNLOADT* - time spent to place the logs in a work cycle.

$$ETMT\ [\mathrm{s}] = ETRMT\ [\mathrm{s}] + ETFMT\ [\mathrm{s}] \quad (2)$$

Where:

ETMT - time spent during empty turn in a work cycle; *ETRMT*- time spent during empty turn rear movement in a work cycle, and *ETFMT*- time spent during empty turn forward movement in a work cycle.

$$LTMT\ [\mathrm{s}] = LTRMT\ [\mathrm{s}] + LTFMT\ [\mathrm{s}] \quad (3)$$

Where:

LTMT - time spent during loaded turn in a work cycle; *LTRMT*- time spent during loaded turn rear movement in a work cycle, and *LTFMT*- time spent during loaded turn forward movement in a work cycle.

Based on video analysis, the time spent in cleaning the work place (*CLEANT*) as well as the time consumed as delays were accounted separately. Cycle wise time consumption data, as well as the time consumption data characterizing the delays were summarized in a database developed in Microsoft Excel ®, where it was paired with records characterizing the date of acquisition, identification of a given work cycle, number of logs per work cycle, species of the logs composing a load, volume of the load (which was calculated in Microsoft Excel ®, based on the diameters and lengths of the logs), and fuel consumption. Data pairing was based on the information extracted from both the video files and field book. Statistical analysis was adapted to the recommendations given in [1] by developing the main descriptive statistics and by characterizing the share of elemental time consumption in the productive time. In addition, a Shapiro-Wilk test was implemented for the relevant variables to check the normality of data.

2.5.2. Movement speed and distance

The movement speed was estimated as the mean of GPS speed weighted by the number of observations falling in a specific speed category (*MMS*, m/s). For this purpose, the .gpx files were imported in the Garmin BaseCamp ® (https://www.garmin.com/ro-RO/software/basecamp/) software from where the information on location, heading, speed and time was exported into Microsoft Excel ® files (1104 observations), following a procedure which was similar to that from studies of [13-15]. Data on speed was first analyzed to detect and remove those observations indicating a speed of less than 0.5 km/h (0.14 m/s) [16], then the remaining data (1047 observations) was transformed from kilometers per hour in meters per second. Based on the refined dataset, the mean movement speed was computed by keeping all the speed categories extracted from Garmin

BaseCamp ®, and used to estimate the movement distances in the empty (*ETD*) and loaded (*LTD*) turns, as well as the average moving (*AMD*) distance according to **Equations 4-6**.

$$ETD\ [\mathrm{m}] = ETMT\ [\mathrm{s}] \times MMS\ [\mathrm{m/s}] \qquad (4)$$

Where:

ETD - distance travelled during the empty turn; *ETMT* - time spent during empty turn in a work cycle, *MMS* - weighted mean movement speed.

$$LTD\ [\mathrm{m}] = LTMT\ [\mathrm{s}] \times MMS\ [\mathrm{m/s}] \qquad (5)$$

Where:

LTD - distance travelled during the loaded turn; *LTMT* - time spent during loaded turn in a work cycle, *MMS* - weighted mean movement speed.

$$AMD\ [\mathrm{m}] = 0.5 \times (ETD\ [\mathrm{m}] + LTD\ [\mathrm{m}]) \qquad (6)$$

Where:

AMD - average moving distance for a work cycle; *ETD* - distance travelled during the empty turn, and *LTD* - distance travelled during the loaded turn.

Statistical analysis related to the speed and movement distance included a normality check by a Shapiro-Wilk test, which was applied to the refined speed dataset followed by the estimation of relevant descriptive statistics to characterize the frequency of speed falling in a given category. In a third step, least square ordinary linear regression analysis was implemented to characterize the dependence relation between the work cycle time (*WCT*, s) and the average moving distance (*AMD*, m) which was estimated based on the weighted mean movement speed (*MMS*, m/s). The developed model was then used to model the work cycle time consumption with the aim of characterizing the productivity and fuel consumption functions.

2.5.3. Log volume, payload volume and production volume

Log volume (*LV*, m^3) estimates were obtained by using the Huber's formula based on field collected log biometrics. Then, the log volume estimates were used to compute the work cycle-based load volume (*PV*, m^3) as the sum of the volumes of component logs. The sum of loads' volumes was assimilated to the volume of production (*P*, m^3). Statistical analysis of load volumes aimed at checking for normality in data (Shapiro-Wilk test), characterizing the frequency of load volumes by considering the number of logs per loads and checking if there were contrasting differences in the load volumes as an effect of the number of logs per load. Most of these statistical steps included the development of histograms and graphs to characterize the mentioned distributions.

2.5.4. Fuel consumption

Fuel consumption estimates were aggregated in the form of hourly (*HFC*, l/h) and unit (*UFC*, l/m^3) fuel consumption by using the estimated production (*P*, m^3), engine running time (assimilated to productive time, *PT*) and the fuel consumption based on the repeated measurements taken in the field (*FC*, l), according to **Equations 7** and **8**.

$$HFC\ [\mathrm{l/h}] = FC\ [\mathrm{l}]\ /\ PT\ [\mathrm{h}] \qquad (7)$$

Where:

HFC - hourly fuel consumption; *FC* - total fuel consumption as the sum of individual measurements taken in the field, and *PT* - productive time converted from seconds to hours.

$$UFC\ [\mathrm{l/m^3}] = FC\ [\mathrm{l}] \ / \ P\ [\mathrm{m^3}] \tag{8}$$

Where:

UFC - unit fuel consumption; *FC* - total fuel consumption as the sum of individual measurements taken in the field, and *P* - production as the sum of loads' volume.

The work cycle-based fuel consumption (*WCFC*, l) was related to average moving distance (*AMD*, m). For this purpose, the productive time of a work cycle (*WCPT*, h) and the global hourly fuel consumption (*HFC*, l/h) were used to estimate the fuel consumption (*WCFC*, l) for each of the observed work cycles (**Equation 9**), then the work cycle-based fuel consumption (*WCFC*, l) was modeled by a regression analysis as a function of average moving distance (*AMD*, m).

$$WCFC\ [\mathrm{l}] = WCPT\ [\mathrm{h}] \times HFC\ [\mathrm{l/h}] \tag{9}$$

Where:

WCFC - work cycle-based fuel consumption; *WCPT* - work cycle-based productive time, and *HFC* - hourly fuel consumption estimated by **Equation 7**.

$$WCUFC\ [\mathrm{l/m^3}] = WCFC\ [\mathrm{l}] \ / \ PV\ [\mathrm{m^3}] \tag{10}$$

Where:

WCUFC - work cycle-based unit fuel consumption; *WCPT* - work cycle-based productive time, and *PV* - load volume.

A similar linear model was developed to characterize the relation between the work cycle-based unit fuel consumption (*WCUFC*, l/m^3) and the average movement distance (*AMD*, m). To do so, the work cycle-based unit fuel consumption was calculated according to **Equation 10**.

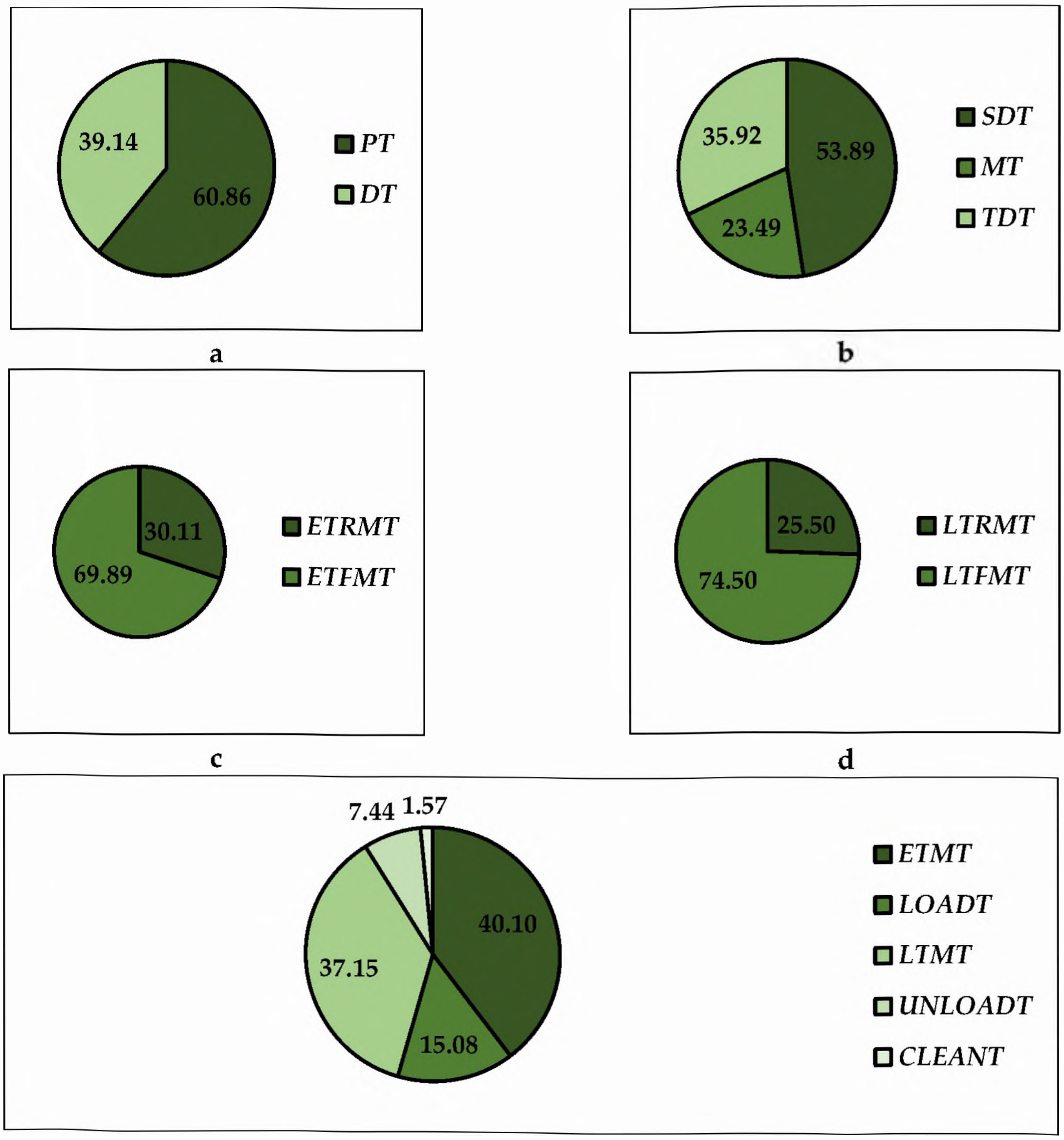
2.5.5. Efficiency and productivity

Similar to fuel consumption, efficiency and productivity of operations were first estimated for the average operational conditions. Estimates were reported both as gross and net figures where the net figures were estimated based on the productive time, whereas the gross figures were estimated based on all the observed time by excluding the delays caused by study. In a modeling approach, the productivity was related to the average movement distance by considering three scenarios. For all scenarios, the average movement distance (*AMD*, m) was estimated based on weighted mean speed and the time spent in work elements which included movement. Then, in the first scenario, the load volume (*PV*, m^3) and the work cycle-based productive time (*WCPT*, h) were used to estimate the productivity at the work cycle level, which was then related to the average movement distance (*AMD*, m). In a second scenario, the mean load volume was used instead of load volume to model productivity as a function of average movement distance (*AMD*, m). In the third scenario, the time consumption was modeled for a range of average movement distance from 1 to 300 m by the time consumption model developed as specified in **Section 2.5.2**, then the mean load volume and its standard deviation were used to estimate productivity in this range of movement distances. Mean load volume was used for productivity estimation while the productivity values computed by adding and subtracting the standard deviation were used to characterize the uncertainty in productivity estimates.

3. RESULTS

3.1. Time consumption

Figure 2 shows the share of time consumption categories in the total, delay and productive time. Productive time (*PT*) accounted for approximately 61% in the total observed time (**Figure 2a**), which was close to 16 hours.



a

b

c

d

e

Figure 2. Share of time consumption: a - productive time and delays; b - type of delays; c - share of rear and forward moving time in the empty turn time; d - share of rear and forward moving time in the loaded turn time; e - share of elemental time consumption in the productive time.

In the delay time (*DT*), the most important category was that of delays caused by study, which accounted for more than half as a result of making repeated measurements on the fuel consumption and biometrics of the operated logs (**Figure 2b**). Overall, the delay time accounted for 6.26 hours. In both, loaded and empty turns, the distribution of forward and rear moving time was similar (**Figure 2c,d**); rear movement accounted for approximately 30% in empty turn movement time (*ETMT*) and for approximately 26% in loaded turn movement time (*LTMT*). *ETMT* and *LTMT* had similar shares in the productive time (*PT*), accounting for approximately 40 and 37%, respectively (**Figure 2e**). Unloading time (*UNLOADT*) was approximately half of the loading time (*LOADT*) while clearing the workplace (*CLEART*) accounted for less than 2% in the productive time (**Figure 2e**). Detailed descriptive statistics on time consumption variables are given in **Table 2**.

