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AN EVALUATION OF RISK-TAKING BEHAVIOR IN MOTOR-MANUAL TREE FELLING AND PROCESSING OPERATIONS

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Abstract: *Motor-manual tree felling and processing is one of the common options used in wood harvesting operations. Still, many accidents are related to it, and evaluations on the way that fellers undertake risks may help in understanding how and on what kind of features training should be designed and administrated. This study evaluated the risk-taking behavior of preparatory, effective felling and post-felling tasks using a questionnaire, face-to-face interviews and field measurements, with a strong emphasis on the presence and use of protective equipment, implementation of safety procedures in operations and the accuracy of felling cuts. The results were rather concerning because the protective equipment was found to be limitedly used which was also the case of safety procedures. In particular, trousers, vests, eye, and ear protection equipment were found to be less worn, while creating and using escape paths and correctly starting the chainsaw were among the most common violations of safety procedures. In terms of accuracy of cuts, both hinge width and notch depth were incorrectly shaped in most of the cases. While standing for rather a low sample of the Romanian fellers' population, these results indicate the need of designing and administrating tailored training courses to prevent job-related accidents.*

Keywords: *motor-manual felling, safety procedures, risk-taking, behaviour, accuracy, training.*

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1. Introduction

Wood is considered to be a renewable, environmentally-friendly material that sustained the development of human kind ever since its beginnings [34]. While in the past it was used mainly to cover the basic human needs, in the current society the wood has many known uses which are sustained by a great variety of procurement and industrialization processes. Most of the procurement processes are taking part into the forest where, to be able to deliver the wood to the industry, it is subjected to a series of transformations [29]. Among these, felling, debranching and bucking operations (hereafter tree felling and processing operations) are aiming to convert the standing trees into logs characterized by various sizes that should be compatible with the capabilities of the used extraction equipment [29]. Motor-manual tree felling and processing is a technical option which fits to steep terrain wood harvesting operations [29], and which is quite easy adapted to a variety of operational conditions [8], [22] including high-sized broadleaved trees [23]. For instance, in the Romanian forest operations, motor manual tree felling and processing is often complemented by extraction using skidders [4], [7], [10], [12], cable yarders [5], [9] and animal traction [6] with only a small part of the operations being completely mechanized, such as those using harvesters and forwarders [2]. While in many parts of the world and in Europe, including Romania [28], motor-manual tree felling and processing is still extensively used, both, practice and science have shown that most of the forest operations related accidents are caused by working with chainsaws [3], [30], [38] with many cases resulting in invalidity or even death [37]. In addition, motor-manual work is considered to be heavy [14], [17], [35-36] exposing the workers to noise [33] hand-arm vibration [32-33] and other harmful factors [29] as well as to the conditions of work under open sky, with many extremes in terms of air temperature that affect the physiological and productive performance [41]. In particular, a very intensive work could increase the fatigue, generating therefore a reduction in attention paid by the workers [1], which can further result in work-related accidents. This is inherently a characteristic of motor-manual operations [29] because the workers are required to carry, often on long distances, additional weight during their work and to undertake uncomfortable postures when operating the chainsaw [13-14], [42], while these postures are associated with increased responses in terms of heart rate [19-20], [38], which is just one of the physiological responses to a high difficulty of work [31]. Beside the difficulty of work, in motor-manual operations, a proper training of the workers is considered to be crucial in achieving their work goal in a safe way. Recent studies have shown that training should combine theory with practice [39] enabling the preparation of well-trained workers which should have a well-established knowledge on motor-manual tree felling mechanics, and on the execution of tasks according to some pre-established procedures which were designed to ensure the safety of the work [29]. Such procedures refer not only to the way that felling cuts should be made but also to the preparatory work and the tasks to be undertaken following tree felling [15], [21], [29], [43]. Compared to other industries, forestry workers are required to wear and use personal protective equipment (PPE) which in many cases is perceived as a supplementary burden. In addition, they should have extensive knowledge on the safety procedures to be implemented when needed. Nevertheless, in practice both, the general procedures associated with the preparatory [27] and post-felling work, as well as those related to the correct execution of the felling cuts [11] are frequently disregarded. Often, such risk-taking behaviors are associated with the level of knowledge of a given individual, therefore they could be corrected by training [11], [27], [39]. On the other hand, the safety concept in motor-manual tree felling and processing is a complex system of inter-related features which spread across but are not limited to technical, social, legal and environmental systems [29], therefore the forestry work stands for a combination of internal (personal) and external (environmental) risks to health and safety of the workers [25 ref. in 16]. At the same time, to achieve sustainability in ergonomics and safety issues related to motor-manual operations several key aspects should be carefully analyzed such as those, but not limited to the risk assessment, accountability awareness, physical and mental workload [26]. According to [26] risk assessment should be calibrated to the local conditions including machines and tools, terrain and vegetation characteristics; accountability awareness refers to responsibilities of workers on their own, co-workers and other persons safety, while the physical and metal workload should be aligned to the capacity of workers. In addition, the quality of the work environment encompasses the physical work environment that surrounds the forest workers referring to working posture, work habitat and its features as well as to how such characteristics contribute to health, competence, job satisfaction and performance [26]. Nevertheless, such critical features, and mostly the risk assessment and accountability awareness received less attention in the scientific literature. Some recent studies described [24] or discussed in more detail such problems [11], [27].

The goal of this study was to evaluate to what extent are the safety procedures used in the Romanian motor-manual tree felling and processing operations with most of the emphasis on the risk-taking behavior and the accuracy of tree-felling cuts. In particular, the objectives of this study were to: (i) characterize the population taken into study by anthropometric, employment type, safety training and accident-related descriptors; (ii) evaluate the existing protective equipment and to what extent such equipment is used during the operations; (iii) evaluate the risk-taking behavior specific to preparatory, felling and post-felling tasks and (iv) evaluate the accuracy of felling cuts relative to the existing recommendations. Based on the evaluation results, this work draws some conclusions on the safety-related sustainability in such operations.

