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CONTENTS

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MULTI-TRAIT SELECTION IN AEGEAN REGION LOW ELEVATION BREEDING ZONE FOR PINUS BRUTIA TEN.

Murat ALAN[1]

Abstract: *Multi-trait selection is crucial for tree breeding. Turkish red pine (Pinus brutia Ten.), for which breeding is carried out in five breeding zones, is economically the most important species in Turkey. In the low elevation (0-400 m) breeding zone of the Aegean Region of Turkish red pine, open pollination seeds were collected from the plus trees in eight populations (five seed stands and three gene conservation forests). Three progeny tests (Marmaris-Hisarönü, İzmir-İzmir, and Bergama-Kınık) were established with 168 families and six controls in 2000. However, a total of 188 families were included in the three tests. All the tests consisted of a randomized complete block design with the four-tree-row plot. At the end of the fourth field age, height, terminal shoot length, and the number of flushes in the terminal shoot were measured. After estimating the genetic parameters, genetic gains were estimated for all traits using the selection index. Economic weight for the traits was determined by contributing to growth in seedlings. Individual heritabilities for height, terminal shoot length, and the number of flushes were 0.16, 0.11, and 0.08, respectively. Genetic gains were estimated as 16%, 13%, and 4%, in the same order for the traits, in the case when the 20 best families were selected using the selection index.*

Key words: *Turkish red pine, Heritability, Economic Weight, Index selection.*

1. Introduction

Turkish red pine (*Pinus brutia* Ten.) is one of the target species for the National Tree Breeding Program of Turkey (NTBP). Its distribution area covers 5.2 million ha (23% of the total forest area). In addition, it is a fast-growing species in the main species, the first for timber production (28% of the total) and the first for plantation area (30% of the total) [16, 21].

Turkish red pine tree breeding studies in Turkey, together with other pine species, were initiated in the 1960s with the idea of providing seeds from superior sources (seed stands) to plantations [25]. In 1974, according to the vegetation period and the relative humidity seen during the vegetation period, the seed harvest and transfer zones recommended by Urgenç [25] were revised [3]. Then, breeding studies based on mass selection (seed

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stand selection, plus tree selection, and seed orchard establishment) started in the 1970s and continued until 1994. The NTBP, which entered into force on this date, started genetic tests (progeny tests) for the agenda in breeding studies and revealed a new understanding by considering gene conservation studies together with breeding studies [16]. In this context, Atalay's [3] seed transfer zones were revised by Koski and Antola [16] to tree breeding zone for Turkish red pine. One of the breeding zones was the low elevation (0-400 m) breeding zone of the Aegean Region where three progeny tests were established in 2000 [1, 2]. Turkish red pine breeding in NTBP targeted growth and wood quality. Therefore, the breeding of Turkish red pine needs multi-trait selection to realize an aggregate gain.

Multi-trait selection allows simultaneous improvement of several traits by giving each candidate tree an aggregate index value. An index selection is a linear function of phenotypic (measured) values for traits, each of which is weighted by a coefficient, such that the index value relates the phenotype to the genotypic worth of that tree. The genotypic worth comprises breeding values weighted by their relative economic values per unit change [14]. In this context, multi-trait selection in tree breeding is crucial due to evaluating both traits and their economic value. Although the theory of index selection was introduced into plant breeding more than 75 years ago [12], its application in the forest tree breeding sector is still not very extensive due to: *(i)* the complexity of the forest production system; *(ii)* difficulties in determining the relationship between wood properties and final product quantity and quality; and *(iii)* uncertainty about the future use of trees due to long rotational age [19]. Nevertheless, selection indices are much more formally quantitative and can make good use of information on inheritance [5, 7, 20, 26]. In this context, selection indices link characteristics that breeders would like to improve (objective traits in H) with the characteristics that they assess (selection criteria in I). The selection index (*I*) is a linear function of phenotypic (measured) values for n traits (p_i) weighted by a coefficient (b_i) and the genotypic worth (*H*) is composed of n breeding values (g_i) weighted by their relative economic values (w_i) [14]. The index coefficients (b) that maximize the correlation between I and H are calculated [10, 24]. In this context, the vector of index coefficients (b) is obtained as partial regression coefficients of genotypic worth on phenotypic values [9, 28].

Economic weights for breeding-objective traits reflect how the improvement in those traits impacts on the overall profitability of an enterprise and the expected change in the overall profitability of an enterprise that results from a unit increase in a given breeding-objective trait [9, 15, 28]. So, economic weight is an integral part of index selection. On the other hand, uncertainty over comparative economic-worth functions for different traits is often among the most vexing problems for the tree breeder [4, 5]. The most problematic uncertainties involving such functions arise when economically important traits are adversely correlated [5, 27]. Indeed, negative economic gains can easily result [5]. In this context, many authors have discussed and evaluated economic weight in terms of index selection [5, 9, 10, 12].

This study is the first on multi-trait selection for Turkish red pine. In this context, an index selection was created for Turkish red pine considering the early age of the seedlings in the progeny tests. The aims were estimating the genetic parameters, determining the economic weights for each trait, and selecting families using index selection.

2. Material and Methods

2.1. Genetic Material

Plus trees were selected from eight populations (Table 1). Open-pollinated seeds were collected from each plus tree and sowed in trays in the nursery to grow seedlings. Then seedlings were labeled with each original plus tree number. In addition to seedlings of plus trees, six checklots were grown to establish progeny tests, compare with plus tree seedlings, and estimate genetic gain.

2.2. Progeny Tests and Data Collection

In the low elevation (0-400 m) breeding zone of the Aegean Region, three progeny tests were established consisting of 168 families with six checklots using a randomized complete block design with the four-tree-row plot in 2000. However, only one test (Kinik-Kinik) included 20 different families from other tests; therefore, the total family number was 188.

Information on selected plus trees populations Table 1

National Code	District	Subdistrict	Latitude	Longitude	Altitude [m]	#Plus tree
TM34	Marmaris	Cetibeli	$37^{00}\ 02'30''$	$28^{00}\ 16'\ 20''$	60	53
TM41	Gordes	Sahinkaya	$38^{00}\ 50'\ 11''$	$28^{00}\ 04'\ 32''$	350	10
TM54	Mugla	Gokova	$37^{00}\ 00'\ 39''$	$28^{00}\ 24'\ 30''$	270	29
TM346	Bergama	Dikili	$39^{00}\ 12'\ 55''$	$26^{00}\ 57'\ 25''$	460	46
TM363	Milas	Karacahisar	$37^{00}\ 07'\ 00''$	$27^{00}\ 50'\ 11''$	350	12
GKO81	Milas	Mumcular	$37^{00}\ 04'\ 16''$	$27^{00}\ 44'\ 50''$	410	8
GKO83	Milas	Kayadere	$37^{00}\ 12'\ 17''$	$27^{00}\ 54'\ 46''$	395	23
GKO107	Milas	Karacahisar	$37^{00}\ 07'\ 30''$	$27^{00}\ 50'\ 35''$	350	7
Total						188

Three progeny tests were established to sample the breeding zone: Marmaris-Hisaronu, Izmir-Izmir, and Bergama-Kinik. Izmir-Izmir and Bergama-Kinik consisted of seven blocks, while Marmaris-Hisaronu consisted of four blocks. Then, the tests were protected using a barbed wire fence against animals, the seedlings were hoed, and a disc harrow was pulled between the rows of seedlings. The height and terminal shoot length (TSL) of the seedlings were measured at the age of four after planting. The number of flushes (NF) was counted for each Turkish red pine seedling due to being a polycyclic species. In total, approximately 12,000 trees were assessed across the three locations.

2.3. Statistical Analyses

The following linear model was used to partition the observed phenotypic variance into genetic and environmental components for tree height, TSL, and NF (Equation (1)):

$$y_{ijklm} = \mu + S_i + P_j + B_{k(i)} + F_{l(j)} + SF_{il(j)} + PB_{jk(i)} + BF_{kl(ij)} + e_{ijklm} \quad (1)$$

where:

y_{ijklm} is m^{th} observation, l^{th} family, k^{th} block, j^{th} population, i^{th} site; μ overall mean;

S_i – the i^{th} test site ~ NID (0, σ^2_S);

P_j – the j^{th} population ~ NID (0, σ^2_p);

$B_{k(i)}$ – the k^{th} block within l^{th} test site ~ NID (0, $\sigma^2_{b(S)}$);

$F_{l(j)}$ – the l^{th} family within j^{th} population ~ NID (0, $\sigma^2_{f(p)}$);

$SF_{il(j)}$ – the interaction effect site *i and* l^{th} family within j^{th} population ~ NID (0, $\sigma^2_{Sf(p)}$);

$PB_{jk(i)}$ – the interaction effect population j and k^{th} block within i^{th} site ~ NID (0, $\sigma^2_{bp(p)}$);

$BF_{kl(ij)}$ – the interaction effect k^{th} block within i^{th} site and l^{th} *family within* j^{th} *population* ~ NID (0, $\sigma^2_{bf(sp)}$);

e_{ijklm} – the residual~ NID (0, σ^2_e).

All effectswere assumed as random.

Individual tree narrow sense heritability (h^2_i), family mean heritability (h^2_f) and genetic correlation ($r_{At_1t_2}$) between trait1 (t_1) and trait2 (t_2) were estimated as (Eqs. (2)-(4)):

$$h^2_i = \frac{4 \cdot \sigma^2_{f(p)}}{\sigma^2_{f(p)} + \sigma^2_{sf(p)} + \sigma^2_{bf(sp)} + \sigma^2_e} \quad (2)$$

$$h^2_f = \frac{\sigma^2_{f(p)}}{\sigma^2_{f(p)} + \frac{\sigma^2_{sf(p)}}{s} + \frac{\sigma^2_{bf(sp)}}{bs} + \frac{\sigma^2_e}{bsn}} \quad (3)$$

$$r_{At_1t_2} = \frac{Cov_{(t_1, t_2)}}{\sqrt{\sigma^2_{t_1} \cdot \sigma^2_{t_2}}} \quad (4)$$

where:

s, b, and n are the number of sites, number of blocks, and harmonic mean number of family, respectively;

$Cov_{(t_1, t_2)}$ – the covariance between trait1 and trait2.