Table 2. Descriptive statistics of time consumption

Time variable (Abbreviation, measurement unit)	Number of observations	Minimum value	Maximum value	Mean value ± Standard deviation	Median value	Sum
Total time (*TT*, s)	-	-	-	-	-	57637
Productive time (*PT*, s)	-	-	-	-	-	35079
Delay time (*DT*, s)	-	-	-	-	-	22558
Delays caused by study (*SDT*, s)	-	-	-	-	-	12157
Meal time (*MT*, s)	-	-	-	-	-	5299
Delays caused by technical reasons (*TDT*, s)	-	-	-	-	-	8102
Empty turn movement time (*ETMT*, s)	358	10	253	39.30±28.08	32.00	14068
Empty turn rear movement time (*ETRMT*, s)	358	3	43	11.83±6.44	10.00	4236
Empty turn forward movement time (*ETFMT*, s)	355	3	242	27.70±27.20	21.00	9832
Loading time (*LOADT*, s)	358	1	147	14.78±18.06	9.00	5290
Loaded turn movement time (*LTMT*, s)	358	10	110	36.40±20.21	29.00	13032
Loaded turn rear movement time (*LTRMT*, s)	356	2	28	9.33±5.08	8.00	3323
Loaded turn forward movement time (*LTFMT*, s)	357	2	87	27.20±18.22	21.00	9709
Unloading time (*UNLOADT*, s)	358	1	41	7.29±7.12	5.00	2609
Workplace cleaning time (*CLEANT*, s)	19	9	71	29.00±14.37	27.00	551
Work cycle time (*WCT*, s)	358	32	327	97.99±48.63	86.50	35079

As shown, a delay-free work cycle time accounted, on average, for approximately 98 seconds and it varied between 0.5 and 5.5 minutes. None of the variables on time consumption has passed the normality test. The mean and median values characterize the central tendency of time consumption for the repetitive work elements within a work cycle. Although the work place cleaning time accounted, on average, for close to 30 seconds (**Table 2**), its share in the productive time was low (**Figure 2e**) because it had the lowest occurrence in the observed time.

3.2. Load volume and production

In total, 816 logs with a dominant length of 4 m were counted during the field observation, of which 254 were of spruce and the rest (562) of silver fir. There was a dominance of loads containing 2 logs (**Figure 3**) and, by the number of logs, loads contained between 1 and 5 logs, averaging a number of 2.28±0.93 logs per turn. Production (*P*) observed during the study accounted for 600.84 m^3, and the load volume (*PV*, m^3) averaged 1.678±0.508 m^3.

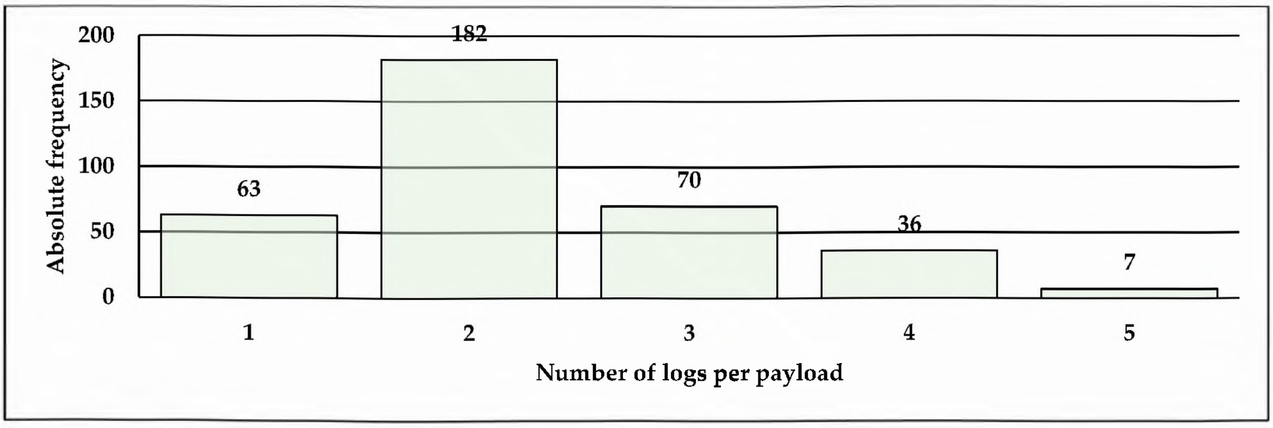
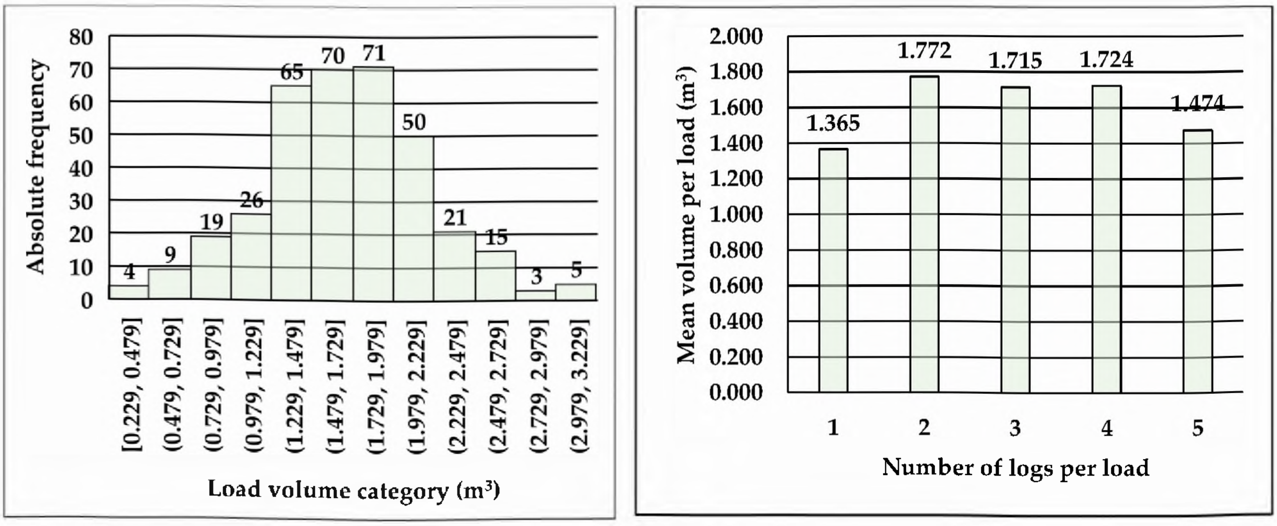


Figure 3. Absolute frequency of the loads by the number of contained logs



a b

Figure 4. Statistics of transported loads: a – histogram of load volume; b – mean volume in loads by the number of logs per turn.

Figure 4 shows the distributions of load volumes (**Figure 4a**) and of the mean volume in loads against the number of logs per turn (**Figure 4b**). Load volume was a variable that passed the normality test, while the mean volume of a load was close as value, irrespective of the number of logs per turn (**Figure 4b**).

3.3. Movement speed

As expected, the movement speed failed the normality test. Most probably this was due to a high frequency of movement speeds in lower speed classes as shown in **Figure 5**. By excluding the observations showing movement speeds less than 0.5 km/h, the refined dataset was characterized by movement speeds in between 0.5 and 11.0 km/h.

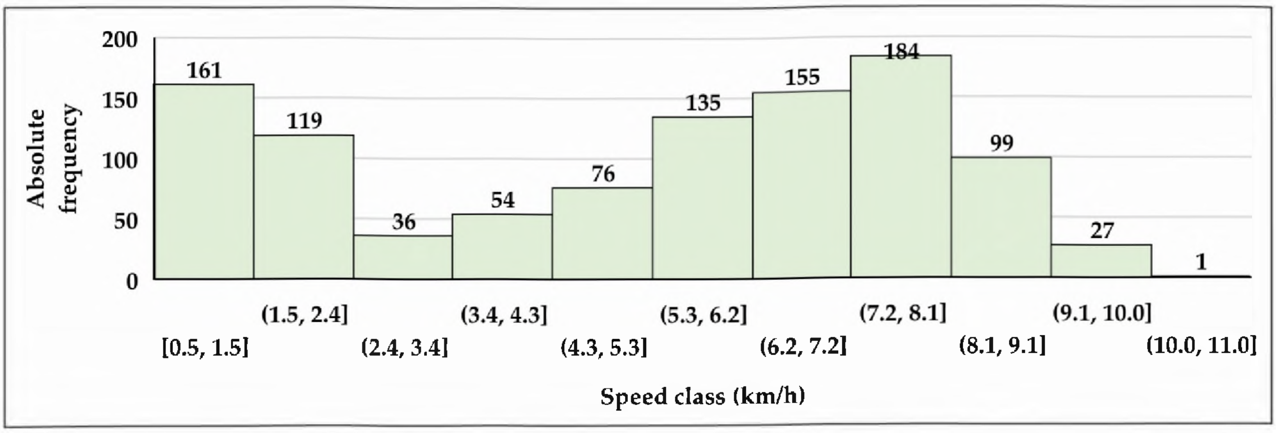


Figure 5. Absolute frequency of movement speed

In these conditions, the mean movement speed was estimated at 5.4 km/h while the weighted movement speed was estimated at 5.36 km/h (1.49 m/s). By the number of observations, dominant in the data set were speeds of up to 2.4 km/h, as well as speeds between 5.3 and 9.1 km/h which, together, accounted for more than 80% (**Figure 5**).

3.4. Work cycle time consumption model

The weighted movement speed (*MMD*, m/s) was used to estimate the empty, loaded and average moving distances by taking into consideration the time spent in these work elements (**Equations 4-6**). The model developed to relate the work cycle time (*WCT*, s) to the average movement distance (*AMD*, m) is shown in **Figure 6**.

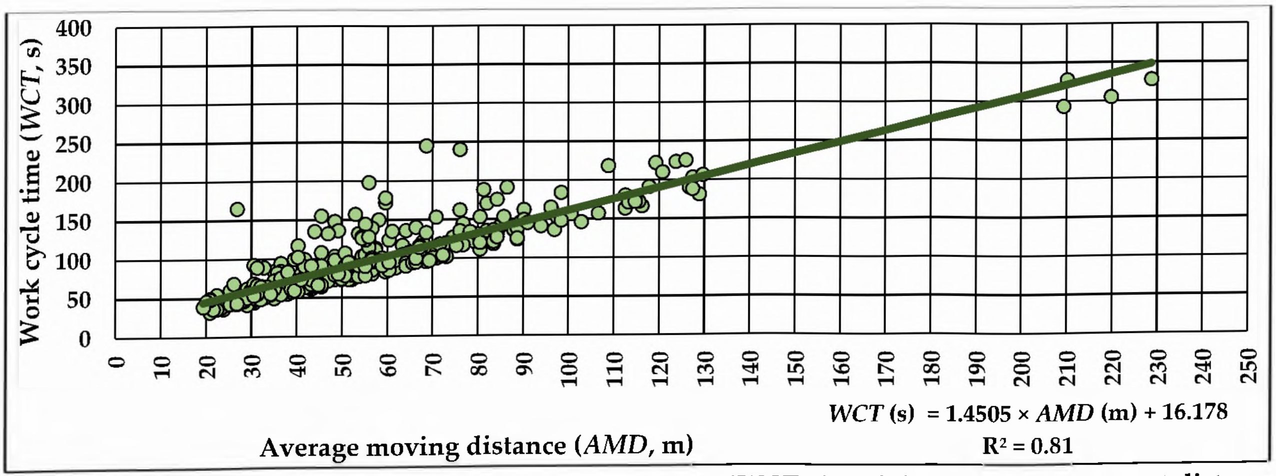


Figure 6. Dependence relation between the work cycle time (*WCT*, s) and the average movement distance (*AMD*, m).

The developed model explained the work cycle time (*WCT*, s) in a proportion of 81%, with the rest of variability being probably the effect of variability in loading and unloading time. The model was used for a part of the productivity assessment as a function of load volume and average movement distance (**Section 3.5**) by modeling the work cycle time consumption as a function of average movement distance and by using the mean load volume to plot the productivity estimates.

3.5. Efficiency and productivity

By considering the average operational conditions described in the materials and methods, as well as the statistics on time consumption and production, the estimates of efficiency and productivity are given in **Table 3**. As observed in this study, delays affected the efficiency and productivity to a significant extent, resulting in gross and net figures of productivity accounting for approximately 45 and 62 m^3/h, respectively (**Table 3**).

Table 3. Estimates of efficiency and productivity

Production (m^3)	Total time excluding delays caused by study (h)	Productive time (h)	Gross productivity (*GP*, m^3/h)	Net productivity (*NP*, m^3/h)	Gross efficiency (*GE*, h/m^3)	Net efficiency (*NE*, h/m^3)
600.84	13.47	9.74	44.62	61.66	0.022	0.016

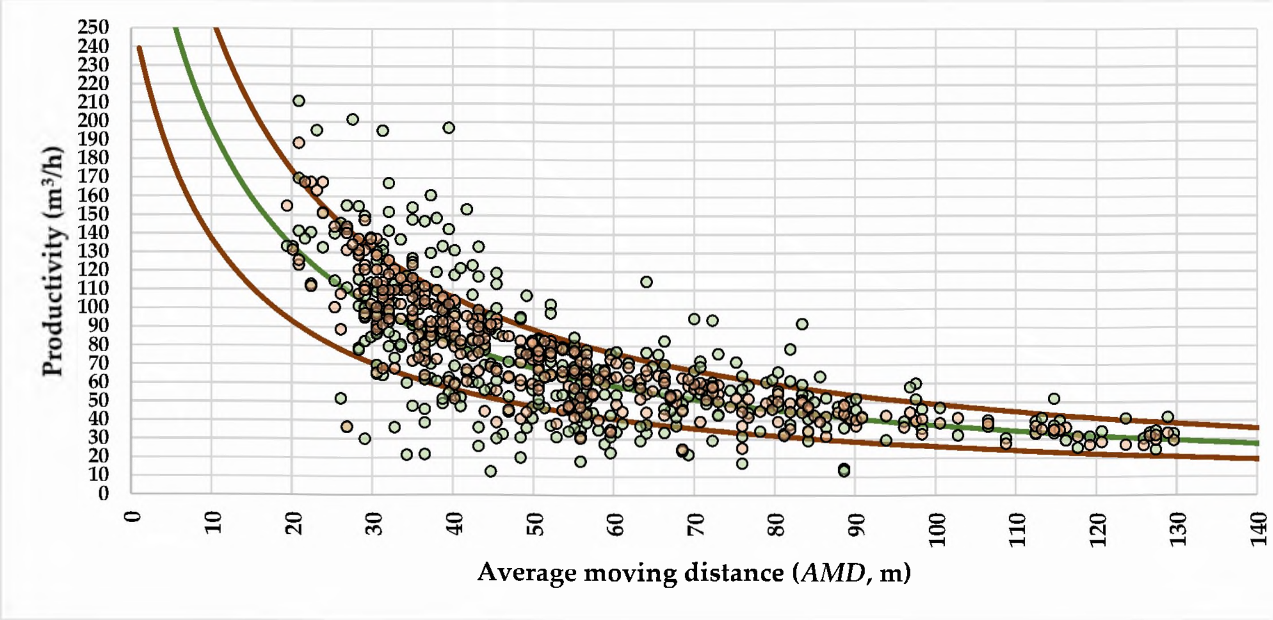


Figure 7. Productivity estimates. Legend: green dots stand for the experimental productivity computed for each work cycle based on load volume and work cycle time, brown dots stand for productivity estimates computed based on the mean load volume and the work cycle time, green line stands for the productivity estimated based on the mean load volume and the time estimated by model from Figure 6, and brown lines stand for upper and lower uncertainties of the productivity estimated by the green line by using as uncertainty measure the standard deviation of the mean load volume. Note: the figure excludes three observations in the range of *AMD* from 210 to 230 m.