2. Materials and Methods

2.1. Study Area

Data used in this study was collected in the field in 2016 and 2017 and it covered a number of 44 felling blocks distributed across 9 counties of Romania (Figure 1, Table 1) that are rich in mountainous forests. Both, the counties of study as well as the felling blocks were selected randomly based on the information gathered from the regional branches of National Forest Administration - RNP Romsilva and their territorial subunits consisting of forest districts. This was possible due to the fact that many of the wood contractors carry on their business by buying wood from RNP Romsilva, therefore each regional branch maintains a database containing harvesting contractors.

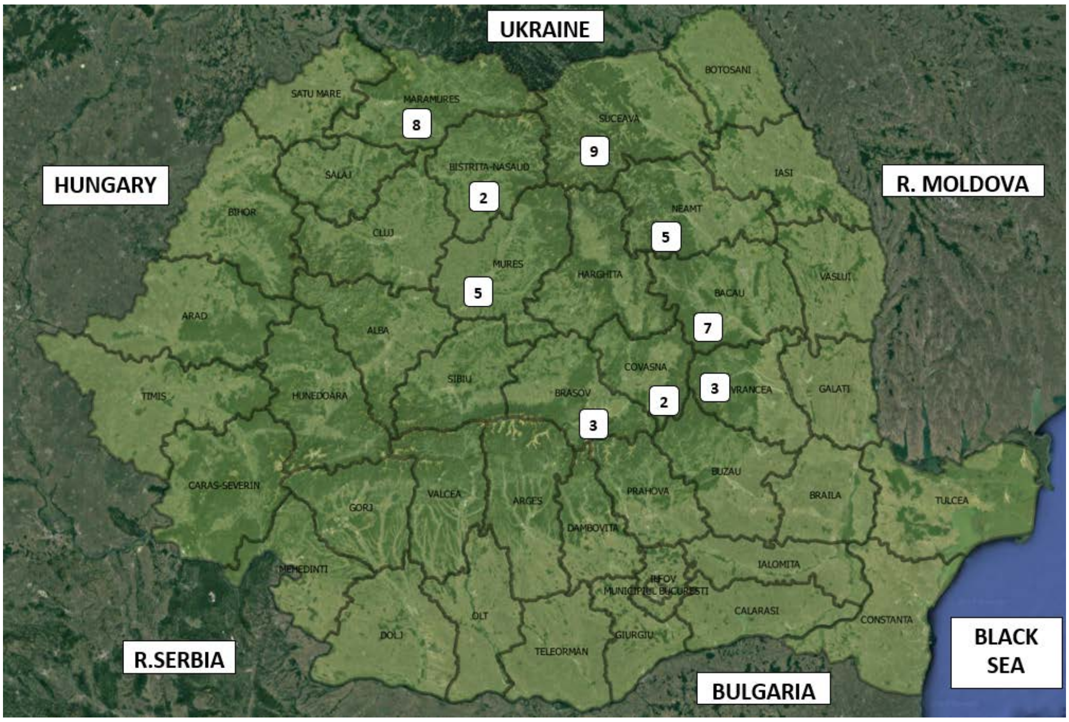

Fig. 1. *Distribution of felling blocks taken into study on counties*

Descriptive statistics of the felling blocks taken into study Table 1

Parameter	Silvicultural system or type of operation	Descriptive statistics				
		Share (%)	Count	Minimum value	Maximum value	Mean ± Standard Deviation
Felling (operation) type	Thinning	22.7	10	-	-	-
	Group shelter wood	31.8	14	-	-	-
	Salvage cut	4.6	2	-	-	-
	Clear cut	34.1	15	-	-	-
	Landing operations	6.8	3	-	-	-
Slope (°)		-	44	5	50	26.7±15.2
Duration of evaluation (minutes)		-	44	15	65	38.8±10.6
Number of observed trees			342	1	10	8.8±2.3

Then, the field data was collected in each felling block based on the verbal agreement of the forest contractors carrying on forest operations in the area, or of the forest districts managing themselves forest operations to undertake such activities. Based on their agreement, a following step was that of obtaining the agreement of workers to be observed during their work. To this end, a full description on what kind of data would be collected and how it would be analyzed was given both, to the employers and employees. Following this step, data was collected in those randomly selected felling blocks (Table 1) in which the final agreement of the workers, based on their anonymity, was obtained. This approach resulted in surveys carried on in felling blocks which fairly resemble the type of silvicultural systems and operational conditions of the Romanian forest operations.

2.2. Data Collection and Analysis

Field data collection was implemented in two stages. In a first step, a questionnaire was used to describe both, the workers and their general behavior as well as the working conditions. In the questionnaire, five sections and their corresponding items were included as presented in the following.

Section A - description of the worker, employer type and of the payment system included the following items: number of the evaluated person; body weight (BW, kg), height (H, cm) and age (years), which were given by the worker during a face-to-face interview; payment system (coded as 0 for hourly rates and 1 for production output rates); employer type (coded as 0 for state enterprise and 1 for private enterprise); type of silvicultural system and of the observed operations (felling and processing, landing operations); terrain slope in the area of survey (°); date and hour of the survey; duration of the survey (minutes); air temperature during the survey (subjective: very cold, cold, moderate, hot, very hot). Based on the body weight and the height, in the office phase of the study were computed the Body Mass Index (BMI) using the common calculation approach.