The selection index was used for multi-trait selection. The selection index (*I*) is a linear function of phenotypic (measured) values for n traits (p_i), each of which is weighted by a coefficient (b_i), such that the index value relates the phenotype to the genotypic worth of that tree. The genotypic worth (*H*) is composed of n breeding values (g_i) weighted by their relative economic values (w_i) per unit change (Equations (5) and (6) – [14]:

$$I = b_1 \cdot p_1 + b_2 \cdot p_2 + ... + b_n \cdot p_n \quad (5)$$

$$H = w_1 \cdot g_1 + w_2 \cdot g_2 + ... + w_n \cdot g_n \quad (6)$$

The vector of index coefficients (b) for the traits was calculated as partial regression coefficients of genotypic worth on phenotypic values (Equation (7) – [9, 28]):

$$b = P^{-1} \cdot G \cdot w \quad (7)$$

where:

P is the matrix of phenotypic variances and covariances among traits;

G – the genetic variance-covariance matrix;

w – the vector of economic weights.

The economic weight of height was assumed to be four due to the seedlings' four-year-old age for Turkish red pine. With the same idea, the economic weight of TSL and NF was assumed to be one due to TSL and NF comprising one year. In this context, the economic weight was determined by four (66%) for height, one (17%) for terminal shoot length, and one (17%) for the number of flushes considering the early age of the seedlings.

3. Results

3.1. Genetic Parameters

The descriptive statistics for the traits of the Turkish red pine seedlings at the age of four are shown in Table 2.

Approximately 12,000 seedlings for each trait were evaluated, and the means of height, TSL, and NF were 101.4 cm, 35.1 mm, and 2.7, respectively.

Descriptive statistics for traits Table 2

Descriptive statistics	Height [cm]	TSL* [cm]	NF*
Number of seedling (N)	11975	11924	11873
General mean ($\overline{X}$)	101.43±0.24	35.09±0.11	2.74±0.002
Max. Family mean ($\overline{X}$)	120.71	45.90	3.51
Min. Family mean ($\overline{X}$)	83.46	25.70	2.03
Coefficient of variance	24.83	33.09	13.73
Standard deviation	26.11	11.61	0.23

*TSL: Terminal shoot length, NF: Number of flushes

Using pooling data across three tests, the individual narrow sense heritability, the family mean heritability, the variance component, and its rate of the total variance were estimated (Table 3). The ratios of family variance to total variance changed by 2-3% for three traits. The individual narrow sense heritability was 0.16, 0.11. The genetic correlation between height and TSL was the highest, and between height and NF was the lowest (Table 4). The phenotypic correlations were also similar to the genetic correlations. Genotype-by-environment interaction for all traits was negligible for application in forestry. The genetic correlations between tests ranged from 0.70 to 1.00, except for 0.29 between Marmaris-Hisaronu and Izmir-Izmir for NF.

Table 3

Variance component, its rate to total variance, narrow sense heritability, and family mean heritability for each trait in pooling data

Parameter*	Height		TSL		NF	
	Value	*%*	*Value*	*%*	*Value*	*%*
σ^2_s	88.22	13	16.65	12	0.0076	15
σ^2_p	17.66	2	4.97	3	0.0002	0
$\sigma^2_{b(s)}$	11.13	2	2.50	2	0.0012	2
σ^2_{ps}	0.57	0	0.00	0	0.0001	0
$\sigma^2_{pb(s)}$	9.79	1	2.18	1	0.0003	0
$\sigma^2_{f(p)}$	23.40	3	3.33	2	0.0009	2
$\sigma^2_{sf(p)}$	7.02	1	0.86	1	0.0006	1
$\sigma^2_{bf(sp)}$	131.07	18	28.14	19	0.0060	12
σ^2_e	436.29	60	84.70	60	0.0361	68
σ^2_T	725.12	100	143.320	100	0.0529	100
σ^2_a	93.58	0.13	13.299	9.28	0.0034	6.52
p_i	597.77		117.02		0.044	
p_{fam}	55.07		9.69		0.003	
h^2_i	0.16±0.02		0.11±0.02		0.08±0.02	
h^2_f	0.42±0.08		0.34±0.07		0.32±0.09	

*σ^2_s, σ^2_p, $\sigma^2_{b(s)}$, σ^2_{ps}, $\sigma^2_{pb(s)}$, $\sigma^2_{f(p)}$, $\sigma^2_{bf(sp)}$ *and* σ^2_e are site, population, block, site population interaction, population block interaction, family, block family interaction and error variance, respectively. σ^2_T is total variance, σ^2_a is additive variance, p_i is phenotypical variance for individual heritability, p_{fam} is phenotypical variance for family mean heritability.

Genetic (below diagonal) and phenotypic (upper diagonal) correlations Table 4

Traits	Height	TSL	NF
Height	-	0.83	0.49
TSL	0.91±0.02	-	0.60
NF	0.38±0.11	0.46±0.11	-

3.2. Index Selection and Genetic Gain

The index coefficient was estimated at 0.3479474, -0.1828657, and -8.725192 for height, TSL, and NF, respectively, using equation (7). The index coefficient for each trait was multiplied by each trait breeding value estimated by the BLUP method. Multiplied values for each trait were summed as an index value for each family (Table 5). Considering a single trait, 12 of the first 20 families in terms of breeding value in height were the same as the first 20 families in the index breeding value. In comparison, the TSL and NF included the same families as seven and six of the 20 families in the index breeding value, respectively.

Table 5

The first 20 families in index selection, the first 20 families in each trait, and the same families in each trait and index selection are marked in bold. The same families with the index were 12 out of 20 for height, seven for TSL, and six for NF

Rank of Family	Only Height	Only TSL	Only NF	Index selection
1	1246	1246	1262	1032
2	1032	1032	1257	1246
3	1262	1247	1246	671
4	1263	1262	1247	1034
5	1034	1257	1267	972
6	1267	1263	1032	1263
7	1247	1267	1022	1013
8	1013	1034	1250	974
9	1257	1016	1263	1234
10	1234	1229	1019	1262
11	1254	995	1256	1239
12	1019	1006	1034	1224
13	1250	1254	1016	998
14	1012	1003	1261	1015
15	671	1265	1025	1267
16	959	1261	1266	1254
17	1264	970	1012	1217
18	1229	1256	1028	673
19	998	973	1229	644
20	974	1019	993	999

The genetic gain was estimated for each trait based on the index value of the first 20 families compared to the checklots (Table 6). The genetic gain for each trait using the index value was lower than the genetic gain for single traits. Differences from index values to single traits were -3, -8, and -9 for height, TSL, and NF, respectively.

Table 6

Genetic gain for each trait and comparison with index selection

Genetic gain	Height	TSL	NF
Index [%]	16	13	4
Single trait [%]	19	21	13
Difference	-3	-8	-9

4. Discussion
4.1. Genetic Parameters

Forest tree breeding needs to obtain substantial genetic gain in a short time. However, forest tree species have long rotation ages. In this context, maximum genetic gain in unit time is the main objective. In this context, breeding activities start at early ages to connect rotation age, and optimum selection age can be decided [11, 18, 23]. In Turkish red pine breeding, data were collected from three progeny tests at the age of four and continued every four years. The average seedling height at the age of four was about 1 m in the low-elevation breeding zone of the Aegean Region. The findings would be supported in the following ages to obtain maximum gain in unit time using juvenile age and mature age (rotation age) correlations [17].

The heritability was reviewed by Cornelius [8] for 67 forest trees containing more than 500 estimates of heritabilities for different species (conifers and hardwoods), traits, and ages. He found the heritability median between 0.19-0.26. White et al. [26] also concluded that narrow sense heritabilities for many stem growth and form traits range from 0.10 to 0.30, while wood-specific gravity ranges from 0.3 to 0.6. In this context, Turkish red pine heritability at the age of four for traits was close to the bottom limit indicated by White et al. [26], and NF was lower than it. However, phenotypic and additive genetic variances along with their ratio, as well as heritability, are proper measures for evaluating whether a trait has the potential to differentiate populations exposed to differential natural selection pressures in distinct environments (White et al. 2007). Therefore, heritability is a crucial parameter for tree breeding due to showing genetic effects transmitted to progeny thanks to the plantation.

The genetic correlation was high between height and TSL. However, other genetic correlations between traits were low. A high genetic correlation between traits indicates that the same genes or set of genes control/influence the two traits, and pleiotropy is the underlying factor of a genetic correlation [5, 26]. Therefore, breeding in one trait means breeding in other traits in the same direction. In this condition, the breeders can preferred just one trait; however, they will improve another trait similtaneusly. However, applying the index selection for three traits was considered a pioneer study for Turkish red pine breeding. So, following ages, traits can be changed. According to current study findings, although the genetic correlation between height and TSL was high, economic weights differed for height and TSL. Therefore, selected families for height and TSL differed from the index selection in contrast to single traits.

4.2. Index Selection and Genetic Gain

Index selection allows simultaneous improvement of several traits by giving each candidate tree an aggregate index value [14]. Therefore, using index selection, the selection set of families includes each trait's contribution to the index and its economic weight. The index selection in Turkish red pine was aggregated height, TSL, and NF at the age of fou rto establish a seed orchard with the first selected 20 families. However, using different alternatives, it would be better to create an index selection with height, breast height diameter (DBH), volume, stem straightness, and specific gravity in the following years in Turkish red pine.

Economic weight is an integral part of index selection. However, determining economic weight results difficulties. Up to now, some suggestions have been made on determining economic weight [5, 9, 14, 22] due to being an instrument of changing enterprise outputs. Some economic weights were determined in Prosobis alba, 60% for height, 10% for breast height diameter, and 30% for stem number [6], and in Pinus taeda, 60% for volume, 20% for stem straightness, and 20% for rust resistance [13]. On the other hand, in *Picea glauca* [22], more than one index selection option was suggested, like S1 (Height 75% and DBH 25%), S2 (height 67% and density 33%), S3 (height 67% and acoustic velocity 33%), S4 (modulus elasticity 25%, modulus rupture 25%, height 50%), and S5 (height 25%, DBH 25%, acoustic velocity 25%, and density 25%). Economic weight in Turkish red pine was four (66%) for height, one (17%) for TSL, and one (17%) for NF, and considered growth ratio. However, for the following ages, economically important characteristics (like height, DBH, volume, specific gravity, and stem straightness) can be preferred in index selection with appropriate economic weights. More effective selection can be made to increase enterprise outputs by including different traits with different index selections.

Genetic gain for each single trait was more than the index value of height, TSL, and NF in Turkish red pine. On the other hand, close genetic gain for height and TSL can be expected due to a very high genetic correlation (almost an equal one) between height and TSL. However, the economic weight of height was four times more than the economic weight of TSL. Therefore, decreasing genetic gain in the index value for TSL might be more than the genetic gain of height. As can be seen, the genetic relationship between traits and the economic weight of traits is effective for index selection due to an aggregation of all of them.