Figure 7, on the other hand, shows the shape of productivity functions in relation to the average movement distance (*AMD*, m) by considering the three productivity estimation scenarios. In all scenarios, the productivity depended on *AMD* (which seemed to be the most relevant predictor), by power functions.

3.6. Fuel consumption

The global fuel consumption estimates which reflect the average working conditions are shown in **Table 4**. The total fuel consumption accounted during the field study was of 94.6 liters. Based on the productive time and the production estimates, the unit fuel consumption (*UFC*) was estimated at 0.157 l/m^3, while the hourly fuel consumption (*HFC*) was estimated at 9.7 l/h. **Figures 8** and **9** show the dependence relations between the work cycle-based fuel consumption (*WCFC*, l), unit fuel consumption (*WCUFC*, l/m^3) and the average movement distance (*AMD*, m).

Table 4. Estimates of fuel consumption

Production (m^3)	Productive time (h)	Total fuel consumption (*FC*, l)	Unit fuel consumption (*UFC*, l/m^3)	Hourly fuel consumption (*HFC*, l/h)
600.84	9.74	94.6	0.157	9.708

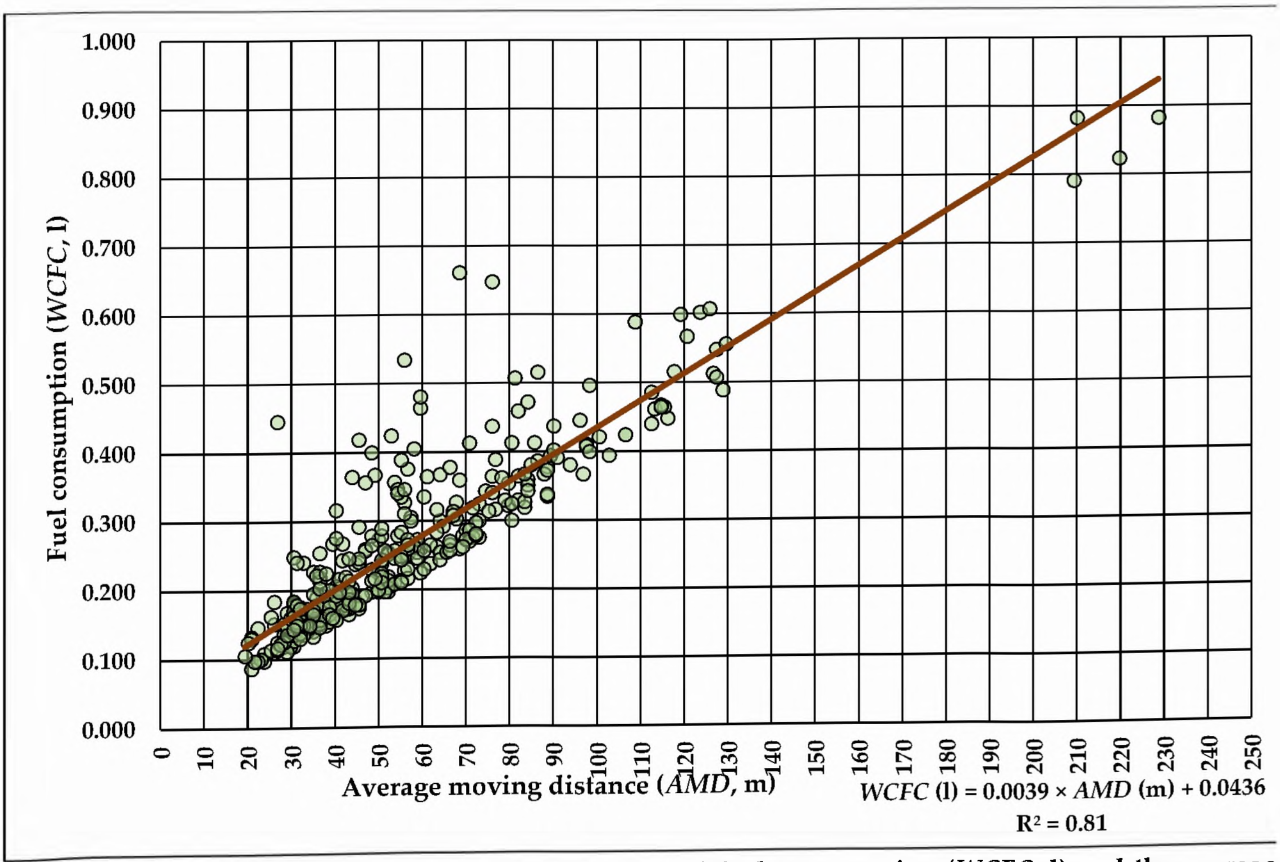


Figure 8. Dependence relation between work cycle-based fuel consumption (*WCFC*, l) and the average moving distance (*AMD*, m).

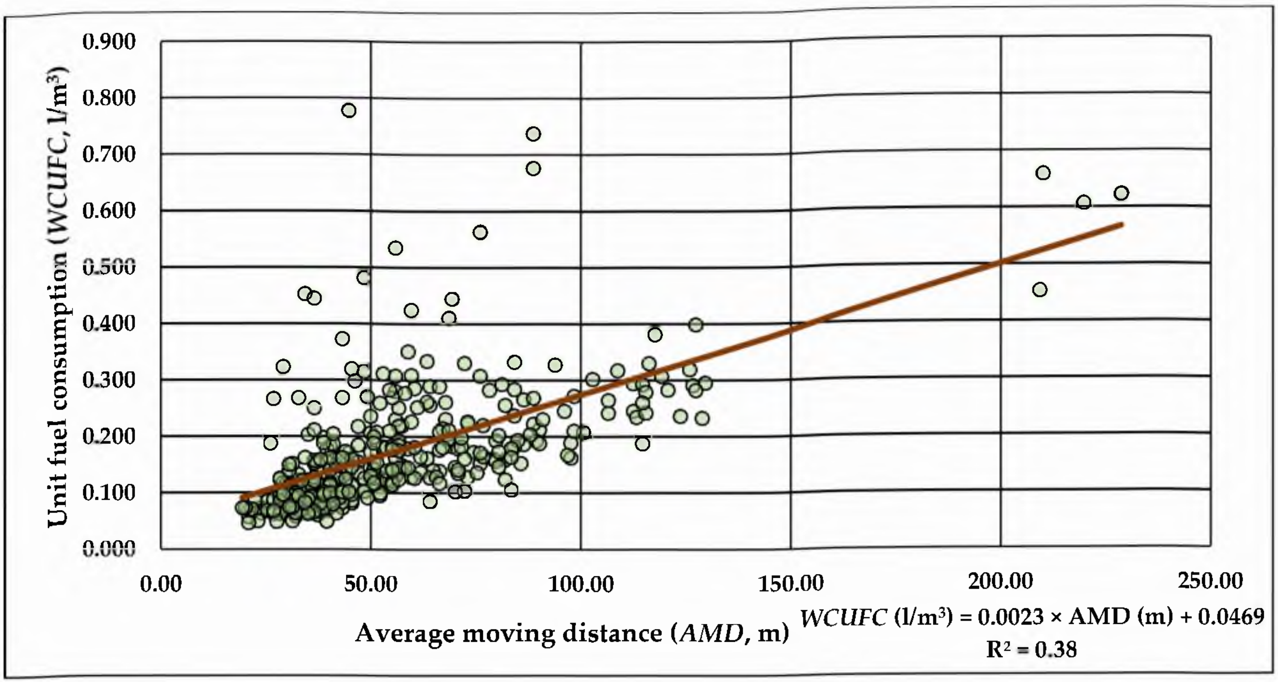


Figure 9. Dependence relation between the work cycle-based unit fuel consumption (*WCUFC*, l/m³) and the average moving distance (*AMD*, m).

4. DISCUSSION

Unfortunately, no studies were found to describe the operational performance of similar operations or machines and to provide data for comparison. However, the rate setting standards developed for older machines [8] may provide useful data for a rough comparison. **Figure A1** from the appendix section of this study plots the productivity rates of the mentioned standard against the center of operating distance categories, by considering the productivity modelled by this study. The mentioned standards set productivity rates which are differentiated by the species group and wood size category, placing the productivity of handling coniferous wood well apart from that of operating with broadleaved wood, at least for lower ranges of operational distances. It is worth to mention that productivity rates specified in [8] include other time categories such as preparing the machine for working, fueling the machine, starting and warming up the engine, and daily maintenance of the machine. The results of comparison (**Figure A1**) indicate a consistently high difference in productivity; it was higher in the case of the machine taken into study as opposed to the standardized rates, for all the range of operational distances taken into study. This does not come as a surprise since the newly-developed equipment is expected to perform better, including in maneuverability, but it cannot be explained by the biometrics of the logs, particularly their length, which is reflected in the load volume, and which was probably higher in the studies supporting the rate setting standards. Therefore, in the limits of handler's lifting capacity, the load per turn can be contrastingly higher, and will depend on the load size. The shape of productivity functions, on the other hand, are similar, with a higher decreasing trend of the productivity modeled by this study in the range of operational distances of up to 50 m, which may be due to the fact that the model of this study does not account for a fixed time for machine maintenance. Adding such a fixed maintenance time will lead to a drop in productivity as a function of operational distance. For instance, adding one hour of maintenance per operational day would drop the productivity rate from 180 to approximately 160 m^3/h for a distance of 12.5 m, and from approximately 16 to 14 m^3/h for a distance of 250 m.

A similar comparison may be made in terms of fuel consumption. For the average conditions of this study, which probably would reflect an average operating distance of approximately 250 m, the unit fuel consumption was estimated at 0.157 l/m^3 which, in standards described in [9], corresponds to a distance of close to 100 m. Similar to productivity, and accounting for improvements in the engine characteristics, the difference may rest in the size of the handled loads, which has changed in time from tree lengths to logs, at least for coniferous wood. In addition, the fuel consumption increases linearly by the operating distance, accounting for approximately 0.45 l for an average distance of 100 m, as shown in **Figure 8**. For an average load of approximately 1.6 m^3 (as of this study), at this distance, it will turn in a unit fuel consumption of approximately 0.28 l/m^3. Doubling the size of the payload (3.2 m^3) moved on the same distance, would mean a unit fuel consumption of 0.14 l/m^3, which is very close to the rates given in [9]. As a fact, the variability brought by the load size in unit fuel use can be seen in **Figure 9**, which describes a wide variation of this parameter for similar operating distances.

This study has some limitations which need to be accounted for. The most important one would be that of estimating the operating distances based on the GPS speed, a fact that may bring some uncertainty in part of the reported statistics and models. When affordable and feasible, the operating distances should be measured carefully and precisely in the field, which was not possible in this study since the logs were not moved in a specific order from given piles. On the other hand, the paths followed by the machine were not the same even in the case of moving the logs between two precisely placed piles. To this end, using the weighted speed to infer the operational distances based on the time consumption in machine moving tasks was the most reasonable approach, which can be validated by the shape of productivity functions shown in **Figure 7** and in **Figure A1**. In addition, there was a high difference between the experimental and modeled productivities, as shown in **Figure 7**. The experimental productivity reflects the variation in cycle wise loads which can be modelled by a power function to closely match the modeled productivity (data not shown herein). The same may be obtained for the productivity estimates based on the average payload, which will only overestimate the experimental productivity in lower ranges of operational distances (data not shown herein). Altogether, and by looking at the shapes of productivity functions shown in **Figure A1**, these indicate that the developed productivity models may stand for a correct approximation of the productivity as a function of operational distance.

5. CONCLUSIONS

The following conclusions may be drawn based on this study:

1. For the same operational distances, the productivity in log handling operations may depend largely on the load size which, in turn, would depend on the practices of log transportation operations. Since the current practice reflects the transportation of wood assortments at least for the coniferous wood, this will reflect negatively in the productivity of log handling operations in the log yards. However, it would be largely compensated by

the maneuverability brought by significant improvements in machine design, as shown by this study. In addition, improvements in productivity of log handling operations may be achieved by an economy of scale which may mean using bigger machines assuming that log sorting would be enabled and feasible in such scenarios. From this point of view, the machine taken into study may be seen as versatile in moving and placing the logs in the right piles;

2. A similar mechanism characterizes the fuel consumption which, although increases linearly, is affected by the load size when accounting for the unit fuel consumption metric. In addition to the load size, the operational distance stands for an important predictor of the unit fuel consumption;
3. The results of this study are descriptive and were not intended as productivity rates. To account for productivity rates, other fixed time categories such as machine maintenance and fueling need to be added in the estimation of productivity. By adding these categories, the productivity reported in this study will decrease for the same range of operational distances;
4. Caution should be used in interpreting the results of this study since some of the important predictors were estimated based on the GPS speed. This applies to the models developed to characterize the cycle time consumption, fuel consumption, unit fuel consumption and productivity as a function of the average movement distance.