Section B - personal protective equipment, was designed to collect data by codes (0 for false and 1 for true) on the existence and use of personal protective equipment. To this end, the following items were included: existence and use of the special protective boots for forest operations; existence and use of the special trousers for forest operations; existence and use of special (highly-visible) vests for forest operations; existence and use of gloves designed for motor-manual operations; existence and use of eye protection features; existence and use of protective helmets; existence and use of hearing protection features; existence of first-aid kits; existence of persons trained to give the first aid and their knowledge on safety.

Section C - risk-taking behavior in preparatory and post-felling operations, consisted of a series of items which were quantified, in terms of frequency, by field observations, following the completion of the first section of the questionnaire. These items referred only to those situations in which the local operational conditions required the execution of some safety-related tasks and they were (1) or were not (0) carried-out. The list of items was adapted from the existing literature [15], [21], [29], [43]: clears the work place to ensure a safe tree felling; removes the branches at the tree bottom to ensure safe tree felling; creates escape paths to ensure a safe retreat; plans the tree felling on the natural lean; starts the chainsaw on the ground before making the cuts; maintains a safe location when making the cuts; gives a warning (signals) prior to tree engaging in felling; uses the escape paths; uses safe procedures and proper postures during debranching; presence of other people in the felling area when felling; uses safe procedures and proper postures during bucking; uses proper procedures when transporting the chainsaw. Evaluation by quantitative measures of the felling cuts was carried out based on a subsection (included in section C) which aimed to collect data for a number of maximum 10 trees per location. In the field, the following parameters were measured, mainly after felling: diameter at the breast height (DB, cm, before felling), diameter at the stump height (SD, cm), notch (scarf) depth (ND, cm), notch (scarf) height (NH, cm), hinge width (HW, cm) and the hinge length (HL, cm) following the procedures described in [11].

Section D - training courses, experience, and safety training data were collected, mainly, by the use of the following items: data on graduated schools; motor-manual training courses and their duration; date of the last on-the-job safety training course.

Section E - other data, which consisted of the following items: accommodation place; marital status; health insurance; quantity of liquids consumed per work day; smoking behavior; type of food used; alcohol consumption; work-related accidents and their summary description; personal perception on the work difficulty; personal satisfaction on the job; willingness to work in another field.

The second step of field data collection was that of observing the workers and their operational behavior during the effective operations. While the targeted value of the number of observed trees was set to 10 for each felling block, this condition was not possible to achieve in all the cases due to some objective reasons related to the type of silvicultural system, therefore to the duration of operations for each felled tree.

At the office, data collected in the field by questionnaires, face-to-face interviews and direct measurements was transferred into MS Excel spreadsheets, then it was systematized and statistically analyzed to extract descriptive statistics and models to show some of the dependence relations. In particular, descriptive statistics were built as shares (%) for categorical variables and as standard descriptors such as the minimum value, maximum value, mean and standard deviation for the continuous variables. Shares were also used to describe the risk-taking behavior, the existence and use of protective equipment as graphs.

Accuracy analysis of felling cuts was constrained to notch depth (ND, cm), hinge width (HW, cm) and notch openness (NO, °), as these features characterize best the risks associated with tree felling [29]. To this end, notch openness was estimated at the office based on the methods described in [11] and comparisons with the recommended dimensions was made based on information given by the literature in the field [15], [21], [29], [43] and by designing a common range for notch openness. Given that different tree felling procedures may be used when dealing with small-diameter trees [15], [29], those observations showing a diameter at the stump less than 20 cm were removed from analysis. Therefore, it was considered that the notch openness (NO, °) was correctly shaped when its values ranged from 25 to 60°, with obvious concerns on that values that were below 25°. Notch depth (ND, cm) was considered to be accurately executed when it ranged between 0.20 to 0.33 of the stump diameter and the hinge width (HW, cm) was considered to be correctly shaped when it was of at least 3 cm for those trees having a stump diameter less or equal to 30 cm [29], and of 10% of the stump's diameter when the trees shown a stump diameter greater than 30 cm [15], [21], [29], [43]. Given the operational conditions in which the hinge width is shaped by cutting, a tolerance threshold was set at ±1 cm relative to the recommended value as a function of the stump diameter. This threshold was set to give the possibility of the data to fall into "correct category" in those situations in which the intention was to make correct hinges.

Thresholds set by the existing literature, as well as the experimental data, were plotted against the variation of the stump diameter, and the technique of least-square simple linear regression through origin was used to model the experimental trends for the notch depth (ND, cm) and hinge width (HW, cm) in function of the stump diameter (SD, cm). This approach was useful in understanding the general behavior of experimental data as well as to make comparisons and to extract the frequency and shares of correctly executed cuts. All the calculations and statistical analyses were carried-out in MS Excel.

3. Results

3.1. Description of Workers and their General Behaviour

The workers taken into study had ages between 22 and 55 years, averaging approximately 39 years (Table 2). Body weight varied widely between 49 and 110 kg, averaging about 80 kg. The Body Mass Index (BMI) is often used to quantify the amount of tissue mass in a given individual, with the aim to categorize that person as underweight, normal weight, overweight or obese, based on its value. The commonly accepted BMI ranges are described as underweight - under 18.5 kg/m^2, normal weight - 18.5 to 25 kg/m^2, overweight - 25 to 30 kg/m^2 and obese - over 30 kg/m^2. In relation to work safety, the BMI is important, especially in steep terrain, because the overweighed persons are more prone to fatigue, therefore to the attention loosening which may result in accidents.