5. Conclusions

The study used the multi-trait selection of *Pinus brutia* in this context for the first time. Multi-trait selection is crucial for tree breeding because all the effects of the traits are included. Index selection is widely used in forest tree species using a multivariate function of the phenotypic values for all the selected traits. Furthermore, index selection involves phenotypic and genetic values and the economic weight of traits. Determination of economic weights for traits is vital for index selection. When economic weight is accurately determined, the selection index can be very effective in tree breeding. In the following ages, a selection index with economically important growth and wood quality traits and determining the appropriate economic weights of the traits can increase enterprise outputs for Turkish red pine.

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HUNTING AND HUMAN – BEAR CONFLICTS

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Abstract: *In the current context of conservation of the brown bear (Ursus arctos L.) population, ensuring the coexistence of the species with humans is becoming more and more difficult to achieve. Thus, in order to evaluate the dynamics of the relationship between the two entities, data were collected from 2010 to 2022 in the Central Development Region of Romania, where most human-bear conflicts were reported. In the period before the ban on brown bear hunting (2010 – 2015), the amount of damage caused by them reached 1,386 cases, and the number of attacks on people was 80. Gradually, with the growth of the brown bear population, human-bear conflicts increased. After there were no more hunting quotas (2016 – 2022), the amount of damage reached 8,328 cases, and the attacks on people reached 155. The brown bear hunting ban also contributed to an increase in the number of bears illegally killed in the study region due to the tensions created by the increasing conflicts, compared with the period when the brown bear could be hunted. Therefore, statistical data show that attacks on people, as well as the damage caused by the brown bear, register significant increases from year to year, and in the current situation, the provisions of the Habitats Directive do not lead to maintaining the protection and favorable conservation status of the brown bear, but rather to the uncontrolled development of the bear population and to illegal killings.*

Key words: *brown bear, human-bear conflicts, hunting, bear conservation, Habitats Directive.*

1. Introduction

In Antiquity, there were no regulations regarding hunting, and hunting was considered a natural right [20].

During the Middle Ages, however, the nobility held the right to hunt big game [1].

In our country, the freedom of hunting ended in the 19th century, with the first regulations regarding the protection of species of hunting interest, in the Rural Police Law of the Old Kingdom of 1868 and the Game Police Law, published in 1891 [27]. Through these normative acts, inspired or even translated from French legislation, prohibition periods were established for certain game species.

The species that were of hunting interest in the historical periods

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mentioned above were the red deer (*Cervus elaphus*), the fallow deer (*Dama dama*), the wild boar (*Sus scrofa*), the roe deer (*Capreolus capreolus*), the hare (*Lepus europaeus*) from the herbivores, and the brown bear (*Ursus arctos*), the wolf (*Canis lupus*), the lynx (*Lynx lynx*), and the fox (*Vulpes vulpes*) from the carnivore species [15].

In order to restore the numbers of non-predatory game and as a result of the increase in predator numbers, Law No. 4264 was published on October 27, 1921 for the protection of game and the regulation of hunting [15], which had unitary applicability in Romania and through which a series of new regulations were imposed. A detail that attracts the authors is that in this law, for the first time, the problems related to compensation for the damage caused by game to crops or livestock was also briefly detailed, as livestock breeding and agriculture is, sometimes, the only source of income for peasants. The persons injured by wildlife could also be compensated in goods or with money.

This study aims to research the dynamics of legislative regulations regarding brown bear hunting in order to establish the evolution of brown bear management and the conflicts between bears and humans.

If, in the past, bear hunting could be done all year round or in predetermined periods, with the approval of a harvest quota that would maintain the ecological balance and a small amount of damage, in recent years, the brown bear has been a strictly protected species. Thus, due to Romania's accession to the European Union in 2007 and the adoption of the Habitats Directive, bear hunting can only be done based on derogations, and these rules produce adverse effects on the ecological and socio-economic environment.

The problem of damage and incidents produced by species of hunting interest has been subject of debate since the Middle Ages. Still, the magnitude of the moral and material damage caused by bears in recent years in the region under study has not been exposed to its actual size, up to now.

Therefore, the first objective of this study was the analysis of the provisions of the normative acts issued in the field of hunting; the second objective was the identification of the number of human-bear conflicts existing before and after the ban on bear hunting, and the third proposed objective was the evaluation of mortality cases recorded by bears.

This information will determine the impact of the lack of annual brown bear harvest quotas on people, their property, and the brown bear (*Ursus arctos* L.) population.

2. Material and Methods

2.1. The Studied Area

The Center Development Region is located in the center of Romania and comprises the counties of Alba, Brașov, Covasna, Harghita, Mureș, and Sibiu (Figure 1). The region's area is 34,097 km^2, of which: 6,255 km^2 (Alba); 5,361 km^2 (Brașov); 3,707 km^2 (Covasna); 6,637 km^2 (Harghita); 6,705 km^2 (Mureș); 5,432 km^2 (Sibiu). The resident population in mid-2021 was 2,613,901 inhabitants distributed as follows: Alba 369,331; Brașov 638,707; Covasna 224,009; Harghita 327,877; Mureș 585,494; Sibiu 468,483 inhabitants [18].

Fig. 1. *Map of the researched area* [26]

The macro-region that is the subject of this study is located inside the Carpathian mountain range in - Transylvania and has varied relief consisting of mountains, hills, plateaus, and meadows. Its surface is crossed by the Olt and Mureș rivers and their tributaries.

The forest area in the region is composed of various resinous and deciduous species and supports one of the highest density of brown bears [22] in the world. Inside, but also outside the forest area, the most significant number of incidents caused by bears in Romania is registered, and bears are the main species of game that causes damage [3].

Agriculture is the main occupation of the rural people, and they cultivate wheat, corn, rape, sunflower, and fruit trees and raise domestic animals, like cattle, sheep, pigs, and goats. We also analyzed the dynamics of this occupation, as this is one of the sectors where most human-bear incidents occur.

The material used for the documentation related to hunting regulations is represented by the scientific studies carried out in the study area and by the national and international legislation that has existed in Romania since the 19th century up to today:

- The Rural Police Law of the "Old Kingdom" from 1868 [27];
- Law No. 4264/1921 for game protection and hunting regulation [15];
- Law No. 231/1947 for the organization of the game economy [12];
- Decree No. 76/1953 regarding the economy of hunting and fishing in mountain waters [5];
- Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES Convention) from 1973 [4];
- Law No. 26/1976 regarding the economy of hunting and hunting [13];
- Convention on the conservation of wildlife and habitats (Bern Convention) from 1979 [2];
- Law No. 103/1996 on the hunting area and game protection [10];
- Ministerial order No. 567/1999 for the approval of the Norms regarding the protection of crops, forestry, and

domestic animals against damages that can be caused by hunting [21];
- Law No. 407/2006 on hunting and the protection of the hunting area [14];
- European Council Directive No. 92/43 EEC regarding the conservation of natural habitats, wild flora, and fauna (Habitats Directive) [9];
- Government Emergency Ordinance No. 57/2007 regarding the regime of natural protected areas, conservation of natural habitats, flora, and fauna [8];
- Government Decision No. 1679/2008 regarding the method of awarding the compensation provided for by the Law on Hunting and the Protection of the Hunting Area No. 407/2006, as well as the obligations of managers of hunting areas and owners of crops, forestry, and domestic animals to prevent damages [7];
- Order No. 625/2018 regarding the approval of the National Action Plan for the conservation of the brown bear population in Romania [22];
- Ordinance No. 81/2021 regarding approving immediate intervention methods to prevent and combat brown bear attacks on people and their property [23].

The material used for researching human-bear conflicts, cultivated agricultural areas, livestock in the region, as well as mortality recorded by bear herds in the Central Development Region, consists of statistical data collected from the administrative-territorial units of the six counties in the region, the Cluj Forest Guard, the County Public Health Departments, the Brașov Forest Guard, the National Institute of Statistics, and the National Agency for Environmental Protection .

2.2. Method

We specify that all the data used in this research are official data.

The first objective was achieved through the bibliographic study of the literature related to the brown bear (*Ursus arctos* L.) management and the normative acts that regulated hunting. Thus, six scientific studies were reviewed and, through the software applications for legal and legislative documentation Ilegis and Indaco Lege 5, several normative acts issued between 1868 and up to now were accessed and reviewed. The results were presented in chronological order.

To achieve the second objective, we collected information about the damage caused by the brown bear and the conflicts between bears and the people in the region. This involved the collection of information from 400 administrative-territorial units and six Public Health Departments. The period under investigation is 2010 – September 2022. The information collected from the administrative-territorial units was correlated with the data collected from the Cluj Forest Guard and with those existing in Brașov Forest Guard, and ordered chronologically.

Additionally, to be able to analyze the evolution of the sector where damage and human-bear incidents are most often reported, we also centralized the statistical data related to cultivated agricultural areas and the main domestic animals attacked by bears. The analysis of these data was carried out for the period 2010 – 2020, and the available data only for this period were taken from the National Institute of Statistics.

For the third objective, the data necessary to carry out the research were taken from the National Agency for Environmental Protection and available only for the period 2017 – 2021. They were ordered chronologically and grouped into two categories, the category of ”accidental catches” and the category of „accidental killings”.

All the information obtained was centralized and then introduced into the Microsoft Excel program, through which the obtained results were represented graphically.

3. Results

3.1. Brief Description of Legislative Regulations

In the history of hunting regulations the ungulates and gamebirds were considered economically important, the wolf, the bear, the lynx, and the fox were considered predatory species, causing damage, and their hunting was not restricted in any way. Although in 1868, by issuing the Rural Police Law of the ”Old Kingdom”, hunting was prohibited from April 1st to August 1st [16], bears, wolves, lynxes, foxes, and wild boar were the species that could be hunted all year round. The provisions of Law No. 4264/1921 [15], which succeeded it, provided prizes for the people who hunted bears and wolves. Alternative measures to kill bears and wolves, such as snares, poisons, and traps were accepted. When local predatory populations increased, their hunting could be carried out ex officio, by the approval of the head of the forestry units, with the notification of the relevant ministry and the land owners, who could only reject the action if the harvesting of the predators was carried out by themselves [15].

In the 20th century, after the Second World War, when the ungulate and bear populations were very low [25], the legislation regarding the protection of species of hunting interest underwent changes and improvements over the years. In 1947, Law No. 4264/1921 [15] was replaced by Law No. 231 [12] for the ”organization of the game economy”.