FUNDING

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

APPENDIX

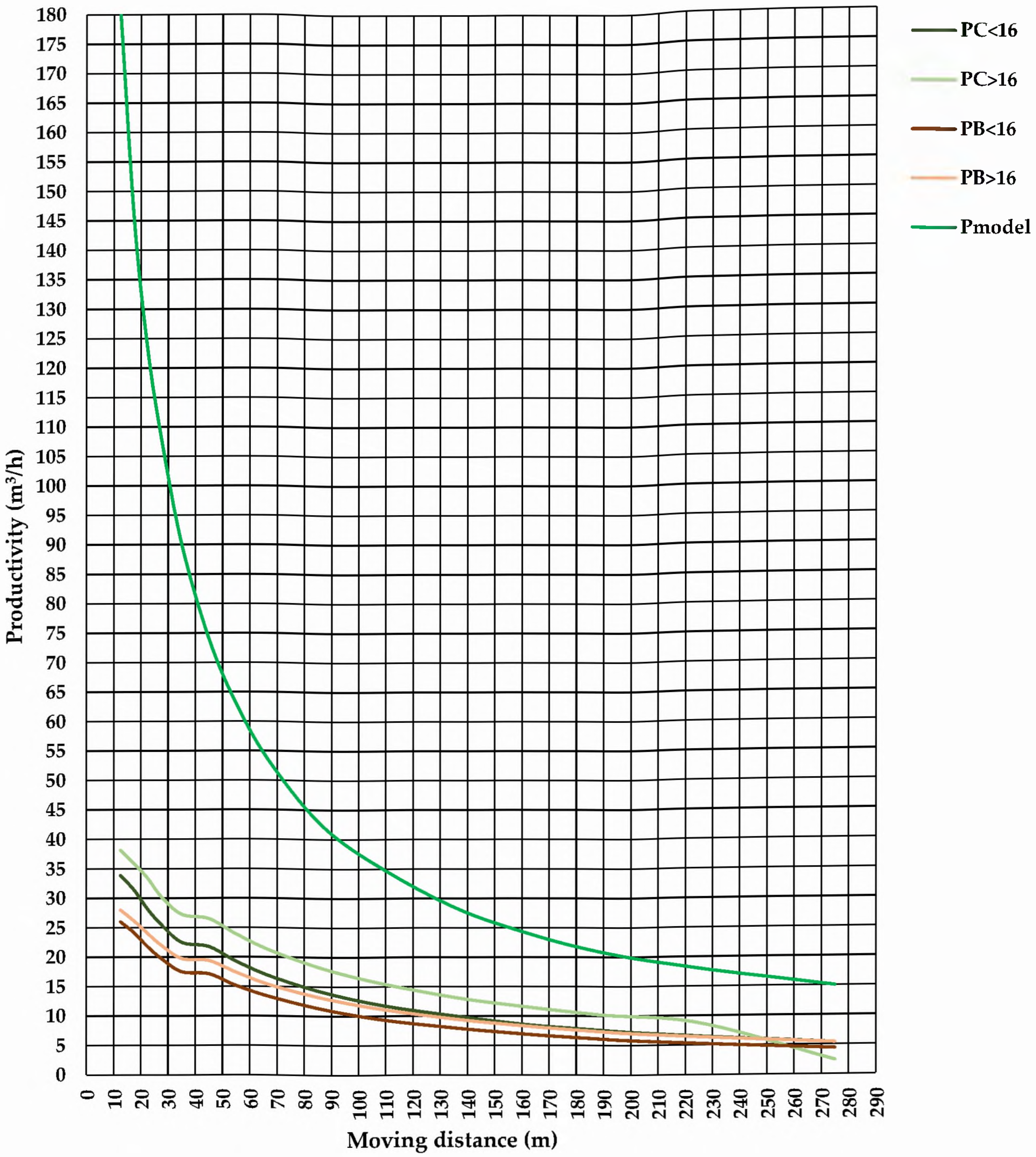

Figure A1. A comparison between the productivity rates (m^3/h) of the IFRON machine and the productivity modeled in this study. Legend: PC<16 - productivity rates of IFRON for coniferous wood with diameter lower than 16 cm, PC>16 - productivity rates of IFRON for coniferous wood with diameter higher than 16 cm, PB<16 - productivity rates of IFRON for broadleaved wood with diameter less than 16 cm, PB>16 - productivity rates of IFRON for broadleaved wood with diameter higher than 16 cm, Pmodel - productivity of Liebherr 451-13 machine as modeled by this study. Note: centers of the distance categories were used to plot productivity in the case of IFRON machine as specified in [8] for concrete paved ground.

EXTENDED ABSTRACT – REZUMAT EXTINS

Titlu în română: *Performanța utilajului Liebherr 451-13 în operații de manipulare și stivuire a buștenilor.*

Introducere: *Evaluarea consumului de timp, carburant și a productivității muncii reprezintă o componentă esențială a activității de exploatare a lemnului deoarece furnizează datele necesare pentru optimizare, elaborarea de norme de muncă, evaluarea costurilor și evaluarea impactului operațiilor forestiere asupra mediului. Astfel de evaluări se implementează sub forma studiului timpului concomitent cu cuantificarea producției realizate și a consumului de carburanți. Deși literatura de specialitate abundă în studii care raportează date cu privire la performanța operațională, nu există astfel de studii cu privire la utilajele moderne folosite în operații de sortat, manipulat și stivuit lemn în depozite. Scopul acestui studiu a fost acela de a evalua consumul de timp, consumul de carburant și productivitatea muncii în astfel de operații realizate cu un încărcător frontal Liebherr 451-13.*

Materiale și metode: *Colectarea datelor s-a realizat în depozitul de lemn administrat de Ocolul Silvic Târgu Neamț, pe durata a patru zile, între 23 și 26 noiembrie 2021, prin utilizarea unei camere video pentru înregistrarea operațiilor, a unei aplicații GPS pentru preluarea datelor necesare pentru estimarea vitezei de deplasare a utilajului, a unei rulete și a unei clupe pentru măsurarea caracteristicilor biometrice ale buștenilor operați și a unui cilindru gradat pentru măsurarea consumului de carburant. Având la bază un număr de 358 de cicluri de muncă, studiul descrie și modelează consumul de timp în funcție de distanța de operare estimată pe baza înregistrărilor GPS, estimează și modelează consumul de carburant în funcție de aceeași parametri și, respectiv, estimează și modelează productivitatea muncii. Estimările și modelele au fost realizate prin tehnici ale statisticii descriptive și prin utilizarea tehnicilor regresiei.*

Rezultate: *În total, în perioada colectării datelor de teren, au fost luate în studiu 816 piese de lemn, având lungimea dominantă de 4 m, care au fost deplasate pe distanțe cuprinse între circa 30 și 500 m. Sarcina medie a fost compusă din 2.28 piese de lemn și a avut un volum de 1.68* m^3*. Pentru operațiile luate în studiu, consumul de timp la nivelul unui ciclu de muncă depinde de distanța de operare. În aceste condiții productivitatea estimată prin excluderea diverselor tipuri de întreruperi a fost de 61.66* m^3/h *și a variat în funcție de distanța medie de deplasare a utilajului. Consumul unitar de carburant a fost estimat la 0.157* l/m^3 *iar consumul orar de carburant a fost estimat la 9.7 l/h. Consumul de carburant a variat în funcție de distanța de operare.*

Discuții: *Rezultatele au fost comparate cu cele redate în normativele de muncă și de consum pentru încărcătoare frontale de producție românească. Productivitatea muncii a fost cu mult mai mare în cazul utilajului studiat, aspect ce poate fi explicat de manevrabilitatea mai bună a acestuia dar nu și de dimensiunile pieselor și a sarcinilor operate. Alura curbelor de productivitate a fost asemănătoare pentru cele două utilaje comparate, indicând faptul că rezultatele acestui studiu sunt valide. Mărimea sarcinilor operate este în măsură să influențeze consumul unitar de carburant. Cu toate acestea, rezultatele trebuie interpretate cu precauție dat fiind faptul că distanțele de operare au fost estimate pe baza vitezei de deplasare înregistrată prin mijloace GPS.*

Concluzii: *Pentru distanțe de operare similare, productivitatea operațiilor de manipulare și stivuire a lemnului rotund poate să fie semnificativ influențată de mărimea sarcinilor operate, prin urmare de practicile curente adoptate în livrarea lemnului în depozite. Cu toate acestea, îmbunătățirile tehnologice aduse utilajelor pot compensa pierderile de productivitate cauzate de dimensiunile mai reduse ale pieselor de lemn și sarcinilor printr-o manevrabilitate îmbunătățită. Un mecanism similar este aplicabil consumului unitar de carburant, care depinde de mărimea sarcinilor operate. Rezultatele acestui studiu sunt descriptive și nu pot fi interpretate ca norme de muncă. Pentru elaborarea unor norme de muncă este necesară includerea altor categorii de consum de timp cum ar fi consumul de timp cauzat de mentenanța zilnică a utilajului.*

Cuvinte cheie: *utilaje moderne, manipularea și stivuirea lemnului, consum de timp, consum de carburant, productivitate.*

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IMPACT OF SKIDDING OPERATIONS ON FOREST SOILS: A NARRATIVE REVIEW

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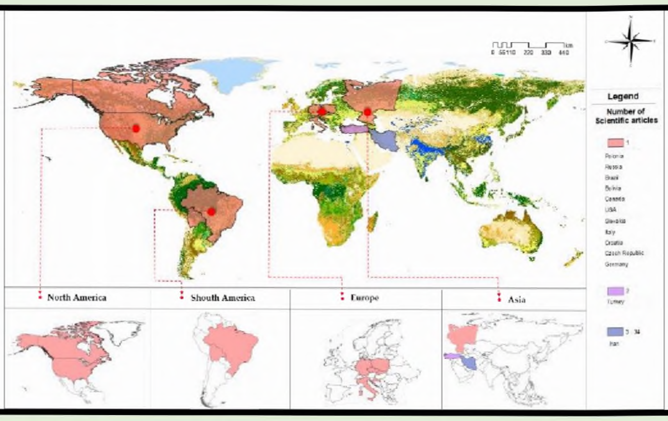
HIGHLIGHTS

- Machine traffic has a negative effect on soil's physical properties;
- Skidding operations contribute significantly to increased soil compaction and erosion;
- The study gives a synthesis of available knowledge on skidding operations and their impact on forest soils.

GRAPHICAL ABSTRACT



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ABSTRACT

Skidding operations contribute significantly to increased soil erosion which depends on the intensity of extraction. The purpose of this review was to identify the most significant information published by specialists in recent years, as well as to synthesize the available knowledge on skidding operations and their impact on the soil. The study was conducted based on available information for countries and locations around the world over a 35-year period (1986-2021). The literature review was based on the search for articles related to skidding operations. The bibliography and information were obtained from online sources and published research papers. The main terms used for the search were "skidding", 'forest operation" and "soil disturbance". 22 variables characterizing the description, the study area, the structural parameters of the stand and the experimental variables, were frequently identified in the analyzed articles. Four variables were recorded in a range of 7 to 7.8%, such as type of machine, precipitation, disturbed bulk density, and soil texture. Future studies should consider variables related to the training, experience and expertise of equipment operators, which may be important. As most of the studies on soil impact focused on the physical properties of the soil, further studies should consider more the changes in biological and chemical composition of the soils.

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INTRODUCTION

Soil is a thin layer of material on the Earth's surface that governs mass and energy flow between the lithosphere, biosphere, hydrosphere, and atmosphere [1]. According to the Food and Agriculture Organization, soils hold approximately 70% of global biodiversity and the second largest carbon reservoir on the planet behind the oceans [2-3]. In forest ecosystems, soils are an important part of the natural environment and a key substrate for a variety of flora and fauna biological processes [4]. Soil degrades quickly as a nonrenewable resource, and its formation and regeneration are extremely slow [5]. Pervious research suggested that in forest ecosystems, soil degradation causes fauna and flora to be more vulnerable [6-7]. Soil disturbance is defined as the changes in the physical, chemical, and biological processes of the soil which are often interconnected [8].

Forest operations are the discipline of planning, implementation, management and continuous improvement of forest management systems [9-10]. It focuses on the rational use of forests with the aim of improving their regeneration, composition and development, as well as adapting their benefits to the societal needs [11]. When managed responsibly, logging has the potential to support local livelihoods, economic development, biodiversity conservation, and other vital services that forests provide such as protecting soils from erosion, regulating groundwater, protecting the soil from the effects of wind and frost, among others [12]. Unfortunately, in practice, most of the logging operations remain unplanned and cause impact to the forest soils [13].

For more than 70 years, several authors have studied how mechanized forestry operations affect the forest floor, as well as ways to mitigate these impacts and promote soil recovery after the operations [14-17]. Skidding operations contribute significantly to increasing the soil erosion [12], which mainly depends on the intensity of extraction and the degree of damage caused by harvesting techniques [18]. Among the negative impacts that directly affect the soil, the following are considered: sedimentation from erosion, excessive soil heating, reduction in structural stability, gradual decline in slope stability [19-21] and mainly the disturbance [12]. Soils with high organic matter content, low bulk density, low strength, and high porosity are prone to compaction [22-26]. Compaction reduces root penetration into the soil [27], growth and plant yield [28, 29]. Vehicle tracks have a negative effect on soil aeration, which makes it impossible for microorganisms to develop [30], resulting in decreased absorption of nutrients and water [31]. Soil's bulk density and porosity are the most direct quantitative measures of compaction and are widely used to indicate changes due to heavy mechanical traffic [26, 28, 32]. The quantification of damages to the soils produced by forest operations is essential to account for production parameters (economic aspects) and negative environmental impacts [16, 33]. Minimizing soil disturbance is currently one of the most important challenges for the forestry sector [34]. Soil disturbances occur when equipment and logs are moved on the ground or skid trails, causing changes in its structural characteristics [35-36] and productivity [37]. One of the main disturbances identified is soil compaction that affects long-term forest productivity [38]. The effects of compaction can persist in a forest for several decades [28, 37, 39], and problems related to soil disturbance have become a challenge faced by foresters, especially in mountainous forested regions [38].