Description of basic anthropometric features Table 2

Anthropometric variable (item)	Descriptive statistics			
	Min.	**Max.**	**Mean ± St.dev.**	**Count**
Age (years)	22	55	38.59±8.38	44
Body weight (kg)	49	110	79.86±11.88	44
Height (cm)	160	190	174.43±7.15	44
Body mass index (kg/m^2)	19.14	32.87	26.17±2.98	44

To this end, more than half of the persons taken into study were classified as overweighed (52.27%) and more than 10% were classified as obese (not show herein). The rest of 36.36% were classified as having a normal weight. Out of the 8 work accidents reported by the observed persons, 6 cases (75%) were reported by overweighed persons (not shown herein).

In the observed population, the majority of workers were employed by private companies, (84%), while the rest were employed by the state, working for the National Forest Administration. More than 70% of the respondents were paid based on the production outputs (*i.e.* per m^3), and most of them graduated 8 or more classes (Table 3). Only 30 of the 44 respondents declared that they actually followed a motor-manual operation training course, which, according to their responses, varied in duration between 1 and 24 months, averaging about 5 months. No obvious relations were found between the occurrence of professional accidents and the duration of the training courses. In what concerns the last on-the-job safety training, it was administrated, according to the respondents, in average, 7-8 weeks before the field study. However, there were cases in which the respondents declared that they did not received any safety training.

Table 3

Status of employment type, payment systems, graduated schools safety training and number of accidents

Parameter (item)	Option	Descriptive statistics				
		Share(%)	Count	Min.	Max.	Mean ± St.dev.
Employer	State	15.91	7	-	-	-
	Private	84.09	37	-	-	-
Payment system	Hour	27.27	12	-	-	-
	Output	72.73	32	-	-	-
Graduated schools	None	2.3	1	-	-	-
	4 classes	2.3	1	-	-	-
	8 classes	36.4	15	-	-	-
	10 classes	27.3	12	-	-	-
	12 classes	27.3	12	-	-	-
	Highschool graduate	4.5	2	-	-	-
Training courses (months)		68.18	30	1	24	4.93±4.95
Last safety training (weeks)		100.00	44	0	156	7.59±24.20
Accidents	Yes	18.18	8	-	-	-
	No	81.82	36	-	-	-

Almost 20% of the respondents declared that they were the subject of a professional accident in the past. Two subjects declared cuts during the work, one subject broke his leg, while the others declared other accidents such as finger crushing, hitting the body etc. These numbers are of a great concern, as also other studies have shown that such figures may account, in tree motor-manual felling and processing operations, for high shares [3], [30]. However, one should take into the consideration that the results reported by this study stand only for rather a small sample of motor-manual fellers. From this point of view, further studies addressing greater populations of workers should be encouraged in the future, at least to be able to align the Romanian knowledge of forest operations safety to the existing international one.

The mean daily liquid consumption averaged, according to the responses, 2.80 l, ranging from 1.25 to 4.50 l per day (Table 4), but no significant relations were found between any of the anthropometric features and the liquid consumption behavior. Almost half of the observed persons declared themselves as being smokers, and more than 70% declared that they drink alcohol occasionally. More than 30% of the observed workers declared that they use to procure and consume natural food from the surroundings of the work area and their majority declared that use to have a mixt diet composed of both, locally procured fully natural food and regular food from the general commerce.

The number of declared pauses taken during a work day varied between 1 and 17.5, with an average of approximately 6, but it was not correlated with the perceived difficulty of the work neither with the body mass index, body weight nor age.

Description of general behavior Table 4

Parameter (item)	**Option**	**Descriptive statistics**				
		Share	**Count**	**Min.**	**Max.**	**Mean ± St.dev.**
Consumption of liquids per day		100	44	1.25	4.50	2.80±0.79
Smoking	Yes	45.45	20	-	-	-
	No	54.55	24	-	-	-
Alcohol consumption	Never	15.91	7	-	-	-
	Occasionally	70.45	31	-	-	-
	Frequent	13.64	6	-	-	-
Food type	Regular	2.27	1	-	-	-
	Mixt	63.64	28	-	-	-
	Natural	34.09	15	-	-	-
Number of pauses per day		100	44	1	17.5	6.23±4.44

In what concerns the number of pauses taken per work day, it is likely that some of the workers understood by taken pauses only that time which was used to take the meal at the worksite.

Most of the respondents declared that they end their work day at their homes (Table 5). Still, an important part of them declared that they accommodate themselves into the forest (34%) while some minor part rent locations for accommodation (4.6%).

Obviously, some of them had to make some compromises between the family life and the job, given the fact that three quarters declared to be married. This situation is characteristic to forest operations jobs where the workers need to spend most of their time into the forest, a fact that could affect their family life. Probably this would be one of the reasons contributing to the decreasing attractiveness of this kind of jobs [44]. More than half of the respondents believe that their work is not heavy. Still, more than 33% of the respondents perceived their work as being a somehow heavy or a heavy one, a figure which could be related to those persons willing to work in another field.

Table 5

Descriptive statistics of accommodation, perception on job difficulty and job satisfaction

Parameter (item)	Option	Descriptive statistics	
		Share	Count
Marital status	Married	75.00	33
	Not married	25.00	11
Accommodation place	Into the forest	34.09	15
	At home	61.36	27
	Rental	4.55	2
Personal perception on the job difficulty	Not heavy	56.82	25
	Somehow heavy	15.91	7
	Heavy	27.27	12
Personal satisfaction on the job	Satisfied	100.00	44
	Not satisfied	0.00	0
Willingness to work into another field	Not willing	76.00	19
	Willing	24.00	6

Of those giving responses on the item related to working into another field, half of those willing to pursuit other fields were those perceiving their work as being somehow heavy or heavy. This is important as in many parts of the world, including Romania, the attractiveness of the forest jobs tends to decrease, with many people choosing to leave this industry for less demanding jobs. In turn, all of the respondents declared themselves generally satisfied with their current job, a figure which should be treated with caution.