With the sharp decrease in the bear population, through Law No. 231/1947 [12], according to Art. 33, catching bears by using traps was prohibited. The law provided prizes only to people who hunted wolves because there was a significant number of them and they were considered pests of domestic animals and for species of hunting interest. These were granted by the Ministry of Agriculture and Domains [12].

The new hunting regulations partially maintained the dispositions imposed by the old normative acts, and as regards the legal seasons in which hunting was allowed, this chapter of the law was amended and supplemented in Decree No. 76/1953 [5] by adding to the list of already existing species, predators such as the brown bear and the pine marten. The other carnivores were not subject to the protection regime.

As we have mentioned so far, *Ursus arctos* could no longer be hunted all year round because a hunting season was established, between March 1 and January 15 [5], except for females with cubs, which were protected. It was also forbidden to hunt the bear in the den or to the bait; the use of traps to capture the bear and the poisoning of predators could only be carried out based on authorizations. Derogations from these legal provisions could only be made when the bear population increase contributed to the damage caused to specific economic sectors.

Law No. 26/1976 [13] brought new changes to the bear hunting period, which was divided into two seasons: from March 15 to May 15 and from September 1 to December 31. Exception to these hunting seasons were only the situations in which individual bears caused damage to livestock, in which case they could be extracted all year round [13]. This time, however, the Romanian legislator no longer distinguished between males and females with cubs, which denotes that bears of either sex could be hunted and that the population of bears had increased over the optimum number.

An important aspect to remember, which took place in 1976, is that the measures adopted for the protection of bears also involved the administration of complementary food throughout the year to avoid damage, for the species’ well-being and to increase the rate of productivity.

Moreover, in the preamble of Law No. 26/1976 [13], a series of reasons were presented:

- "The state creates conditions for the continuous development of the game species, as well as for the exercise of recreational-sports hunting, within the measures to permanently raise the material and spiritual living standards of the population."
- "The management of the game is carried out in a unitary concept and must lead to the increase of its weight in the national economy, by ensuring optimal game numbers, the continuous increase of the biological and productive potential, the reintroduction of species and the permanent increase of the productivity of the hunting areas."

The provisions regarding the granting of compensation for damage to crops or domestic animals are no longer found in its contents. However, they were reintroduced with the entry into force of Law No. 103/1996 [10], and compensations were supported by the ”game protection fund”. At the same time, under the new law, hunting bears from high sites was also prohibited [10].

In 1999, by Order No. 567/1999 [21], the rules regarding the protection of crops, forestry, and domestic animals against damage that could be caused by game were developed and approved. This normative act, in Art. 1, mentioned among other things, the placement of fixed or mobile means of scaring the game, the provision of continuous guarding and supervision of domestic animals grazing and crops by their owners, and the keeping of domestic animals only in fenced and guarded places, during night time [21]. The granting of compensation depended on compliance with these obligations, the method of granting them being regulated by Government Decision No. 1679/2008 [7].

The brown bear became a protected fauna species in 1993, according to Annex II of the Convention on the Conservation of WildLife and Habitats (Bern Convention), with Romania's accession to it through Law No. 13/1993 [11]. This statute was also reflected in the provisions of Law No. 103/1996 [10] which required that bear hunting be carried out only based on the derogations provided in the international conventions concluded by the Romanian State.

Over the years, Romania has also acceded to other international conventions, which have maintained the conservation status of bears to this day, and these are:

a) Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES Convention), adopted in Washington, to which Romania acceded in 1994 and in which the brown bear was considered an endangered species or threatened with extinction and which could be affected by trade. It was listed in Annexes I and II of the convention;
b) European Council Directive No. 92/43 EEC [9] regarding the conservation of natural habitats, flora, and fauna (Habitats Directive), whose provisions place the species *Ursus arctos* in Annex II, being considered a priority species of community interest whose conservation requires the designation of particular conservation areas. The dispositions of this Directive were transposed into the national legislation by the [8] approved by Law No. 49/2011, where the *Ursus arctos* species is found in Annex 4A.

Also, the effect of acceding to the above-listed conventions has begun to be felt in the last seven years, since the Romanian legislator no longer provided harvest quotas for brown bears [6].

Law No. 407/2006 [14], the most recent hunting law, complements the other normative acts indicated in this study, and by its provisions, the distribution of particular complementary food for bears is prohibited. The prohibited food consists of synthetic sugar products and waste of animal origin, and food administration is not permitted between March 1 and November 30 [14].

Government Emergency Ordinance No. 81/2021 [23], the newest regulatory act, which targets the brown bear, was issued by the authorities of the Romanian State.Through it, the ways of preventing bear attacks on people or their property were regulated. It changed over a year, so its applicability was also extended out of the localities and not only inside, as it had originally been approved [23].

3.2. The Evolution of Human-Bear Conflicts and Agricultural Property

As a result of the analysis of the statistical data by years (Figure 2), the damage caused by bears has existed in all these years. In 2010, the amount of damage to crops and domestic animals reached 75 cases. Gradually, they began to increase, and in 2014 their number was 424.

The graphic representation of the processed data continues to show a gradual increase in the amount of damage so in 2019, 1,376 cases were recorded, and in 2021 2,233. The data received for 2022 (damage recorded from January 1 – September 10) show that the amount of damage recorded was already 1,219 cases of the total damage produced by bears in the studied area.

The distribution of damage cases by county (Figure 3) shows that the highest number of damage cases caused by the brown bear in the studied period was 3060, recorded in Harghita county. The lowest number was 169, and it was recorded in Alba county.

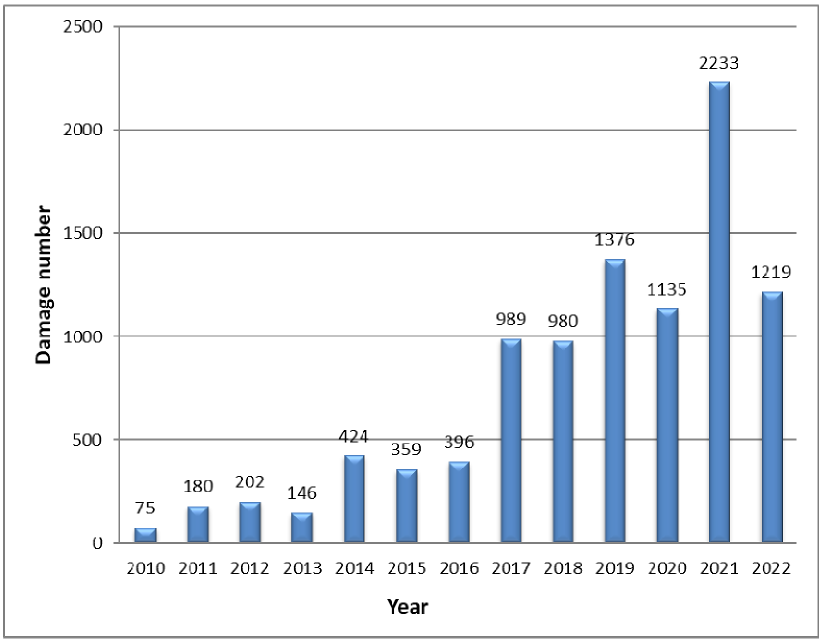

Fig. 2. *The evolution of brown bear damage in the studied period*

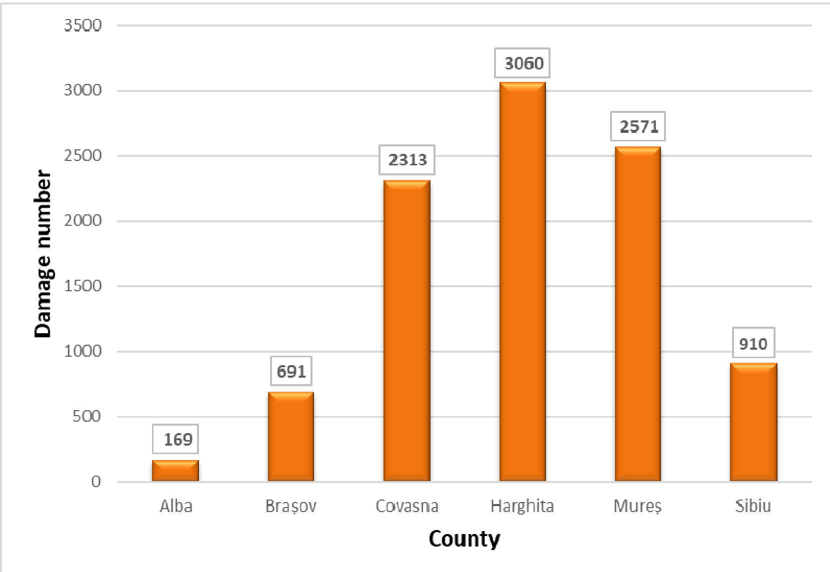

Fig. 3. *The situation of brown bear damage by county*

During the analyzed period, there were also attacks on people in the Central Development Region, which occurred in various circumstances and different numbers. The beginning of the studied period shows ten attacks on people, which increased in the following years (Figure 4), so that in the year 2016, 19 attacks were recorded, and in 2017, 23.

The peak of brown bear attacks on humans was reached in 2021 when their number was 30. Such events were also recorded during the year 2022 (from January 1 to September 10), and their number was 13.

The distribution of brown bear attacks by county (Figure 5) shows that the highest number of attacks on people was 152, recorded in Harghita county. The lowest number was one and it was recorded in Alba county.