The purpose of this review was to identify the most significant information published by specialists in recent years, as well as to synthesize the available knowledge on skidding operations and their impact on forest soils. The findings of this study may be useful in gaining a better understanding of the field's scientific achievements.

2. MATERIALS AND METHODS

This study is based mainly on the review of the literature on skidding operations, which allowed to know the current state on the subject in the research area and the advances made to date. The study was conducted based on information available for countries and locations all over the world covering a 35-year period (1986-2021). The literature review was based on searching papers that were related to the performance of skidding operations. This work used a narrative review approach that was developed based on a bibliographic review. The literature and information were obtained from online sources and research papers published in English and Spanish languages, such as Google Scholar, Web of Science, Scopus, and CABI, by using keywords and various combinations of them defined to search for articles relevant from the perspective of skidding operations **(Figure 1)**. The main terms used for the search were "skidding", "forest operation" and "soil disturbance".

3. RESULTS AND DISCUSSION

The use of keywords mentioned above, returned a total of 155 articles of which 67 in Google Scholar, 44 in Web of Science, 31 in Scopus, and 13 in CABI (as of December 20, 2021) (**Figure 1**). The articles were categorized into different topics: soil disturbance (with 43 articles), productivity (31), modeling (20), machinery (18), time consumption (14), ergonomics (7), roads (7), forest disturbance (4), skidding with animals (3), review (6), GHG emissions (1) and hydrology (1). Some articles were not included in this study for reasons related to downloading charges, registration of university users, etc., and also, when establishing the elimination criteria, presentations at conferences and duplicate articles were not taken into consideration. From the total of 155 articles collected, 34 articles were chosen that clearly fitted the review topic and met the selection criteria. The review focuses on the issues of soil disturbance, which were identified as the most studied topic and with the largest number of articles, in relation to skidding operations. The study focuses on identifying the effects that skidding operations produce on the morphology of the soil.

The information was organized in a Microsoft Excel ® sheet, by considering the reference, authors, article title, year, journal, country, month of study, study area in hectares, skidding distance, type of machine and harvesting system. Each skidding system has its own specific characteristics, depending on the natural and production conditions, the technology used and the proportion of manual operations in the general process [40]. A large number of factors influence the extent and severity of soil compaction [41]. In this bibliographic review, variables have been identified and collected for each study. To organize these variables, they were arranged into 4 groups:

1. Descriptive variables: study area, skidding distance, type of machine, method and harvesting system [42, 37];
2. Local variables: elevation, temperature, precipitation [43], slope [37], soil moisture, undisturbed bulk density, undisturbed porosity, disturbed bulk density, disturbed porosity and soil texture [37];
3. Stand structural parameters: stand density, forest age, tree diameter, tree height, species [44];
4. Experimental variables: number of plots and machine passes [37].

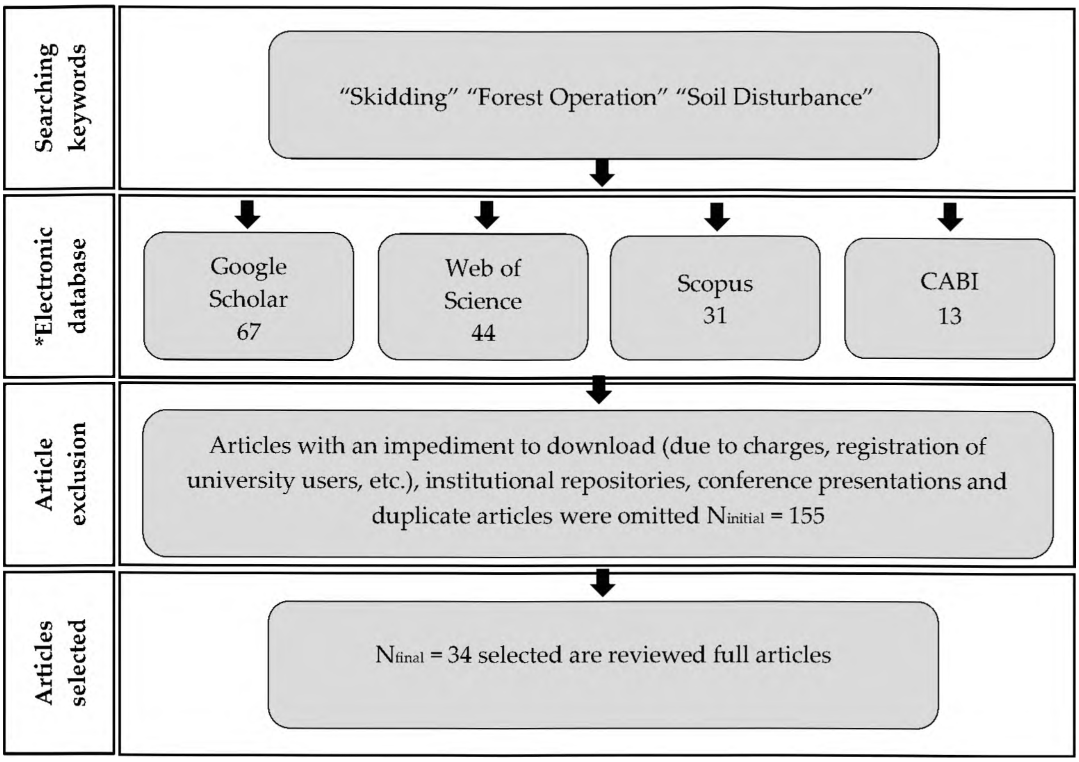

Figure 1. Flowchart of stages in the literature review process. Note: * The order of the databases presented is based on the number of publications.

The total number of articles taken into study was 34. However, in several articles it was found that various comparisons were made; some studies presented a number experimental circumstances giving in many cases more than one result which was considered a group in the analyzed data. As such, the results were considered by an individual analysis, which yielded 105 data groups with their specific variables. All data analyzes were done separately, regardless of the dependent and independent variables used. For example, some used soil disturbance in relation to soil type, slope, sample collection depending on the depth that was taken, number of passes the machine made along the trail, type of machine used etc. Also, due to reporting data standards, some of the results required conversions to provide a common point of comparison. Imperial to metric, as well as time and coordinate conversions, were among the necessary transformations.

The majority of the articles were published in peer-reviewed journals (155 references). There were also 15 oral presentations and three university publications. From all of them, 8.38% were published in Spanish and 96.61% in English. The journals with the highest number of publications were the *Croatian Journal of Forest Engineering* (29), *Journal of Forest Science* (16), *Forests* (6), *Northern Journal of Applied Forestry* (4) and *Journal of Forest Engineering* (4). In presenting the findings of the literature research, according to a simple chronology of the publications gathered, in line with the broad focus of the review, peer reviewed publications on skidding operations have steadily risen over the past two decades (**Figure 2**), in particular since 2007. The identification process returned a number of 155 studies for the period of 1986-2021. The average number of publications per year was 5.50, when calculated for the entire period.

It was found that studies related to skidding operations were on the rise in recent years. In relation to the subject, the first topic studied was focused on productivity and dates back to 1986, in which the time study methodology was applied to calculate production rates and the costs of thinning operations [44]. Productivity studies were more frequent in the period 1986-1999 [45-48]. In that period, currently active Journal of Forest Engineering and Northern Journal of Applied Forestry were the main publishing journals, with a total of 4 and 2 publications respectively. In 1990, the first article that analyzed soil disturbances was identified; this study evaluated the changes in the dry apparent density of the soil (dry unit weight) and evaluated the soil disturbance associated with the traffic of forest tractors with wide tires in five forest soils [49]. In the 2000-2005 period, the most studied topics were "time consumption" corresponding to 4 articles, "productivity" (2) and "soil disturbance" (3 references).

As shown in **Figure 2**, there was a growing trend in publications after the year 2006, with the highest number of articles in the year 2015. The research approaches were extended with topics such as ergonomics [50], roads [51], forest disturbance [52], GHG emissions [53], and hydrology [54]. This reflects the growing attention given to skidding operations and their impacts. However, in the period of 2006-2021, productivity, soil disturbances, modeling, machinery, and time composition remained the main research topics.

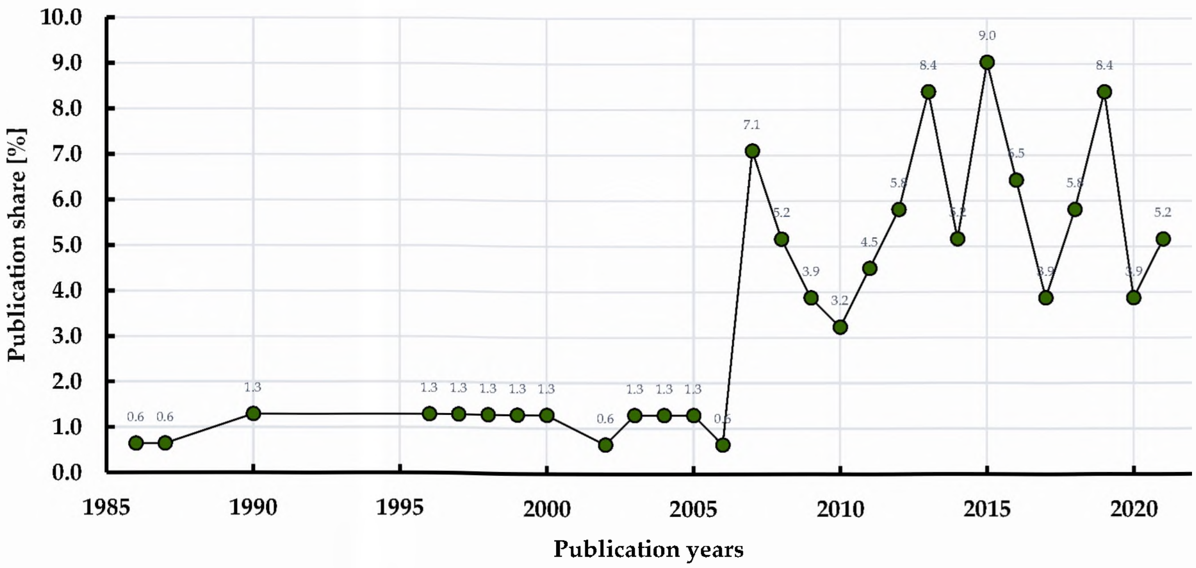

Figure 2. Peer-reviewed publications on skidding operations during the period 1986-2021, gathered from Google Scholar, Web of Science, Scopus and CABI.

Another important topic was the comparison between machines and animals (buffalo, oxen, mules, and horses) that carry out skidding operations. Most of the studies on this topic were found in Spanish-speaking countries: Mexico (2), Cuba (2), Costa Rica (1), Argentina (1) and Spain (1), representing 5.8% of the articles [55-60].

Figure 3 shows that in the period 2000-2005 there were 3 publications that referred to soil disturbances; it was the period with the least number of publications referring to the subject. From 2006, the number of publications begun to be constant at an average rate of 1.8 publications, and in the period of 2012-2015, there was the highest number of publications about the soil disturbances topic; 2015, for instance, with 5 articles, was the year with the highest number of articles published.

In relation to soil disturbance, a study was identified in 2000, in which Startsev & McNabb analyzed the effects of skidding on the infiltration properties of the surface soil. Common topics discussed relate to the effects of operations on soil properties by accounting for different slope levels and traffic frequency [29, 35, 37, 39, 42, 61-66]. Various research has looked at the relationship between soil disturbance and the number of loaded machine passes [67], as well as at comparisons between the effects of traditional (animals) and mechanical equipment [68, 32].

In terms of geographical origin, the articles came from four continents. More than half of the total were mainly concentrated in Asia with 68.06%, but although the Asian continent has a greater number of publications, only three countries contributed to this count (Iran, Turkey, and Russia), with Iran standing out with 21 studies. Europe accounted for 17.6% of the studies which were more diverse in terms of contributing countries (examples: Italy, Croatia, Poland, Slovakia, Germany, and the Czech Republic).

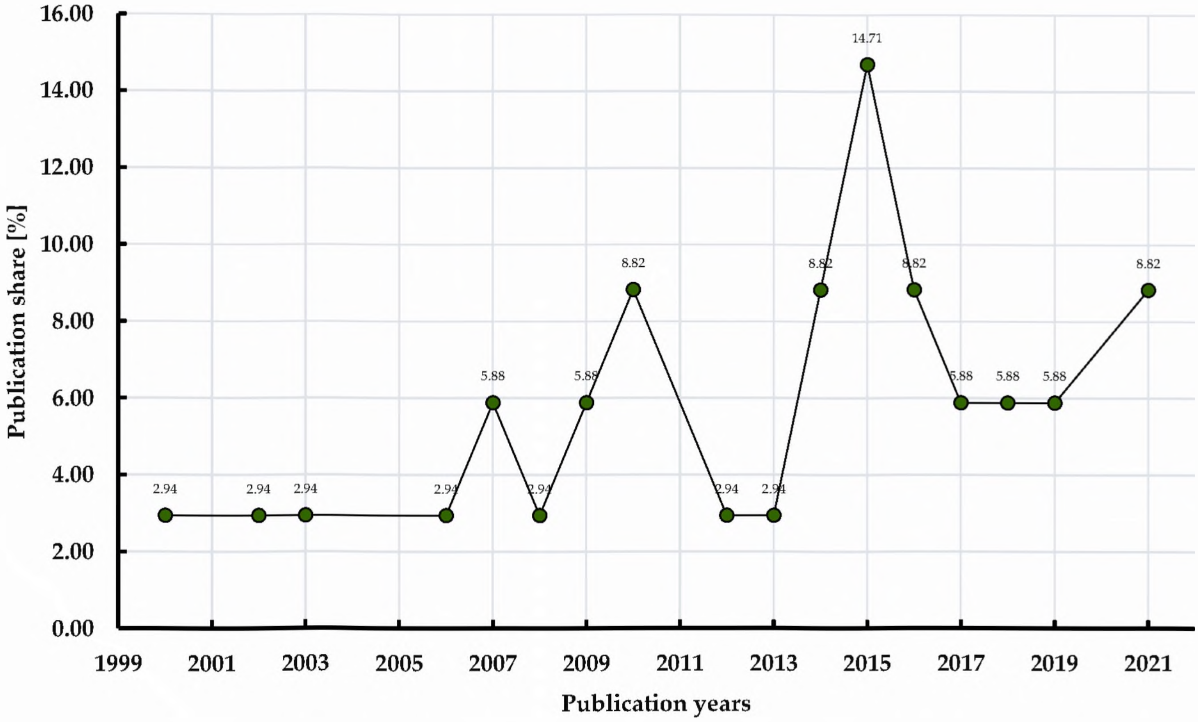

Figure 3. Peer-reviewed publications on soil disturbance during the period 1986-2021, collected from Google Scholar, Web of Science, Scopus and CABI.