3.2. Risk-taking Behavior

Figure 2 shows a breakdown on the protective equipment existence in the field as well as on the behavior of workers related to actually wearing such equipment. In more than 50% of the observed cases, the workers were equipped with special boots but only half of them actually worn such equipment at the field study time. In less cases (40.91%) special trousers were present at the field study site but they were actually worn in lesser cases (25.00%). A similar situation was observed in the case of special vests, with a trend of not being fully equipped as well as of wearing the equipment in only about half of the cases when it existed at the work place.

On the other hand, the numbers improved in what concerns the existence and wearing of protective gloves and helmets, but special concerns would be those related to wearing eye and ear protection equipment, as some studies pointed out that a significant part of the accidents are those affecting the eyes of the workers [30], while not wearing the ear protective equipment in forest operations results in hearing loss for the workers in the forestry industry [18], [40].

Safety kits were present at the work location in almost 80% of the cases and the subjects declared that there are available persons to undertake first aid measures, most of them having knowledge on the first aid protocols.

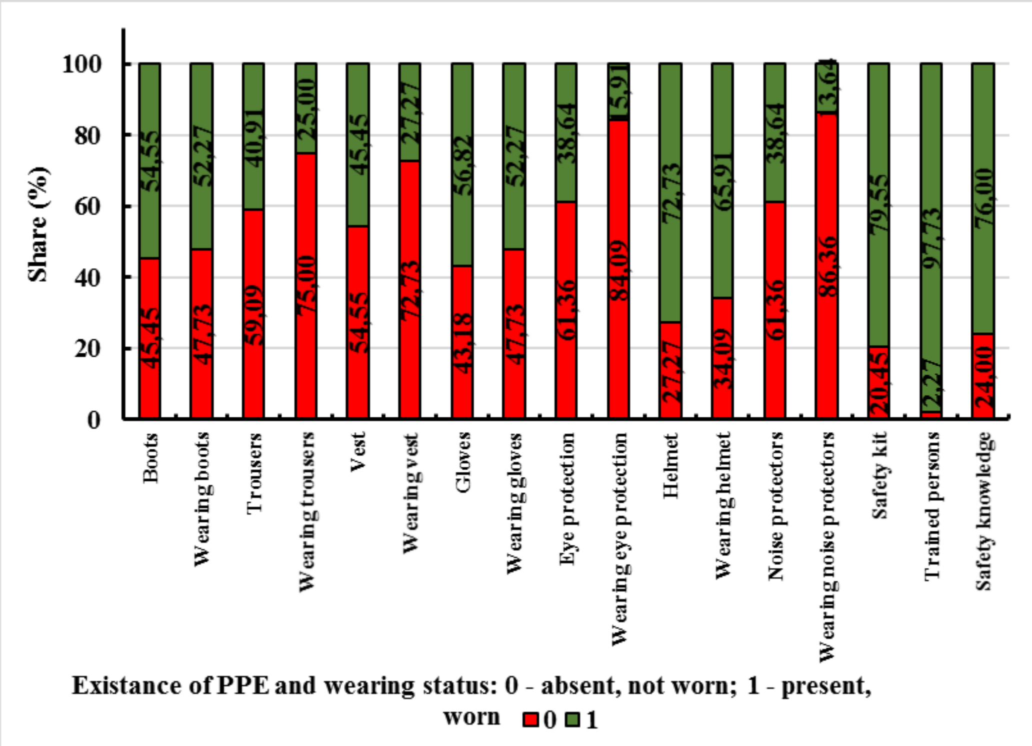

Fig. 2. *Shares of existence and use of protective equipment*

Figure 3 shows a breakdown on risk-taking behavior during preparatory, felling and post-felling tasks. As shown, the greatest concerns were those related to the creation of escape paths; in more than 88% of the cases when they were required, they were not actually made. Also, the use of the escape paths seemed to be a problem, but this was also related with failing to create escape paths. Another common failure was that related to the procedures used to start the chainsaw's engine, where all of the observed workers failed to use the recommended procedures. It should be mentioned here that only the cold-start approach was considered to comply to the recommended procedures given the fact that in most of the observations it willy was the case due to the interventions caused by the study in the way that operations were carried-out. In real operational conditions, however, where there are no intrusions in the way the work is carried out, other starting procedures are also accepted for warmed-up chainsaws.

Signaling (warning) the tree felling was done only in 18% of the cases. In general, clearing the workplace, removing the branches at the tree bottom, planning the felling on the natural lean, maintaining a safe location when making the felling cuts, adopting and maintaining safe procedures when debranching and bucking were done correctly in more than 67% of the cases. In about 37% of the cases, there were other persons (co-workers) in the area during tree felling.