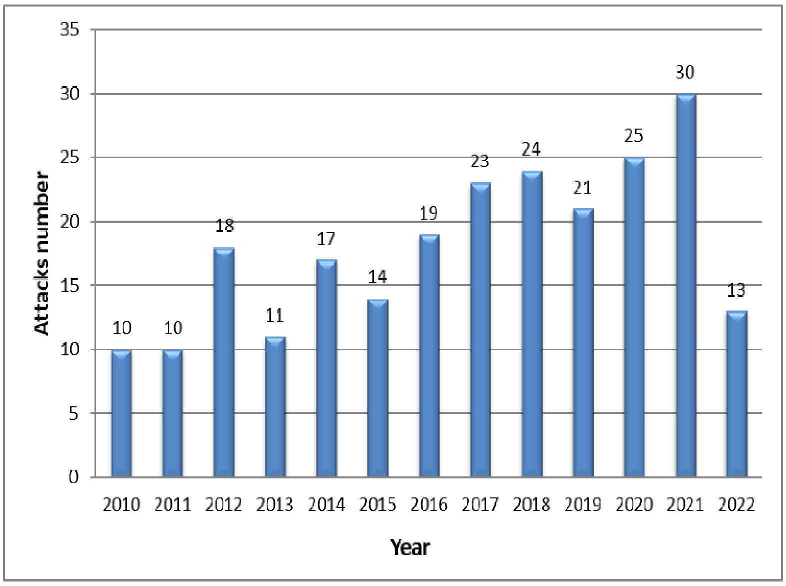

Fig. 4. *The evolution of brown bear attacks on people in the studied period*

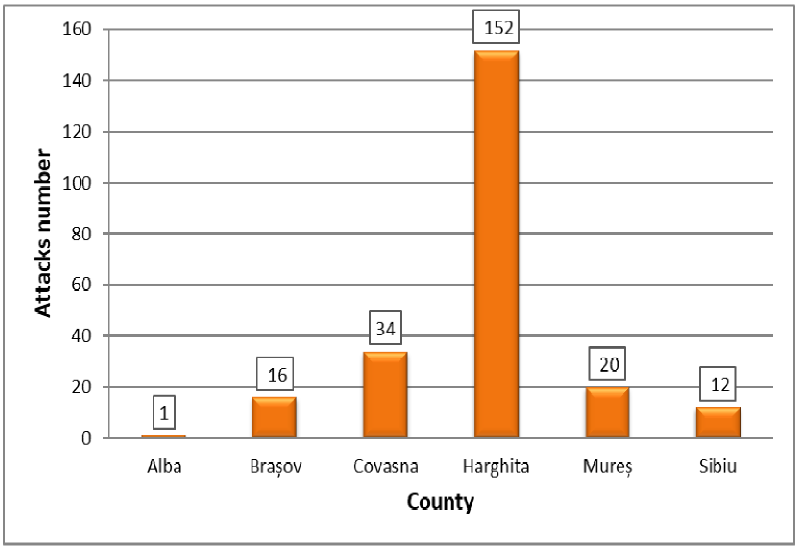

Fig. 5. *The situation of brown bear attacks by county*

As highlighted in section 2.1, the main occupation of the rural population is agriculture. Field-specific activities were also carried out in 2010-2020 on a different number of hectares from one county to another (Figure 6).

The most significant areas were cultivated in Mureș and Alba counties, with Harghita county at the lowest. The evolution of crops fluctuated from year to year, and the most significant increase in cultivated areas was reported in 2018 in Alba county, where 121,768 ha were cultivated and in 2019 in Mureș county, where 190,549 ha were cultivated [19].

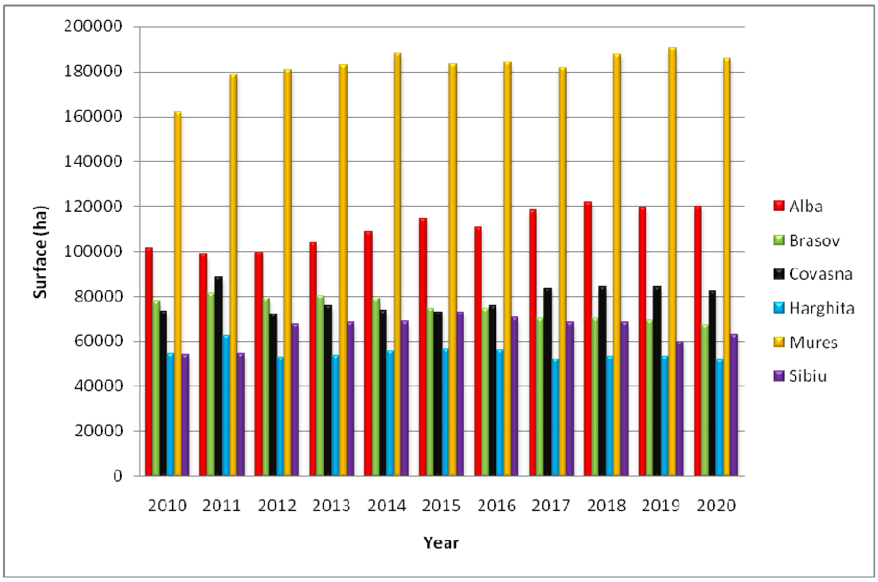

Fig. 6. *Evolution of cultivated areas in the Central Development Region*

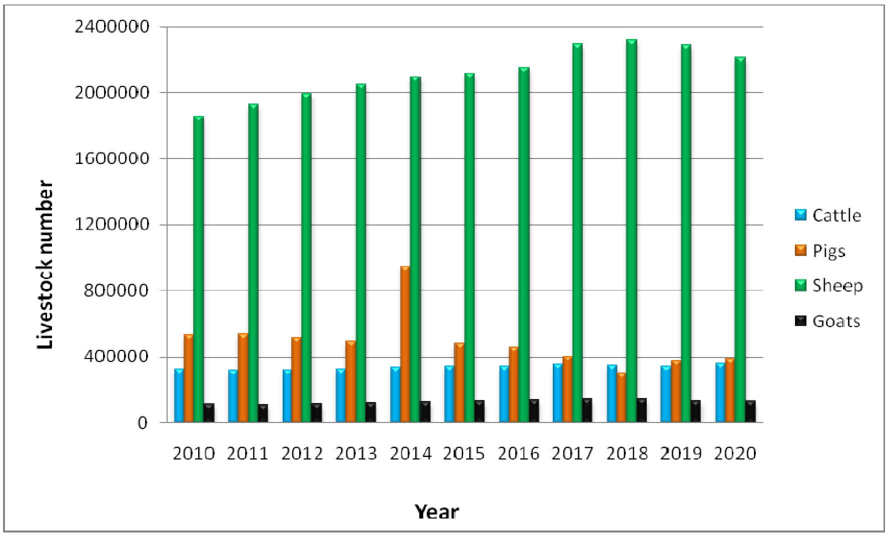

Fig. 7. *Livestock dynamics in the studied area*

In the researched region, sheep and pig farming is placed at the top of the preferences (Figure 7). The maximum number of sheep in 2010-2020 was 2,316,081,and that of pigs was 947,587.

The other two analyzed species were cattle and goats, and in the studied period, at least 300,000 cattle and 100,000 goats were farmed.

3.3. Bear Mortality situation

Cubs, juveniles, youth, or adults, were captured or accidentally killed. In 2017, no accidental catches were registered and the number of bears found dead was 18. In 2018, three bears were captured and released, and the number of bears found dead was 35 (Figure 8).

And in the following period, there were still cases of both captured/released and killed bears. In 2021, the National Register of Catches and Accidental killings reported 17 cases of the first category and 74 cases of the category of bears found dead.

Many of the reported cases involved bears caught in snares and in the case of deceased individuals, these events were consequences of car or railway accidents, as a result of their poisoning or from unknown causes [17].

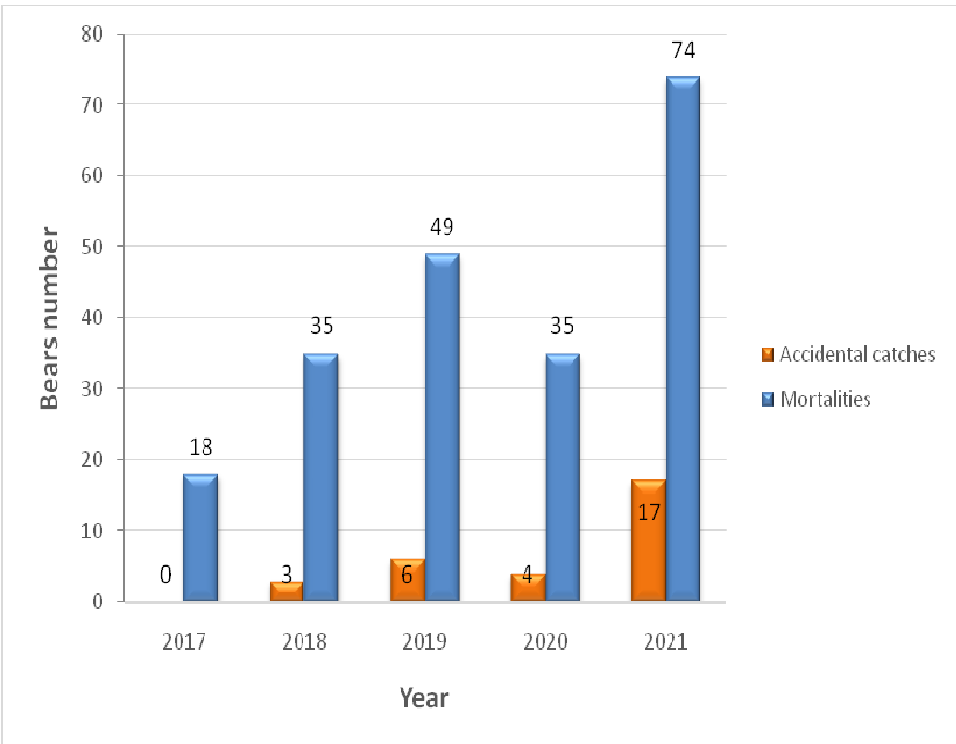

Fig. 8. *Status of catches and accidental kills of the brown bear in the studied area*

4.Discussion

4.1. Dynamics of Hunting and Bear Regulations

Through the normative acts issued from the 20th century until now, it has been regulated that the right to hunt belongs to the Romanian State and this right can only be exercised on the hunting areas established for this purpose. Game was considered of national and international interest.

We also understand from the results obtained that the adoption of normative acts from the 20th century was aimed at protecting game, as well as at sustainable management in order to maintain the ecological balance, but especially for the economic and social development of the country.

In the legislative study period, bears were considered a predatory species that caused damage to game, crops or livestock. In the second part of the 20th century bears received a certain degree of protection and became subject to sustainable management. However, from the national and international regulations issued in the 21st century, it is clear that the goal is no longer the same as in the past and that the brown bear has advanced from the position of a destructive species to the status of a strictly protected fauna with priority conservation status in its natural range.

In other words, the ministry has not approved derogations/maximum intervention numbers for this species since 2015. Starting this year, the Romanian State has had a reactive position, approving individual derogations or level of intervention (and less prevention) in repeated cases of attacks on animals, property or people. In addition, the administration of complementary food for this species is no longer allowed.

4.2. Evolution of Human-Brown Bear Conflicts

As shown in section 4.1, the damages caused by the brown bear has existed since ancient times, and the results obtained highlight the fact that bears also caused damage during the period under investigation. Most of the damage to agricultural property occurred during the period when bear harvest was strictly prohibited and hunting could only be done under derogations. What is noticeable is the fact that in this period, compared to the period in which harvest quotas or intervention level were approved, the amount of damage is significantly higher.