In this bibliographic review, 34 scientific articles were analyzed, and in several of them, the authors made comparisons by considering various scenarios related to the type of soil, type of machinery and slope, among others; these factors were also considered in the present study. Having this in mind, 105 data groups were generated and taken into analysis, based on their study characteristics. As a result (**Figure 4**), it was identified that 55% of the data records relate to the variables in the study area, 19% to stand structural parameters, 17% to descriptive variables and 9.1% to experimental variables. In the study area, elevation, temperature, precipitation, slope, soil moisture, undisturbed bulk density, undisturbed porosity, disturbed bulk density, disturbed porosity, and soil texture were analyzed. They were the variables with the highest percentage due to the focus of the articles that analyze the soil disturbances.

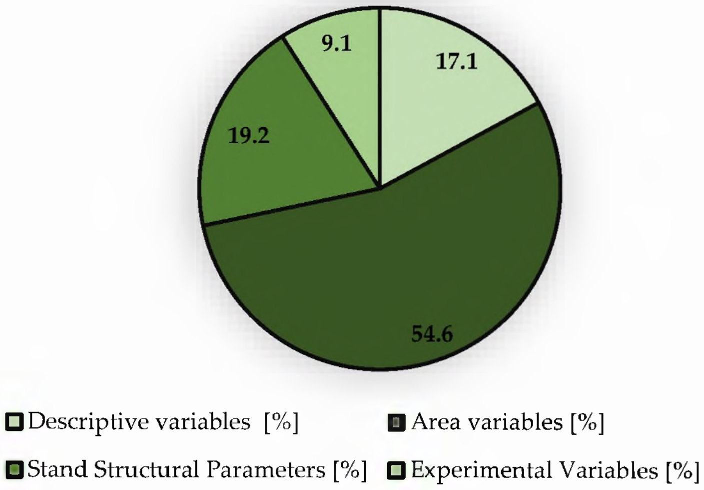

Figure 4. Share of the types of variables analyzed in the articles.

In fact, 22 variables characterizing the description, study area, stand structural parameters and experimental designs, were frequently identified in the articles taken into analysis. Four variables were recorded in a range of 7 to 7.8%, such as the type of machine, precipitation, disturbed bulk density, and soil texture. Considering the variables mostly recorded by the authors, these were the slope, species and number of machine passes (6 to 6.9%). Two variables that were also recorded with higher shares in the analyzed papers were the temperature and undisturbed bulk density, 5.4% and 5.2% respectively. The other variables accounted for shares of less than 5%.

The articles with the highest number of variables recorded were "*Effects of rubber-tired skidder and farm tractor on physical properties of soil in plantation areas in the north of Iran*" [69], "*Soil disturbance caused by different skidding methods in mountainous forests of Northern Iran*" [70] with a total of 18 variables identified per article, followed by articles that recorded 17 variables such as "*Effects of skidder passes and slope on soil disturbance in two soil water contents*" [65], "*Effects of ground-based skidding on soil physical properties in skid trail switchback*" [71], and 16 variables - "*Impact assessment of skidding extraction: effects on physical and chemical properties of forest soils and on maple seedling growing along the skid trail*" [72] and "*Soil compaction and porosity changes caused during the operation of Timberjack 450C skidder in northern Iran*" [73] (**Table A1**).

Study area represents the area in which the research was done and the data collection was carried out. Approximately 43% of the publications described the study area variable quantified in hectares, accounting for a total of ca. 128545 hectares. The maximum area taken into study was of approximately 54442 hectares.

Skidding trail (distance) is an important element of forest management, allowing harvested wood to be extracted [74-75]. A skid trail is defined as a strip of land within a stand, devoid of woody vegetation and undergrowth, with certain technical parameters; in some cases, its parameters were described to include slope lengths, cross slope, area, and radii of horizontal and vertical curves [66]. In forest stands, there is commonly a network of paths with a certain density resulting from the distance between them, which in turn is influenced by the way the forest is managed [74, 76-77]. It was identified that 11.4% of the articles taken into study recorded the distance on which the skidding was done; the minimum distance was 30 and the maximum 1300 m.

The use of machines was found to be the main cause of the soil compaction [78]. Skidders are widely used in mechanized harvesting operations generating impact on the soil's physical properties [65, 73]. However, each skidder model has different mechanical characteristics such as its mass [79]. Harvesters, skidders, and forwarders, which the modern forestry industry uses for mechanized harvesting operations, reach up to 45 tons and, when loaded, up to a maximum of 60 tons [80]. Machines for logging operations are almost constantly increasing in size and in terms of power and load capacity [81]. 93.3% of the papers taken into study recorded the type of machines used: Timberjack 450C was found in 47 data groups with a share of 48%, being followed by HSM 904 in 18 data groups, representing 18.4%. European studies considered machines such as HSM 805 HD (2 data groups), Timberjack 1110 8WD, SLKT 81, John Deere 548H and ECOTRAC 120 V. A North American paper analyzed the use of machines such as John Deere 648E, 748E, Timberjack 480B, 450C, Valmet 540, Timberjack 520A. In South America (Brazil) the use of a Caterpillar 525 machine was described in an article. Several Timberjack models were described as the studied machines: 450C, 1110 8WD, 460D, 480B, and 520A, which represented 55.1% of machines, followed by HSM 904 and 805 HD which represented 20.4%. Other machines with lower numbers of studies were TAF with 7.1%, John Deere 548H and 648E (6.1%), LTT 100A and 55A (5.1%), ECOTRAC 120 V (3.1%), Caterpillar 525 (2%) and SLKT 81 (1%) (**Figure 5**).

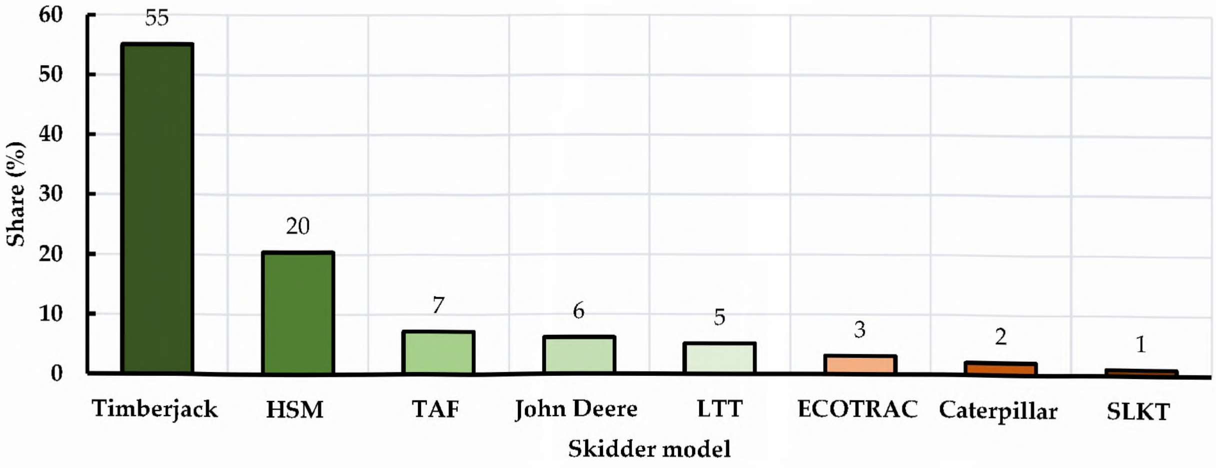

Figure 5. Models of skidders described by the papers taken into study.

Each skidder model has different mechanical characteristics [82], and several authors mention that these characteristics of the machines contribute to the generation of soil compaction [83-85]. However, in the analyzed articles, no information was recorded to specify other parameters such as acceleration, tire radius, length dimensions, width dimensions, height dimensions, operating weight, loaded travel speed, unloaded travel speed, load capacity, work schedule per day, and fuel consumption. Only two articles were identified that recorded information concerning the acceleration of machines.

In terms of harvesting systems, commercial forestry uses increased mechanization with heavy machines and high operational capacity for the extraction and transport of wood. In recent years, these vehicles have been improved [86] and became more powerful and cheaper [26]. A wide range of wheeled and tracked vehicles, such as harvesters, forwarders, skidders, were taken into study [16, 87, 88] and the dominant harvesting systems were described as fully mechanized (**Figure 6**). 28.6% of the articles recorded information on mechanized systems, 23 data groups recorded the use of semi-mechanized systems, which represents 79.3%, and there were 6 studies on fully mechanized systems, which represented 20.7%. Most of the harvesting operations were semi-mechanized, as chainsaws were used in several experimental studies, followed by mechanized extraction with different types tractors. Highly mechanized systems were not recorded in many cases because some studies were carried out in forests located in mountainous sites with steep slopes or in lowlands on clay soils [68].

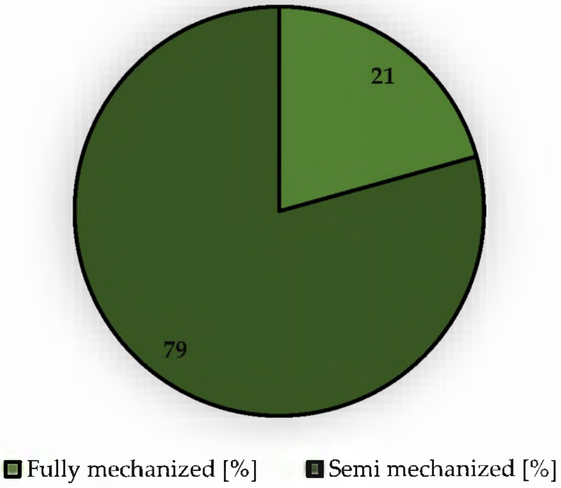

Figure 6. Share of papers taken into study by the described degree of mechanization.

Modern techniques have a major negative impact on forest ecosystems [16, 89-90]. The larger the cutting area, the greater its consequences for surrounding forest communities [91], and it can cause changes in the microclimate, composition, abundance and ecology of plants and animals [91]. The effect of selective logging is known to be much weaker than that of clearcutting [92]. There were two systems commonly described in forest utilization: individual selective logging, group selective logging, and in some cases the two can be combined in the same area [93]. Each system has its own specific characteristics, which depend on natural and production conditions, technology, and the proportion of manual operations in the overall process [40]. This study found that 27.6% of the articles collected information on the silvicultural system, where 16 data groups recorded that simple selective cutting was carried out and 13 group selective cutting.

The elevation of a geographic location represents the height above or below a fixed reference point, most commonly a reference geoid, which is a mathematical model of the Earth's sea level as an equipotential surface [94]. By this study, the minimum elevation was identified at 140, and the maximum at 1500 meters above sea level; 41.9% of the data used in this study described the elevation.

By the studied conditions, forest operations were more common in summer and autumn [68]. However, the fastest rate of soil recovery occurs in areas with cold winters and high rainfall, under humid conditions, where freeze-thaw cycles can loosen soil pores [95]. By this study, it was found that 64.8% of the publications collected information regarding temperature with a minimum of -5.4° and the maximum of 25°C. The studies were carried out mainly in the months of September, October, and November, in the Asian continent; in Iran, 7 studies collected information in this period, 5 studies collected information in the months of June, July and August, while in the case of Europe most of the studies collected data in the months of September, October, and November that belong to the autumn season (3 studies). Studies were found also in the winter, summer and spring seasons in Europe. In the articles from North and South America, no information was identified on the months in which the data collection was carried out.

Precipitation is used in meteorology to refer to all the phenomena of falling water from the sky in any form: rain, hail, snow, etc. Soil moisture content depends on the amount of precipitation. Increased amounts of precipitation can cause a significant decrease in resistance to soil penetration. Water weakens the bonds between particles and reduces internal friction by lubricating the particles, allowing the particles to slide together and compact by expelling air [67]. In the analysis of the articles it was observed that the use of tractors in the first thinning or the skidding of wood after heavy rains usually cause damage to the surface and properties of the soil [67]. The precipitation variable was recorded in 89.5% of the data groups; the lowest precipitation recorded was 10 mm and the highest 2070 mm.

Slope is the inclination of a linear, natural or constructive element with respect to the horizontal (0° or 180°) [96]. Identification and consideration of slope in planning forest operations and skid trails, in particular, can be an important measure in protecting soil resources [68]. The slope affects the physical properties of the soil [35]. Most soil damage occurs after few passes of a tractor, and particularly on steep slopes, the highest level of soil deterioration occurs [63-64, 97]. When a skidder passes more slowly due to slope steepness, the topsoil vibrates more and consequently becomes more compact compared to trails on gentler slopes [43]. Every effort should be made to avoid slopes more than 20% on skidding pathways [38]. According to this study, 75% of the examined articles described the slope variable, which had a range of values between -20 and 70%.