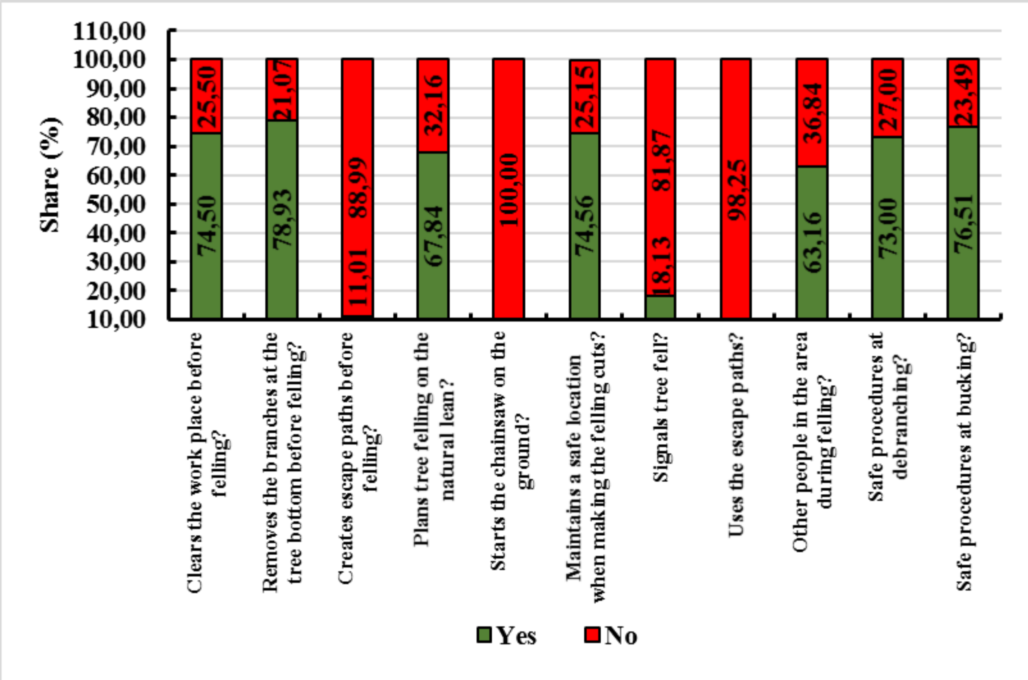

Fig. 3. *Shares of risk-taking behavior during preparatory and post-felling tasks*

3.3. Accuracy of the Felling Cuts

Accuracy of the felling cuts was evaluated based on recommendations and provisions given by the existing literature and it concerned three parameters: notch depth (ND, cm), hinge width (HW, cm) and notch openness (NO, °). As a fact, there are other parameters which may contribute to a safe tree felling procedure such as the hinge length, but its size still depends largely and it is correlated with the notch depth [29]. Since smaller trees may be felled using other procedures [15, 29], the initial dataset was reprocessed to extract and analyze only those trees showing a diameter at the stump height higher or equal to 20 cm. This resulted in a refined dataset containing a number of 288 trees where, for each tree, the field collected dimensions were compared to those provided by the literature. Notch depth (ND=17.82±7.74, cm) was observed to be accurate only in 15.28% (44) cases of the new sample, hinge width (HW=4.15±2.84, cm) was found to be accurate only in 9.38% (27) of the cases and notch openness (NO=24.78±14.13, °) was found to be accurate in about 50% (143) of the cases. However, those cases in which all of the parameters were correctly shaped by the fellers were much less, accounting for only 0.69% (2 cases).A detailed comparative analysis of the parameters taken into study is given in Figures 4-6.

In practice, it is likely to have some variations of the hinge width given the fact that in some cases it accounts for very small proportion of the wood, therefore it would be virtually impossible to exactly shape this parameter during the cutting activity. Therefore, Figure 4 shows the distribution of the observed hinge widths along with the general trend, correct dimension in relation to the stump diameter and a tolerance range set at ±1 cm relative to the correct hinge width. As shown, there was a general trend to relate the hinge width with the stump diameter, which can be statistically described by the enclosed regression equation. It shows that the hinge width, as it was collected from the field, was explained in a proportion of 52% (R^2=0.52) by the stump's diameter as well as the fact that the predicted hinge width stands for about 0.10 (10%) of the stump diameter, which would be correct according to the prescriptions given by the scientific literature.

However, most of the resulted hinge widths were highly inaccurate, with only 70 (24%) cases found in the tolerance range set at ±1 cm. Also, the general trend found in the practice was that of making very narrow hinges in the case of small-medium tree diameters (SD≤40 cm), with some cases (11) in which a proper hinge was not left at all.

For medium-large sized trees (SD>40 cm), the hinge was either over-shaped (27) or under-shaped (29 cases).

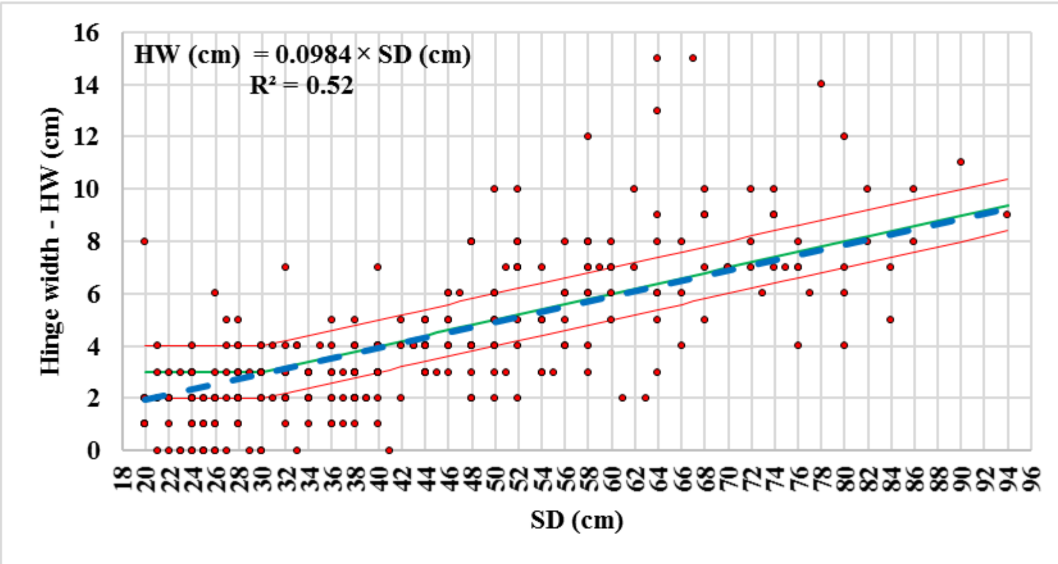

Fig. 4. *Hinge width (HW, cm) in relation to stump diameter (SD, cm): green line - the recommended width, red lines - the recommended width including a tolerance of ±1 cm, blue dashed line - trend of hinge width according to this study, red dots - observations of this study on hinge width (HW, cm) for stump diameters (SD) ≥ 20 cm*

The notch depth (ND, cm), on the other hand, was almost systematically over-shaped, with only 44 cases falling into the recommended prescriptions of the scientific literature (Figure 5). Under-shaping cases were only minor (3 cases).