For the material damage suffered by the affected population, the Romanian State grants compensations, but the victims must follow a series of steps. If the damaged persons do not meet the criteria for granting compensation established by [7], some of them are unable to compensate their damaged goods, and as a result they are deprived of their source of food or income.

Considering the data on cultivated areas, we can say that their evolution is notable in some counties, but because the variations are small from year to year, this denotes the fact that in the six counties land cultivation was practiced throughout the analyzed period constantly. Also, the number of livestock presented in the graphic representation, suffered small fluctuations from year to year, but their breeding was practiced continuously in the region under investigation, in a considerable number.

There is a high correlation between the dynamic of bear population and the number of conflicts in the study area after the prohibition of hunting.

Following the number of attacks on people, which resulted in the injury or death of some people, we deduce that they also existed during the entire period under investigation, but we have to notice the fact that they also manifested themselves in a much higher number between the years 2017-2022. Many of the attacks are closely related to the agricultural activities of the people in the study area, as a result of people's desperate attempt to defend their properties.

Most conflicts were registered in the counties with the highest bear densities, such as Brașov, Harghita, Mureș, Covasna. The cause of the conflicts is the presence of bears in large numbers, as a repercussion of their management change over the last seven years [24].

4.3. Mortality Dynamics of Brown Bears

In the five years for which the statistical data on the catches and killings of bears were collected, numerous events resulted in the catches or killing of bears. The causes of the events are most often the product of a combination of anthropogenic factors, with bear population densities and its ecology and ethology.

Referring to the number of conflicts analyzed, we conclude that the mortality dynamics of the bears increase almost similarly to the number of bear-human conflicts, and this denotes the fact that there is a close connection between the two analyzed situations.

5. Conclusions

In the last century, the “thoughtful management of the species of hunting interest was wanted, for the development of the economy and raising the degree of spiritual and material satisfaction of the people”, and for this, decisions were made that came to support the idea. Currently, the phrases "rational management of game" and "raising the level of spiritual living" are no longer reflected in the current stage of events, in which the main leading “actor” is the brown bear.

Legislation from the 19^{th} and 20^{th} centuries attested to the existence of damage to crops or livestock, but none mentioned the prevention of attacks on people, as mentioned in the ministerial orders on the approval of derogations for brown bears issued during 2007 – 2015, or in the Government Emergency Ordinance No. 81/2021 [23]. The lack of such regulations in past centuries was motivated by the lack of such events, or at least by their existence, but at a different level than today, correlated with bear distribution and density.

Maintaining optimal bear numbers is no longer possible under the given conditions and the population balance may be affected by people's revulsion towards the species due to the many conflicts in which both entities have been involved.

Considering the evolution of brown bear hunting regulations, as well as the dynamics of existing conflicts between this species and humans, it is possible to have an increase of the conflicts with negative effects in bear population, the economic sectors, and social acceptance in the future.

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USING ICESAT-2 SATELLITE DATA FOR THE RETRIEVAL OF FOREST CANOPY HEIGHTS IN LATORIȚEI MOUNTAINS, ROMANIA

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Abstract: *The overall purpose of this study was to assess the potential of ICESAT-2 satellite LiDAR data for evaluating canopy heights in forested environments. For this goal,, two ICESat-2 products (ATL03 and ATL08) were taken into consideration for the evaluationof changes in canopy heights for a forested area represented by the boundary of Latoriței Mountains, part of the Carpathians, located in the central part of Romania. One potential issue identified and presented in the study is that the extraction of raw, individual photon data from ICESat-2 data products involves complex processing steps that require significant resources of Random Acces Memoryand CPUpower. Additionally, gaps in the data collection are found to be a common occurrence and no predictable timeframe of data collection over the same area is possible, which limits the applicability for monitoring of vegetation height changes. However, ICESat-2 canopy height data is available at a global scale, with a revisiting timescale of 91 days adequate for monitoring purposes and a high accuracy of ground and canopy height estimations, as reported in recent studies. When the atmospheric conditions are such that data collection is not hindered, a highly detailed profile of terrain/canopy height variation can be generated from the individual point observations.*

Key words: *Laser altimeter, vegetation height, satellite LiDAR.*

1. Introduction

In the last couple of decades, LiDAR (Light Detection and Ranging) has seen a rapid increase as a tool to measure forest biophysical characteristics [23, 32], both in terms of algorithm development [24, 39, 44] and industry use [1]. A LiDAR scanner emits laser pulses at a very high frequency, which are reflected by the target surface back towards the sensor where the ToF (Time-of-Flight) is recorded [36]. Thus, the distance (or range) from the sensor to the surface is determined, which together with other elements (the roll, pitch and yaw of the sensor platform and its position) [40] is used to determine the x-y-z coordinates of the point where the reflection of the laser pulse took place [3]. Thus, a data structure comprised of

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millions of randomly distributed, geo-located point observations [41], commonly called point cloud, is generated.

Historically, in the early stages of development, LiDAR scanning was predominantly done from airborne platforms, a technique which is commonly called ALS (Airborne Laser Scanning) [4, 7, 18]. During the 1990s and 2000s, NASA started developing satellite-based LiDAR sensors, the first of which was used from 1997 to 2001 to carry out the mapping of Mars' surface at an unprecedented level of detail [34]. Subsequent sensors were used to map the surfaces of Mercury [9] or the Moon [37].

In January 2003, NASA launched the ICESat (Ice, Cloud and land Elevation Satellite), a pioneering satellite platform equipped with a laser scanning sensor called GLAS (Geoscience Laser Altimeter) [38] mainly focused on the precise measurement of height changes of polar ice caps [45]. However, the 15 science data products generated from GLAS-collected data have seen numerous interdisciplinary applications, including forestry [35] as one of the products offers vegetation canopy height measurements [11, 17]. GLAS collected data until the program was discountinued in 2009.

ICESat was followed by ICESat-2, which was launched in September 2018 and is still in operation. The new platform not only offers better overall accuracy, but also better coverage as the laser pulses are split into six beams by a refractive optical element [22]. In just four years of data collection, ICESat-2 data has already become an established source for forest structure data for researchers [21, 25-28].

It should be noted that terrain and canopy parameters derived from ICESat-2 data are offered by the data provider at a step-size of 100m (referred to as segments). This is done to ensure that sufficient photon observations are present [20], so that a high degree of statistical reliability of height estimations is maintained. Although individual photon values are also available, this format of data aggregated over 100m segments is the most commonly used and user-friendly. In terms of accuracy estimation, [28] report an overall RMSE of 0.85 meters for terrain height and 3.2 meters for canopy height, Liu et al. [20] report RMSE values for canopy height estimation between 3.5-3.9 meters in ideal conditions (during nighttime data collection and using only strong beam data), while Xing et. al [43] reported an overall RMSE of 0.75 meters for terrain height estimation using ICESat-2 data.

Forest ecosystems have a significant role in regulation of the global climate [19] and the carbon budget [6]. The height of the forest canopy, which is to be understood as the mean relative height above ground of the top layer of a forest's canopy [25], is a very important variable involved in the estimation of aboveground biomass –AGB – [10] and carbon stock [12]. Therefore, both the estimation and tracking over time of canopy heights plays an important part in the sustainable management of forested areas, the monitoring of overall ecosystem health [13], even moreso when considering the present and future challenges of climate change [27].

For the specific case of Romania, it is worth mentioning that the country is home to some of the largest areas of primary forests worldwide [16]. Many of these forest ecosystems are located in rugged, mountainous terrain which, coupled with the relatively poor density of access roads, makes a case for the use of remote sensing data for the assesment of stand characteristics [2]. Taking the above into account, this study aims to answer the following question: how feasible is the extraction ofindividual photon observations from ICESat-2 data products in order to profile canopy height changes at a much finer scale than the conventional one consisting of 1 observation (obtained by aggregation) per 100 meters ? To answer this question a software program that extracts photon data and exports it into common geospatial data formats was developed and a study area was chosen as a test case.

2. Material and Methods

2.1. Study Area

A mountainous landform called "Latoriței Mountains", located in Vâlcea county of Romania, was selected for this study. This mountain range is part of the Carpathians and is located in the central area of the country (Figure 1) covering about 420 square km, it has a relatively high percentage of dense forest cover. In terms of forest compositionthe predominant species is spruce (*Picea abies* Karts.), with pine (*Pinus* spp.) stands present to a lesser degree [8].

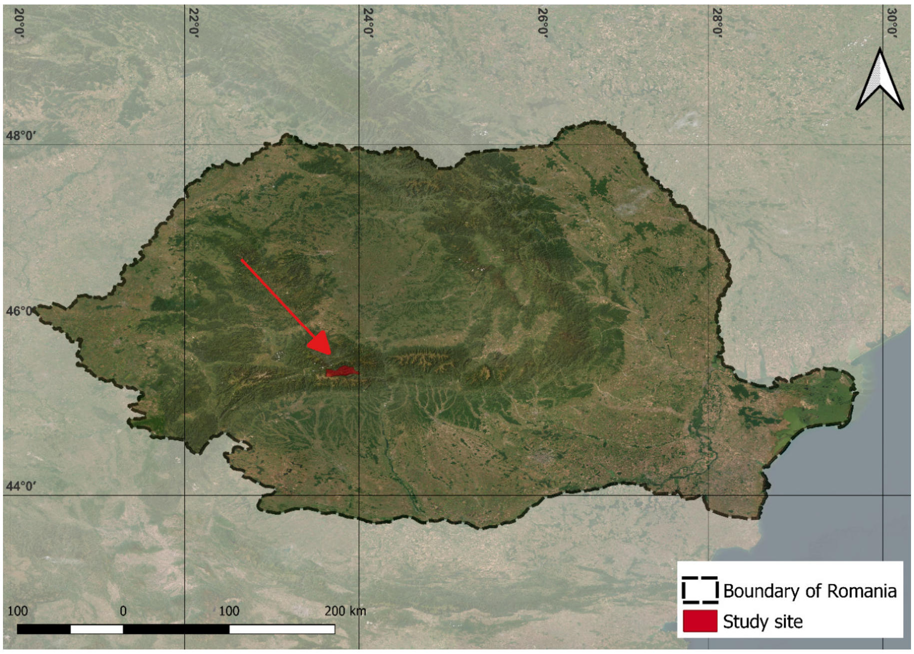

Fig. 1. *General location of the study area*

2.2. The ICESat-2 Satellite Program

The Ice, Cloud and land Elevation Satellite-2 (ICESat-2) is a NASA-coordinated satellite mission which uses a photon-counting altimeter to take measurements of the Earth's surface at an unprecedented spatial and temporal scale. The nominal spatial scale of one pulse every 0.7 m along the ground track direction is assured by the very frequency of emitted laser pulses, which is around 10 kHz. Meanwhile the timeframe for orbit revisitation is 91 days. Although the main focus of the program is cryosphere monitoring, given the near-global coverage of the satellite orbits, data provided by ICESat-2 has been successfully used for the detection of forest canopy and its characteristics, mainly height and density.