Soil moisture content is a value that characterizes the amount of water in the soil; it can be expressed as a percentage, water by weight or volume, or inches of water per foot of soil [98]. The movement of forest machinery on the soil surface causes changes in the chemical and physical composition of the soil [67]. Examination of the moisture content in soil is important to establish the limits for the use of harvesting and transport machinery in unfavorable conditions [67]. Studies have indicated that erosion damage is intensified if skidding operations take place when soil moisture is high [84, 99]. When the soil moisture content reaches or exceeds the critical value, it is advisable to prohibit all machinery traffic in forest stands [67]. In 47.6% of the papers, data on soil moisture were reported; the minimum and maximum values were 16 and 38%, respectively.

Soil compaction results in the increase in bulk density [37, 39]. The increase in apparent density is mainly due to soil slippage [78], and in the case of forest operations it happens when a machine passes only once on the skid trails [84]. In this study, it was identified that bulk density was one of the variables with the highest share reported in the reviewed papers; data was collected in undisturbed soils (before the operations) and disturbed soils (after the operations); the data with reference to undisturbed soils were lower compared to the disturbed ones, in the case of bulk density (g/cm^3) - 61.9% of the studies; the lowest value identified in the apparent density was 0.1 and the maximum value was 1.6 g/cm^3. For disturbed soils, the minimum bulk density was 0.1 and the maximum was 2.7 g/cm^3. It was one of the main variables analyzed in the studies, because they focused on the morphological change of the soil after the operations. A soil bulk density value between 1.40 and 1.55 g/cm^3 is considered to be at the critical level, where plant roots cannot penetrate light and medium textured soils [28]. Through this review, it was identified that 53 data groups presented a lower value compared to the aforementioned range, 27 data groups remained between these values but they represented a critical level for the soil, and a total of 11 data groups exceeded these values, with a gradual increase from 1.60 to 2.65 g/cm^3. Consequently, the bulk density exceeded the critical level, but not in most cases. Soil pore space refers to the percentage of the soil volume not occupied by solids; the soil volume is made up of 50% solid materials (45% minerals and 5% organic matter) and 50% pore space [100]. After skidding operations, soil compaction occurs, causing an increase in soil bulk density and a decrease in total porosity [87, 101]. Porosity is significantly affected by traffic intensity and slope gradient [35]. In the case of porosity of undisturbed soils, the minimum and maximum values reported were of approximately 37 and 95%, respectively; for soils with disturbances, the reported porosity was in the range of approximately 1-66%.

The soil is body formed by the interaction of five main elements: parent rock, climate, relief, living beings and time [102]. Soils can be divided into three types according to the predominance of the textural fraction they present, which can be: sandy soils, loamy soils, and clay soils [103]. Soil texture determines the susceptibility of a soil to erosion, since erosion rates can differ between various soil types under the same conditions of rainfall intensity, slope gradients, and amount of vegetation cover [71, 104]. Soil variations, related to timber harvesting operations, can generate changes in biogeochemical cycles that affect soil ecosystems [16]. The physical and also morphological properties of soils are severely altered at skid trails and loading sites [92]. 90.5% of the studies collected information regarding the soil texture; 61.7% of them identified clay-loams, 18.1% silt-loams, 5.3% loam-sands, 5.3% sand-loams soils, while 8.5% of the studies reported more than one type of soil (**Table 1**).

Stand density, represents the number of trees per area [105]. Density is a reliable indicator of the degree of occupation of trees in a specific place and time, and it is also one of the few variables that represent, in a simple and objective way, the structure of forests [106]. 41.9% of data records reported information related to stand density, with a minimum of 140 and a maximum of 169 trees per hectare. Within forest operations, the age of the forest is rather an unpredictable variable [38].

21% of the data records provided information related to the age of the stand, with a minimum of 17 and the maximum of 130 years. Tree diameter is the unit of measure that is calculated from a straight line that joins two points on a circumference, a closed curve or the surface of a sphere passing through its center [107]. Diameter at breast height, or DBH, is a standard measure of expressing the diameter of the trunk or bole of a standing tree [108]. DBH is one of the most common dendrometric measurements [109]. 43.8% of the data records contained information related to the diameter of the trees, with a minimum of 23.1 and a maximum of 135 cm. Tree height is a geometric variable that is used to determine the height of a tree [110]. This study identified that 43.8% of the data records contained information related to tree height, with a minimum of 22 and a maximum of 30.7 meters. 82.9% of the studies identified the species that were part of the skidding operations. 83 data groups described deciduous forests, 4 coniferous forests and 3 data groups recorded data from mixed forests. The main tree species that were identified in the data groups are given in **Figure 7**.

Table 1. Types of soils identified in the studies by the texture.

Soil texture	Number of studies	Share (%)
Silt loam	7	**18.1**
Sandy loam	6	**6.4**
Clay loam	8	**61.7**
Loamy sand	5	**5.3**
More than one soil type	8	**8.5**
Total	**34**	**100**

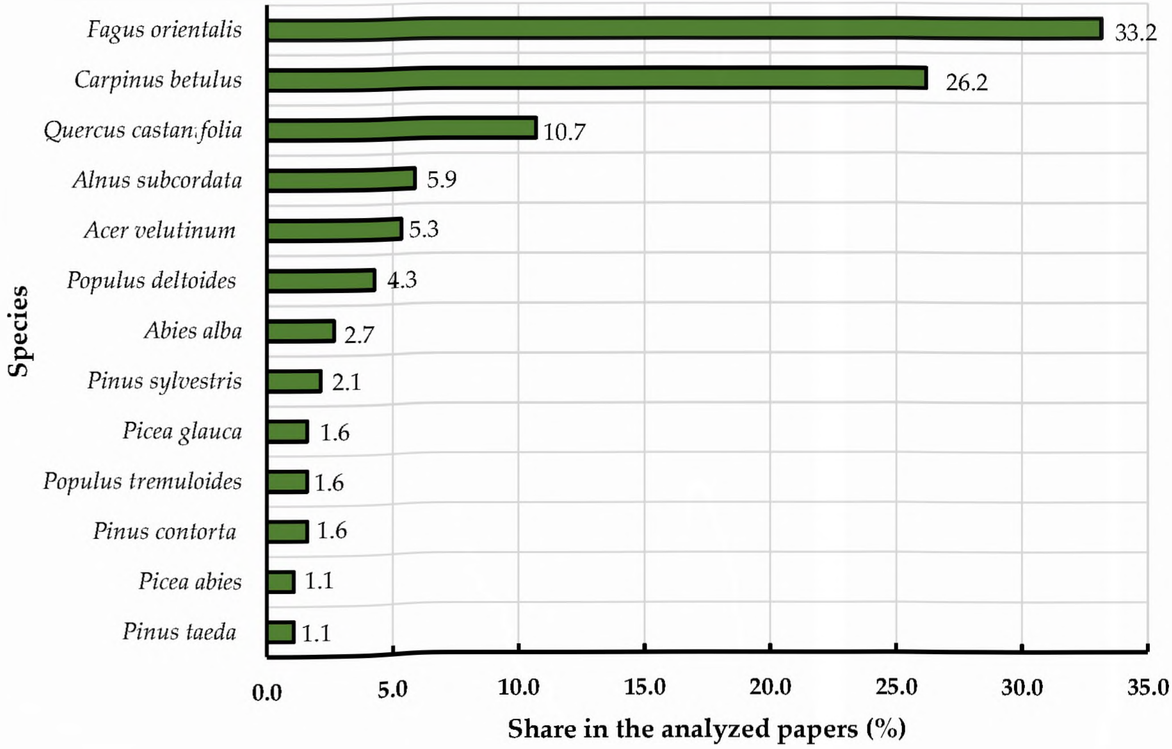

Figure 7. Tree species described by the analysed papers.

35% of the data described the variable on number of plots, with a minimum of 2 and a maximum of 94 plots. Number of machine passes represents the number of passes over the same ground [111]. The machine passes have an important influence on the structural characteristics of the soil, aeration and water balance and, therefore, can considerably affect the organisms, the development of the roots [65], and the increase of soil compaction [112]. The first pass of heavy forest machines over the forest floor surface causes significant structural changes in its upper layers. This can reach damaging levels with a detrimental effect that can last 30 years or more after extraction [8, 35, 113-114]. 73.3% of the studies recorded data related to the number of passes that machine had in a day/work cycle, since it is relevant when analyzing the compaction that occurs in the soil after skidding operations. The number of passes made by the machines and recorded by the analyzed papers reached to 40. In some studies data comparisons were made against noncompacted soil after each pass or at the end of the activity, to analyze the level of compaction produced.

The analysis of papers allowed to identify that precipitation and disturbed bulk density were the variables analyzed to a large extent which accounted for 89.5 and 86.7%, respectively. However, it is important to acknowledge that all the variables interact as well as they were analyzed according to the need of each study. Although the existing studies analyzed some variables more frequently, such as slope, number of machine passes, undisturbed bulk density, undisturbed porosity, disturbed bulk density, altered porosity, machinery, soil texture, etc., in some regions the applicability of their results is limited.

5. CONCLUSIONS

It is concluded that in the studies on soil disturbance in skidding operations, 4 types of variables were analyzed (descriptive, local, structural and experimental parameters), where the location variables were the most represented as a group (54.7%); however, the type of machinery, precipitation, disturbed bulk density and soil texture were the most collected data in the studies. It is recommended in future studies to consider variables related to the training, experience and expertise of equipment operators, which may be important factors to consider. It is also necessary to identify variables such as the number of cycles, the speed with which the machines are operated, the number of work cycles that are done per day and the time they take, the production per working day, which are also variables that would provide relevant information for soil disturbance studies. Most studies on soil compaction focused on the physical properties of the soil, therefore, further studies should consider more the changes in biological and chemical composition of the soils.

FUNDING

This work received no external funding.

CONFLICT OF INTEREST

The author declares no conflict of interest.

APPENDIX

Table A1. Scientific publications taken into study.

Paper No.	Authors	Year	Country	* Number of case studies	Variable type - Description	Variable type - Study Area	Variable type - Stand Structural Parameters	Variable type - Experimental	Number of variables recorded
1	Agherkakli et al.	2010	Iran	1	3	5	2	0	10
				2	3	5	2	0	10
2	Allman et al.	2015	Slovakia	3	3	8	2	0	13
				4	3	8	2	0	13
3	Borchert et al.	2015	Germany	5	3	7	4	1	15
				6	3	7	4	1	15
				7	3	7	4	1	15
				8	3	7	4	1	15
4	Demir et al.	2010	Turkey	9	1	7	4	0	12
				10	0	6	4	0	10
5	Ezzati et al.	2012	Iran	11	3	10	1	0	14
				12	3	10	1	0	14
				13	3	10	1	0	14
				14	3	10	1	0	14
6	Ilintsev et al.	2018	Russia	15	2	6	1	0	9
				16	2	6	1	0	9
7	Jamshidi et al.	2008	Iran	17	1	4	1	0	6
				18	1	4	1	0	6
				19	1	4	1	0	6
8	Jourgholami et al.	2014	Iran	20	3	5	1	1	10
				21	3	5	1	1	10
9	Majnounian & Jourgholami	2013	Iran	22	3	7	2	1	13
				23	3	7	2	1	13
				24	3	7	2	1	13
				25	3	7	2	1	13
10	Makineci et al.	2007	Turkey	26	1	6	4	0	11
				27	1	6	4	0	11
11	Modrý & Hubený	2003	Czech Republic	28	2	3	1	1	7
12	Naghdi & Solgi,	2014	Iran	29	1	10	4	2	17
				30	1	10	4	2	17
13	Naghdi et al.	2009	Iran	31	5	5	1	1	12
				32	5	5	1	1	12
14	Naghdi et al.	2015	Iran	33	3	9	4	2	18
				34	3	9	4	2	18
				35	3	9	4	2	18
15	Naghdi et al.	2016	Iran	36	2	5	4	2	13
				37	2	6	4	2	14
				38	2	6	4	2	14
				39	2	6	4	2	14
16	Najafi et al.	2009	Iran	40	1	7	4	2	14
				41	1	6	2	2	11
				42	1	6	2	2	11
				43	1	6	2	2	11
17	Najafi et al.	2010	Iran	44	1	5	1	1	8
				45	1	5	1	1	8
				46	1	5	1	1	8
				47	1	5	1	1	8
18	Nikooy et al.	2015	Iran	48	1	4	1	1	7
				49	1	4	0	1	6
				50	1	4	0	1	6
19	Proto et al.	2016	Italy	51	1	7	4	1	13
				52	1	9	4	1	15
				53	1	9	4	1	15
				54	1	9	4	1	15
				55	1	9	4	1	15
20	Solgi et al.	2015	Iran	56	3	8	2	1	14
				57	3	10	2	1	16
				58	3	10	2	1	16

Paper No.	Authors	Year	Country	* Number of case studies	Variable type - Description	Variable type - Study Area	Variable type - Stand Structural Parameters	Variable type - Experimental	Number of variables recorded
				59	3	10	2	1	16
				60	3	10	2	1	16
21	Solgi et al.	2016	Iran	61	1	5	3	1	10
				62	1	7	3	1	12
				63	1	7	3	1	12
				64	1	7	3	1	12
				65	1	7	3	1	12
22	Solgi et al.	2017	Iran	66	3	7	4	2	16
				67	3	9	4	2	18
				68	3	9	4	2	18
23	Solgi et al.	2019	Iran	69	3	6	4	2	15
				70	3	8	4	2	17
				71	3	8	4	2	17
24	Solgi et al.	2019	Iran	72	2	7	4	1	14
				73	2	8	4	2	16
				74	2	8	4	2	16
				75	2	8	4	2	16
				76	2	8	4	2	16
25	Startsev & McNabb	2000	Canada	77	1	1	1	1	4
				78	1	2	1	1	5
				79	1	2	1	1	5
26	Šušnjar et al.	2006	Croatia	80	1	5	0	1	7
				81	1	5	0	1	7
				82	1	5	0	1	7
27	Wang et al.		USA	83	3	2	0	1	6
28	Yazarlou et al.	2017	Iran	84	2	7	0	1	10
				85	2	7	0	1	10
				86	2	7	0	1	10
				87	2	7	0	1	10
				88	2	7	0	1	10
				89	2	7	0	1	10
29	Fredericksen & Pariona	2002	Bolivia	90	1	3	3	1	8
30	Jaafari et al.	2014	Iran	91	1	6	1	2	10
31	Kormanek & Gołąb	2021	Poland	92	0	4	2	0	6
				93	0	3	2	0	5
32	Reichert et al.	2018	Brazil	94	2	6	5	2	15
				95	2	6	5	2	15
33	Solgi et al.	2021	Iran	96	2	7	1	2	12
				97	2	7	1	2	12
34	Tavankar et al.	2021	Iran	98	3	6	2	1	12
				99	3	6	2	1	12
				100	3	6	2	1	12
				101	3	6	2	1	12
				102	3	6	2	1	12
				103	3	6	2	1	12
				104	3	6	2	1	12
				105	3	6	2	1	12

*** Note that the total number of papers taken into study was 34; however, some papers reported on a number of experimental designs giving the opportunity to form 105 data groups with their specific variables.**

EXTENDED ABSTRACT – REZUMAT EXINS

***Titlu în română**: Impactul colectării mecanizate a lemnului asupra solurilor forestiere: studiu de sinteză.*

***Introducere**: Prejudicierea solului este definită sub forma modificărilor proceselor fizice, chimice și biologice din sol, care sunt adesea interconectate. Colectarea mecanizată a lemnului contribuie semnificativ la creșterea gradului de compactare şi eroziunii solului, care depind în principal de intensitatea extracției și de gradul de deteriorare cauzat de metodele folosite în exploatarea lemnului. Circulația tractoarelor are efecte negative asupra componentelor fizice, chimice şi biologice ale solului. Scopul acestui studiu a fost de a identifica cele mai semnificative informații publicate de specialiști*

în ultimii ani, precum și de a sintetiza cunoștințele disponibile despre operațiile de colectare și impactul acestora asupra solurilor forestiere.