The general trend shown in Figure 5 was that of making the notch at depths of about 0.4 (40%) of the stumps' diameter

(R^2=0.67), which is well outside the 0.20-0.33 range. This is more important and alarming as in practice the control over the notch dept size is greater when making such cuts, compared, for instance, to the control over the hinge size.

Notch openness, was correctly shaped in approximately half of the cases. It should be mentioned here that the magnitude of this parameter may have effects on the time spent by tree to fall and on the quality of the wood in the near-ground part of the stem [29].

Therefore, the greater the notch openness the greater the time spent by the tree during falling and the greater the time given to the feller to retreat. This is particularly important in steep terrain where, given the procedures used to fell the trees downhill [29] a greater openness could provide additional time for the workers to retreat in the uphill direction. To this end, small angles between the two notch cuts, as shown by this study, ranging between 0 - 81.17° and averaging 24.78±14.13°, could lead both to safety and wood quality related problems. Therefore, what willy matters in practice is the minimum threshold set for this parameter.

Figure 6 plots the observed values against the recommended thresholds and the diameter of the stump. As shown, there was a trend of under-shaping, with more than 120 cases (43%) in which the notch openness was smaller than the recommended value, out of which, in 12 cases, this feature was not made at all.

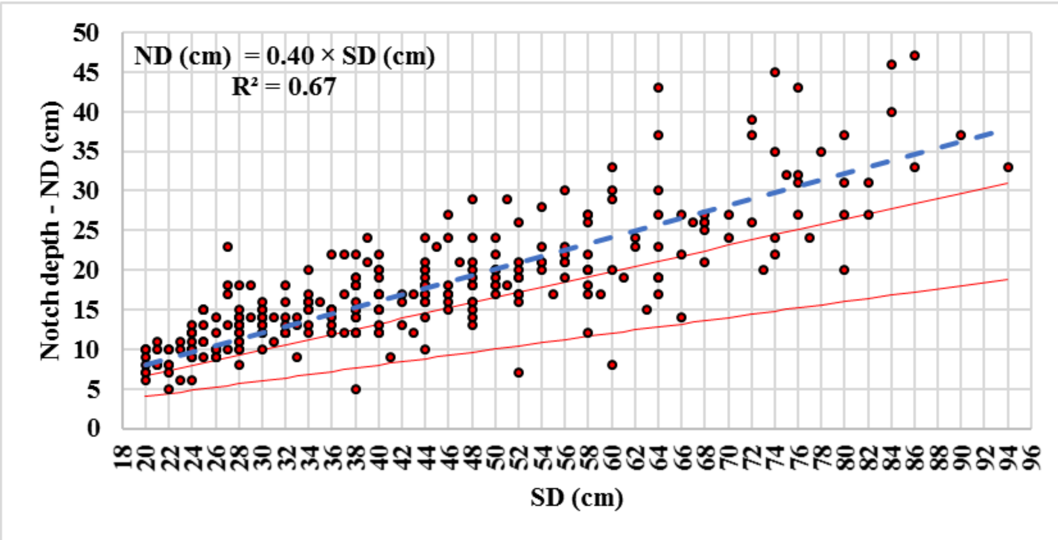

Fig. 5. *Notch depth (ND, cm) in relation to stump diameter (SD, cm): red lines - range of the recommended values (0.20-0.33 of the SD, cm), blue dashed line - trend of notch depth according to this study, red dots - observations of this study on notch depth (ND, cm) for stump diameters (SD) ≥ 20 cm*

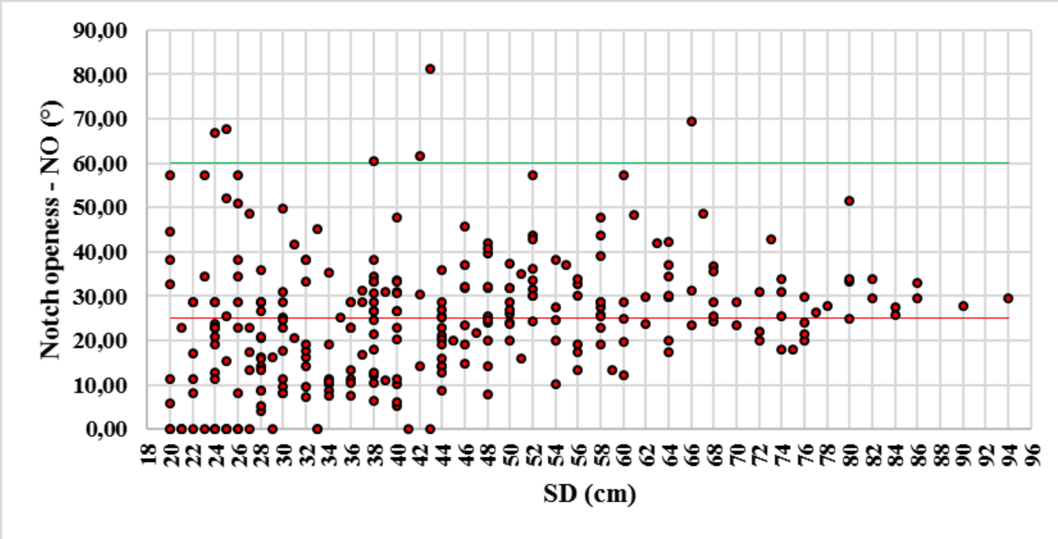

Fig. 6. *Notch openness (NO, °) plotted against stump diameter (SD, cm): red line - the minimum recommended value, green line - maximum recommended value, red dots - observations of this study on notch openness (NO, °) for stump diameters (SD) ≥ 20 cm*