The sensor installed on-board the ICESat-2 platform is called ATLAS (Advanced Topographic Laser Altimeter), which is a photon-counting LiDAR instrument collecting data over six ground tracks (GT 1-3, each with a Left/Right component) [22]. The distance between the left-right components of the same ground track is about 14 meters, while the distance between the adjacent tracks is about 3100 meters [28]. Data collection is carried out at a temporal resolution of 91 days [19]. ATLAS data resulting from an orbit around the Earth is organized into multiple numbered products, called granules. For this study, two granules are of particular interest:

1. ATL03 (also known as Global Geolocated Photon Data), which contains positioning data (latitude, longitude and height above the WGS84 ellipsoid) and timestamps for all photons downlinked by the ATLAS laser altimeter on board the ICESat-2 platform [31]; in other words, ATL03 contains all the raw photon data, with minimal post-processing, which is used as a basis for the creation of the other, higher-level products;
2. ATL08 (also knowns as Land and Vegetation Height) is a higher-level product which contains height values for both canopy and ground observations [29].

The ATL08 product is mainly intended to provide aggregated canopy and ground data. As previously mentioned, this aggregation is done by dividing the along-ground track direction of the sensor into 100-meter segments, with valid (non-noise) photons in each segment being used for the calculation of segment-wide average values of height. However, individual photon heights are also provided. This is fortunate, as the nominal spacing of the system is 0.7 meters, which makes data suitable for lower-scale studies, much more so than aggregated values over 100 meters.

Some of the variables associated with individual photons and provided in ATL08 datasets, which are of particular interest to this study, are [30]:

- ph_h: the relative (above-ground) photon height;
- ph_segment_id: the ID for the segment of which the photon is part of and classed_pc_indx: positioning index of the photon inside its segment; these can be used in tandem to link the photon with unaggregated photon data from ATL03;
- classed_pc_flag: a numerical value labelling the photon as: noise, ground, canopy and top_of_canopy; this is very useful for the removal of non-valid observations (noise) and for separating observations recorded at the top of the canopy (used for Canopy Height Modelling) from observations recorded inside the canopy structure.

All ATLAS/ICESat-2 data is provided using the HDF5 (Hierarchical Data Format), which is a file format designed for fast and efficient storage and processing of large datasets.

2.3. Satellite Data Used for This Study

ICESat-2 LiDAR data is freely available on several online repositories, such as NASA's EarthData Search platform [15]. Using a boundary of the Latoriței Mountains for spatial subsetting, a number of 149 granules were identified as overlapping the study area. It is worth noting that, while the EarthData platform offers spatial subsetting for the selection of datasets crossing an area of interest, no subsetting of the data itself is carried out on the server side. In other words, users must download the entire dataset and then apply subsetting themselves, in order to remove observations falling outside the region of interest.

Out of the 149 datasets crossing over the study area, a part of the oldest ones (nine datasets, ranging from November 2018 to April 2019) and a part of the newest ones (also nine sets, ranging from October 2021 to March 2022 – Table 1) were selected for analysis.

2.4. Software Design

Since ATL08 datasets do not include positioning data (latitude and longitude) for individual photons, a script was developed in order to identify eligible photons. In this context, an eligible photon is one that can be safely identified in both ATL03 (where location data is present) and ATL08 (where canopy and ground height data is provided by the data publisher). Another condition is that the photon should not be labelled as noise by the data provider. The script was developed in the R programming language [33] and makes use of the rhdf5 [14] library for accessing data stored in the HDF5 format and the rgdal [5] and dplyr [42] libraries for various spatial analysis operations. The algorithm receives as input a pair of corresponding ATL03/ATL08 datasets and iterates over each of the six tracks included in the files, carrying out the following operations (Figure 2):

1. ATL03/ATL08 data is imported and spatial subsetting of ATL03 photons is carried out using a user-provided boundary in shapefile format; after this step, all photon observations located outside the latitude/longitude of the boundary are discarded;
2. Each non-noise ATL08 photon is searched for in ATL03, by using the photon index inside its segment and the total number of photons in previous segments as a substitute for a general, dataset-wide photon index (which is not included in ATL08, but is present in ATL03 data); note that since ATL08 does not contain photon location data, no spatial subsetting can be carried out so all photons must be analyzed;
3. Location and canopy/ground height data for all eligible photons is stored in a dataframe;
4. Observations are exported in commonly-used formats, such as .Rda for statistical analysis or .shp for spatial analysis.

It must be mentioned that the validation of point labelling and canopy height estimations carried out by the provider of ICESat-2 data products is beyond the scope of the present research. For in-depth technical details about the methods used for the identification of canopy photons and subsequent canopy height estimations, the reader is referred to the'Data Product Algorithm Theoretical

Basis Document' for ATL08, available on the National Snow and Ice Data Center's website.

ICESat-2 datasets taken into consideration for this study Table 1

Granule ID	Acquisition date	Ground track orientation	Study area covered by satellite ground track
20181101125453_05180102_005_01	1st of Nov 2018	NW-SE	Partial
20181104010228_05560106_005_01	4thof Nov 2018	NE-SW	Partial
20181130113049_09600102_005_01	30thof Nov 2018	NW-SE	Full
20181206233001_10590106_005_01	6thof Dec 2018	NE-SW	Partial
20190104220609_01140206_005_01	4th of Jan 2019	NE-SW	Full
20190131083450_05180202_005_01	31st of Jan 2019	NW-SE	Full
20190301071051_09600202_005_01	1st of March 2019	NW-SE	Full
20190330054649_00150302_005_01	30th of March 2019	NW-SE	Partial
20190405174601_01140306_005_01	5th of April 2019	NE-SW	Full
20211026085246_05181302_005_01	26th of Oct 2021	NW-SE	Partial
20211028210017_05561306_005_01	28th of Oct 2021	NE-SW	Partial
20211124072853_09601302_005_01	24th of Nov 2021	NW-SE	Full
20211130192801_10591306_005_01	30th of Nov 2021	NE-SW	Partial
20211229180403_01141406_005_01	29th of Dec 2021	NE-SW	Full
20220125043238_05181402_005_01	25th of Jan 2022	NW-SE	Partial
20220223030842_09601402_005_01	23rd of Feb 2022	NE-SW	Full
20220301150752_10591406_005_01	1st of March 2022	NW-SE	Partial
20220330134357_01141506_005_01	30th of March 2022	NE-SW	Full

3. Results

As previously discussed, a total of 18 datasets having an overlap with the study area were initially selected for analysis. Subsequently, part of these were discarded as having an insignificant amount of overlap with the test site. Therefore, the final number of ATL03-ATL08 datasets included in the analysis is four: two older datasets (end of 2018) and two newer datasets from 2021-22. For clarity, the involved ground tracks of these granules have been labelled from A to E (for the 2018 datasets) and from F to K for the 2021-22 datasets. Note that for the simplification of presentation, the Left-Right components of the same ground track have not been analyzed separately.

The spatial coverage between observations in these files and the study area is presented in Figure 3. These datasets comprise approx. 305,000 canopy observations (including both top_of_canopy and inside_canopy reflections) and approx. 163,000 ground observations. Additional statistics per track are presented in Table 2.

An example of an along-track profile showing the variation of both altitude and canopy height is presented in Figure 4, for a pair of Left-Right components of a track recorded in October 2021. For better visualization of the variance in height values over short distances, Figure 5 presents a small part of this same profile for 200 consecutive observations covering about 2.6 kilometers.

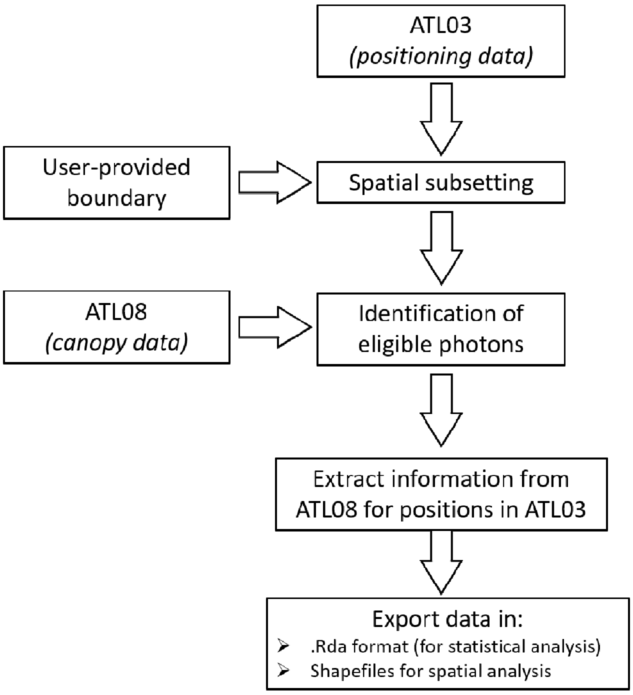

Fig. 2. *Flowchart of software design*

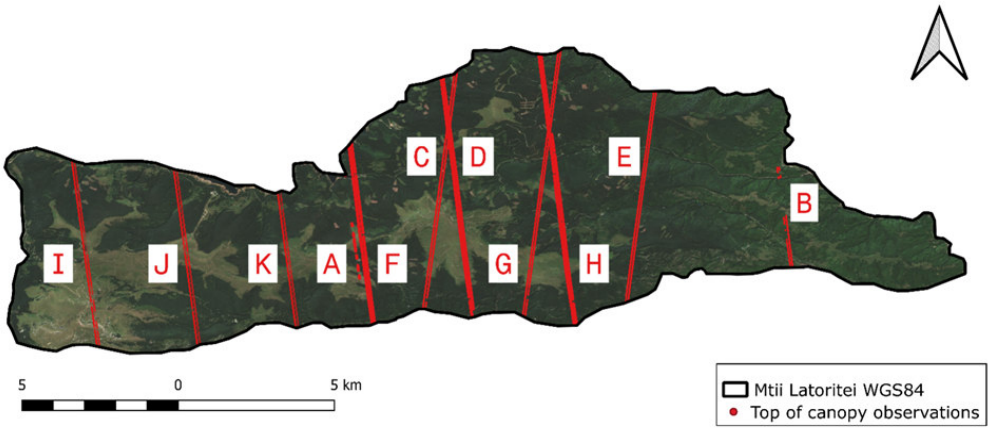

Fig. 3. *Map of study area with coverage of ATLAS-collected top_of_canopy observations. Background imagery: Sentinel-2 data*