Materiale și metode: *Studiul a fost realizat pe baza informațiilor disponibile pentru țări și locații din întreaga lume pe o perioadă de 35 de ani (1986-2021). Revizuirea literaturii de specialitate s-a bazat pe căutarea articolelor legate de efectuarea operațiilor de colectare. Bibliografia și informațiile folosite în acest studiu au fost obținute din surse online și lucrări de cercetare publicate în engleză și spaniolă, indexate în baze de date cum ar fi Google Scholar, Web of Science, Scopus și CABI, prin utilizarea unor cuvinte cheie specifice precum și a unor combinații între acestea.*

Rezultate și discuții: *22 de variabile ce caracterizează descrierea, zona de studiu, parametrii structurali ai arboretului și designul experimental au fost frecvent identificate în articolele analizate. Patru variabile au fost raportate în proporție de 7 - 7,8%, cum ar fi tipul de utilaj, precipitațiile, densitatea aparentă și textura solului. Luând în considerare variabilele înregistrate în cea mai mare parte de către autori, acestea au fost panta, specia și numărul de treceri ale utilajelor (6 până la 6,9%). 2 variabile care au fost înregistrate cu procente mai mari au fost temperatura și densitatea aparentă: 5,4% și, respectiv, 5,2%. Celelalte variabile au fost descrise în proporție mai mică de 5%.*

Concluzii: *Se concluzionează că în studiile privind prejudicierea solului ca urmare a operațiilor de colectare a lemnului au fost analizate 4 tipuri de variabile (parametri descriptivi, locali, structurali și experimentali), iar variabilele de localizare au fost cele mai analizate (54,7%); totuși, tipul de utilaj, precipitațiile, densitatea aparentă și textura solului au fost printre cele mai colectate date în studiile analizate. Se recomandă ca în studiile viitoare să se ia în considerare variabile legate de pregătirea muncitorilor, numărul de cicluri de muncă, viteza cu care este operat utilajul și producția realizată.*

Cuvinte cheie: *Prejudicierea solului, operații forestiere, colectare, sol, impact, sinteză.*

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REPERE

- Aniversarea doamnei prof. dr. ing. Valentina Doina Ciobanu la venerabila vârstă de 75 ani

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75 de ani

REZUMAT

Doamna Profesor universitar dr. ing. Valentina Doina CIOBANU împlinește astăzi - 17 noiembrie 2022 - venerabila vârstă de 75 de ani, moment dublat și de o altă aniversare frumoasă, respectiv aceea de 47 de ani de activitate desfășurată în învățământul superior silvic brașovean. Pentru împlinirea totală pe plan profesional, Doamna Profesor a devenit conducător de doctorat în anul 2006, reușind, printr-o preocupare continuă și multă perseverență, să rezolve diverse probleme din sectorul forestier prin coordonarea celor 16 teze de doctorat. Cum profesia de cadru didactic îmbinată cu cea de conducător de doctorat nu poate conduce decât la rezultate deosebite în cercetare, Doamna Profesor a ținut mereu pasul cu cerințele din ce în ce mai exigente, referitoare la diseminarea rezultatelor cercetării în reviste indexate Web of Science. Întreaga sa activitate profesională a fost caracterizată de implicare, profesionalism și de dorința de a susține orice inițiativă realistă de a umple unele sincope ale domeniului, dedicându-și întreaga viață acestor cauze. În acest moment solemn de aniversare, adresăm Doamnei Profesor, cu respect și căldură, urarea de viață lungă, cu sănătate și împliniri frumoase alături de cei dragi!

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DOAMNA PROFESOR DR. ING. VALENTINA DOINA CIOBANU ÎMPLINEȘTE 75 DE ANI

În general, aniversările sunt momente de analiză și bilanț din viața fiecăruia, cu satisfacții sau chiar insatisfacții. Un asemenea moment ne adună în jurul Doamnei Profesor universitar dr. ing. Valentina Doina CIOBANU, care împlinește astăzi - 17 noiembrie 2022 - venerabila vârstă de 75 de ani, moment dublat și de o altă aniversare frumoasă, respectiv aceea de 47 de ani de activitate desfășurată în învățământul superior silvic brașovean.

Sărbătorita de astăzi - Doamna prof. dr. ing. Valentina Doina CIOBANU - este născută la data de 17 noiembrie 1947 și crescută în Brașov, deci brașoveancă, ca fiică a lui Mihai FOCŞA - tatăl și a Mariei FOCŞA - mama, având o singură soră - Rodica, mai mare cu trei ani.

Pregătirea sa școlară a început la Şcoala Generală Nr. 3 Tractorul și a continuat la Liceul Nr. 3 (actual Colegiul Național „Dr. Ioan Meşotă"). După absolvirea liceului, a urmat cursurile Facultății de Silvicultură din Brașov (1966 - 1971), ajungând ca în anul 1971, după susținerea examenului de diplomă, să fie încadrată la C.E.I.L. Târgu Secuiesc, ca inginer stagiar, având în atribuții lucrări de drumuri forestiere și utilaje pentru construcții, activități de care s-a lăsat cucerită și pe care le-a abordat și în etapa următoare în plan profesional. Astfel, în 1975 a dat concurs pentru ocuparea postului de asistent universitar la Facultatea de Silvicultură din Brașov, pentru pregătirea studenților în domeniul complex al utilajelor folosite la execuția și întreținerea drumurilor forestiere, incluzând aspecte legate de proiectarea și construcția acestor obiective de investiții.

Din 1975 până la pensionare, în 2018, Doamna Profesor a urcat pe toate treptele ierarhiei didactice, începând cu postul de asistent universitar (1975 - 1990), apoi la șef de lucrări (1990 - 2001), conferențiar (2001 - 2006) și, în final, profesor (2006 - 2018), post pe care s-a menținut în activitate și după pensionare, în calitate de cadru didactic asociat (2018 - 2022).

Preocupările științifice ale Doamnei Profesor au început odată cu activitățile de predare și au continuat de-a lungul timpului cu elaborarea tezei de doctorat (susținută în 1998) în domeniul drumurilor forestiere, culminând cu articolele științifice publicate în colaborare cu colegii de muncă și doctoranzii îndrumați. Activitatea științifică a Doamnei Profesor, consistentă și variată în ceea ce privește domeniul de preocupare, însumează peste 140 de articole publicate în reviste de specialitate, unele susținute la conferințe naționale și internaționale, 21 de cărți de specialitate și 3 brevete de invenție, la care se adaugă normative specifice lucrărilor de proiectare, execuție și reabilitare a drumurilor forestiere, pentru care a primit premii de la entități de seamă din domeniul forestier (Premiile Societății Progresul Silvic - ediția a IV a, 2013).

Cum profesia de cadru didactic îmbinată cu cea de conducător de doctorat nu poate conduce decât la rezultate deosebite în cercetare, Doamna Profesor a ținut mereu pasul cu cerințele din ce în ce mai exigente, referitoare la diseminarea rezultatelor cercetării în reviste indexate Web of Science. Astfel, a publicat peste 30 de articole ISI, aducându-și contribuția atât la prestigiul Şcolii Doctorale Interdisciplinare, cât și la recunoașterea Facultății și Universității la nivel național și internațional.

Pentru împlinirea totală pe plan profesional, Doamna Profesor a devenit conducător de doctorat în anul 2006, reușind, printr-o preocupare continuă și multă perseverență, să rezolve diverse probleme din sectorul forestier prin coordonarea celor 16 teze de doctorat. Astfel, problemele abordate în cercetări s-au axat pe îmbunătățirea capacității portante la drumurile forestiere dotate cu diverse structuri rutiere, la folosirea unor materiale relativ noi în domeniu și a unor emulsii spre a menține o circulație corespunzătoare și sigură pe drumurile forestiere, inclusiv studiul degradării carosabilului, a volumelor de lemn transportate și evoluția acestora, de-a lungul timpului, la autovehiculele de tonaj sporit. Nici utilajele folosite la construcția și întreținerea drumurilor forestiere nu au fost lăsate deoparte, una dintre tezele de doctorat abordate având ca subiect chiar îmbunătățirea și fiabilitatea celor mai utilizate mașini de construcții.

Din dorința de a susține preocupările și visurile unor persoane determinate, dornice de aflarea unor răspunsuri în domeniile lor de activitate, Doamna Profesor Ciobanu a abordat cu succes teme de doctorat axate pe calitatea buștenilor destinați pentru furnir și a caracteristicilor materialului lemnos, respectiv a cunoașterii rețetelor folosite la obținerea plăcilor OSB. Din același considerent, a abordat și o temă de cercetare care a avut ca subiect factorii de risc la care se expune resursa umană ce activează în sectorul exploatărilor forestiere.

Întrucât profesia didactică universitară este strâns legată de cercetarea științifică, Doamna Profesor a fost responsabil și membru în numeroase contracte de cercetare științifică (13 contracte, dintre care la 9 director), desfășurate în parteneriat cu diverse entități importante la nivel național (11 contracte), cât și internațional (3 contracte). În acest sens, unul dintre contractele internaționale a abordat o problemă veche, dar din ce în ce mai pregnantă în zilele noastre, respectiv aceea a incendiilor de pădure. În urma acestui proiect a luat naștere cursul de *Prevenirea și combaterea incendiilor forestiere*, de la programul de studii *Management și sisteme tehnice în exploatările forestiere* (ciclul de masterat, anul II). Toată această implicare a condus la recunoașterea Doamnei Profesor ca specialist în domeniul incendiilor de pădure, fiind invitată, în calitate de co-tutore, la îndrumarea unei teze de doctorat în cadrul Universității de Vest din Timișoara.

Datorită implicării de care a dat dovadă în rezolvarea problemelor și a sarcinilor din sfera profesională, Doamna Profesor nu a fost ocolită de unele atribuții care vizau mai mult partea administrativă, fiind membru al comisiilor de evaluare, analiză și management în cadrul Facultății și de editor al Buletinul Universității Transilvania din Brașov - Seria II, jurnal consacrat la Universitatea noastră, ce se bucură de o recunoaștere din ce în ce mai mare pe plan internațional. Este de menționat și participarea sa ca membru în Comisia Națională de Acreditare a Proiectanților de Drumuri Forestiere, de la București.

Doamna prof. dr. ing. Valentina Doina Ciobanu a fost și va rămâne un exemplu pentru numeroase generații de studenți care de-a lungul timpului au reușit să ocupe funcții importante în domeniul forestier, atât în producție, cât și în cercetare și învățământ. Întreaga sa activitate profesională a fost caracterizată de implicare, profesionalism și de dorința de a susține orice inițiativă realistă de a umple unele sincope ale domeniului, dedicându-și întreaga viață acestor cauze. Chiar dacă traseul parcurs până acum nu a fost întotdeauna lipsit de piedici, fiind de multe ori sinuos, cu urcușuri și coborâșuri, Doamna Profesor a reușit mereu să surprindă prin tăria sa de caracter și optimismul caracteristic, dar a lăsat puține persoane să-i cunoască latura mai sensibilă.

În viața privată are parte de o familie împlinită, alături, din 1980, de soțul său, doctor inginer, cercetătorul CIOBANU Ioan, și fiica sa, Valentina, născută în 1981, acum absolventă a Facultății de Drept din Brașov.

Prin profesionalism, bunătate și determinare a reușit să depășească încercările pe care viața i le-a pus în față, atât în domeniul de activitate, cât și în plan personal.

În acest moment solemn, de aniversare, fiecare dintre noi, fie foști studenți, colaboratori, colegi sau prieteni, îi mulțumim doamnei profesor pentru toate învățămintele, sfaturile și încurajările oferite și îi dorim multă sănătate, liniște și împlinirea tuturor dorințelor, asigurând-o de toată prețuirea și aprecierea noastră.

LA MULȚI ȘI BINECUVÂNTAȚI ANI!!!

Ș.L. dr. ing. Elena Camelia MUȘAT

Prof. dr. ing. Valeria Maria ALEXANDRU

Facultatea de Silvicultură și exploatări forestiere

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