4. Discussion and Conclusions

In our knowledge, there are few studies on the subject considered herein, a fact that could somehow limit the extent of discussions. While not using pretentious data processing and analysis techniques, this study emphasized that the safety procedures in the Romanian motor-manual tree felling and processing are frequently disregarded, a fact which should be seen as a serious concern. Nevertheless, the sample size used in this study stands only for a small proportion of the entire population of Romanian fellers, which could limit somehow the scope of the study. From this point of view, a standardized approach to evaluate the situation at national level could use the procedures described herein but, at the same time, it would involve significant resources given the fact that field data collection in this study took couple of months. In addition, it would be virtually impossible to evaluate all the population due to the involved resources and workers' consent. On the other hand, given the randomized approach in selecting the observed workers, we believe that the results shown herein could provide a pertinent overview on such sensitive problems.

As a fact, a similar study [27] has shown the frequencies in terms of violations of common safety procedures during the preparatory work, effective tree felling and processing. Among the common violations, absence or improper use of the personal protective equipment seemed to have a high frequency. The situation was similar also for the improper felling techniques (*i.e.* incorrect hinge, small back cut) in the case of private companies [27], being further complemented by the incorrect start of the chainsaw. The last violation of the safety procedures was specific also to this study where the chainsaw was judged to be incorrectly started in all of the observed cases. Obviously, such chainsaw starting techniques could lead to serious injuries, a fact that should be considered in the training programs which should present examples of injuries and accidents related but not limited to the use of such procedures. The same was somehow true for the protective equipment existence and use which was characterized by different shares in this study. In addition to the study of [27], this study addressed also other common features of tree felling preparatory work and emphasized the fact that such safety procedures are disregarded in many of these additional cases. For instance, the creation and use of escape paths showed that this feature represents a problem in the practice. Indeed, it can account for supplementary effort and time but it also may help in saving lives. In few cases the fellers gave warnings of tree felling which was found to be a common violation also in the study of [27]. Given the shares characterizing the violation of safety procedures, tailored training courses should be designed for the fellers to understand the risks they are taking.

Violation of recommended dimensions of the felling cuts was studied by [27] and [11] respectively. The study of [27] has found low frequencies of such events, but this still depends on the time spent to fell and process the trees. Based on three case studies, [11] found that the notch openness tended to be under-shaped, with mean values of the case studies ranging between 16 and 26°. The same study points out that the fellers tended to lead the notch depth as far as almost half of the stump diameter, results which are comparable to those from this study, while the hinge width was considerably reduced by the trend of leading the back-cut almost to the joining point with the notch cut [11]. Often such behaviors are the result of local practice, even if such practices are not sustained by the science. For instance, Koger [24] has carried out an observational study on the dimensions of felling cuts with the aim of modeling such features and he showed how such features are inter-related. The results of this study support some conclusions. Firstly, tree felling and processing work was perceived by many workers as being a difficult job, a fact that may have consequences on the industry by shortages in the manual labor. Even if working with a limited sample, this study emphasized that the rate of accidents in these operations is quite high. The needed personal protective equipment was either not present at the job site or it was not worn in all cases by the workers. In particular, the limited use of eye and ear protection seemed to be of a great concern according to the results of this study. Preparatory, effective-felling and post-felling safety procedures were disregarded to a significant extent. In particular, creation and use of escape paths, as well as the correct starting of the chainsaw and warning when felling the tree seemed to be among the most frequent violations of safety procedures this study. Last but not least, felling cuts were almost systematically inaccurate with obvious trends to under-shape the hinge width and to over-shape the notch depth. Obviously, such behaviors could lead to accidents, but, fortunately, this was not the case during the study. The approach used in this study has also some limitations. Firstly, the hinge width was measured at its middle-length, therefore the results cannot account for those hinges shaped disproportionality at their ends. Often such procedures are used to alter the felling direction [29], but there were few such cases in this study. Secondly, the calculation of the notch openness assumed a right angle in between the notch depth and its height, which is not common to all the trees, therefore it could systematically underestimate this feature. Nevertheless, the effect on the results could be seen as being negligible given the small deviations of notch height from the vertical plane as well as the fact that such deviations usually characterize large-size trees cases in which, in this study, notch openness was found to be accurate. In addition, very large trees may require quite different procedures to make the cuts aiming to align the capabilities of chainsaws to the diameter at the stump [15, 29]. While such procedures may affect the notch openness which should be greater, they do not decisively affect the hinge width and notch depth. Therefore, at least for the data shown for stump diameters of up to 70 cm, the results presented herein would not have been affected. At the same time, as underlined in this study, the lower limit of the notch openness is that what counts in ensuring a safe felling.

On the other hand, it was willy hard to find the origin of concepts and reasons standing behind the recommended dimensions of the felling cuts in relation to the tree size characteristics, therefore this study used the concepts described by the existing Romanian and international literature. Probably the recommended dimensions as a function of the tree size characteristics entered into the science following a trial-and-error approach, a case which advocates for scientific studies aiming to relate such dimensions with safety procedures. Anyway, until proven wrong such recommendations should be strictly followed in the practice.

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