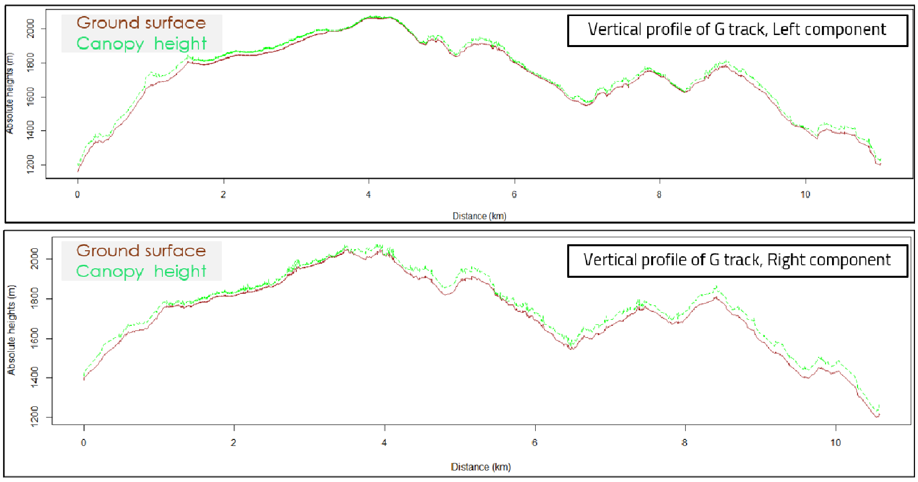

Fig. 4. *Vertical profiles showing ground altitude and canopy height changes over approx. 10 km*

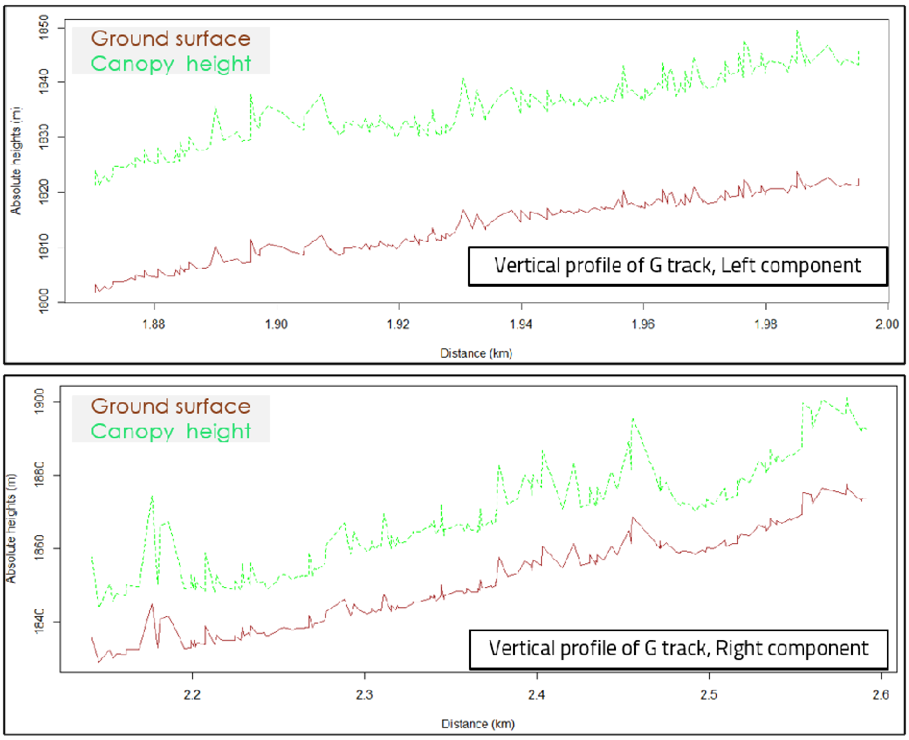

Fig. 5. *A subsection of the profiles presented in Fig. 4, containing only 200 pulse returns each and covering 2 and 2.6 km, respectively*

Statistics for the six ICESAT-2 granules analyzed (totaling 11 eligible ground tracks) Table 2

Granule ID	No. of points	% of ground points	% of canopy points	% of inside canopy points	% of top of canopy points	Vegetation height statistics (calculated from top_of_canopy observations)					
						Min	Q_1	Median	Q_3	Max	St.dev.
2018											
A	828	12.0	88.0	87.0	13.0	3.86	11.56	21.46	43.63	83.46	21.36
B	5379	17.1	82.9	60.7	39.3	1.18	3.56	5.01	7.42	106.84	7.68
C	65519	50.8	49.2	85.0	15.0	1.89	2.60	3.84	11.78	86.16	10.41
D	42136	56.8	43.2	84.0	16.0	1.88	3.46	17.72	24.22	69.40	11.79
E	24064	26.3	73.7	87.3	12.7	0.51	6.10	17.42	26.95	82.41	12.52
2021-22											
F	19315	15.1	84.9	73.0	27.0	1.98	8.81	17.50	25.25	91.85	11.29
G	21574	5.4	94.6	59.6	40.4	2.00	9.55	20.49	24.41	76.77	10.02
H	21558	6.5	93.5	69.9	30.1	1.52	10.38	18.69	24.54	104.17	11.30
I	117526	43.7	56.3	77.8	22.2	1.81	2.74	3.77	5.80	42.55	7.74
J	75565	30.6	69.4	83.5	16.5	1.86	5.62	16.31	20.44	44.42	9.00
K	69912	27.0	73.0	83.4	16.6	1.85	3.18	15.17	22.35	42.22	10.58

4. Discussion

As can be seen with tracks A and B in Figure 3, in some cases there are significant gaps in data collection, likely due to cloud cover hindering the propagation of laser pulses through the atmosphere. For this same reason, most of the granules that initially show an overlap with the study area do not actually have any eligible photons identified.

It is worth noting that small gaps in data collection are frequent and have various causes (for example during satellite maneuvers or when the laser is shutdown in order to avoid illuminating other spaceborne sensors nearby). Overall these gaps amount to less than 1% of data collection time [22], therefore they are not the most likely explanation.

A few issues are highlighted by analyzing the results presented in Table 2. First, even if the nominal spacing of the granules is the same, there are relatively high differences of point density between ground tracks. For example, both tracks E and J cross over the entire study area, with a length of about 10 km and 8.5 km, respectively. However, track J has an average spacing of 1 point per 7.2 cm (very close to the nominal spacing), while track E has a significantly reduced number of observations leading an average spacing of just 1 point per 41 cm. Therefore, even if cloud cover is not an issue (since neither of these tracks has significant gaps in data collection, as per Figure 3), other factors (possibly relating to atmospheric conditions) can hinder the amount of laser pulses which are recorded. Atmospheric conditions can attenuate the intensity of the laser pulses so that returned signal photons are indistinguishable from background noise [30].

It is worth noting that Liu et. al [20] find in their analysis of over 32,000 ICESat-2 segments that only 64% of them have valid canopy height measurements. However, this issue is not looked into further by the authors.

In terms of the relative proportions for top_of_canopy/inside_canopy observations, we find a relatively consistent split for most tracks of 15-20 percent for top of canopy returns and 80-85 percent of returns located inside the forest canopy. This implies that ICESat-2 data is not particularly suited for canopy height detection and modelling (where only top_of_canopy returns matter), but is appropriate for modelling the vertical structure of forest environments (where the high penetration of laser pulses into the canopy is an advantage).

The maximum values of vegetation height for almost all tracks are unrealistically high (going as far up as 80-100 meters). This indicates that there is still an amount of noise left, even after the denoising algorithms applied by the data provider. However, these outliers are very rare and can be easily identified and removed using established statistical methods. Meanwhile, standard deviations in canopy height values for top_of_canopy observations are relatively consistent, ranging from approx. 8 to 11 meters. The only exception is track A, which has a standard deviation of 21.36 meters, but this track has a very low number of 95 top_of_canopy points.

Finally, as Figure 5 presenting a portion of a profile generated on the along-track direction shows, scarcer point densities lead to a jagged appearance of both the ground and canopy profile. Therefore, additional smoothing of ground/vegetation height values is desired for more polished end products.

5. Conclusions

The aim of this paper was to establish the viability of using individual photon ICESat-2 Land and Vegetation Height data for the estimation of forest canopy height.While ICESat-2 offers many advantages with ICESat-1 and has an unprecedented nominal resolution and accuracy at a near-global coverage, some issues were still identified. Many of the analyzed datasets have a significant number of observations in ATL03 granules missing from corresponding ATL08 granules. In other words, these observations are recorded but then are removed by the denoising filters applied by the data provider. As an extreme example, one of the datasets initially selected for this study had over 600 thousand ATL03 observation located inside the study area, none of which made it into the corresponding ATL08 file.

On the other hand, the lack of a unique photon ID linking observations across granules of the same fly-over make the process of extracting photon-level, geolocated vegetation heights very computing-intensive. This is compounded by the lack of spatial subsetting carried out on the server-side, which means entire fly-overs need to be analyzed instead of only the observations found inside the user’s area of interest.

Since gaps in the datasets are a common occurrence, no predictable timeframe of data collection over the exact same forested area can be established, even if the provider ensures a 91-day timeframe for revisiting the same orbit (Magruder et. al 2021). Therefore, LiDAR data provided by the ATLAS sensor on-board the ICESat-2 platform is not particularly suited for continuous monitoring of canopy height changes. However, it could be a viable source of data for long-term tracking of variations in canopy height, as long as the satellite program has a longer lifespan than its predecessor.

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DETECTION OF LAND COVER / LAND USE CHANGES IN A SEMI-MOUNTAINOUS FOREST SUBURBAN AREA

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Abstract: *Changes in land use and land cover date back to prehistoric times and are the direct and indirect consequence of human actions to secure the necessary livelihood resources. The use of land and natural resources in the past, as an expression of the natural environment, was based solely on the highest economic gain without taking into account the effects on the natural environment. The spatial planning of the development of the semi-mountainous areas, presupposes the inter-temporal control of the land uses in the four main axes of development, namely agricultural, livestock (meadow), residential and forest use. The purpose of this study is to monitor and record the inter-temporal evolution of land cover / land use changes in a semi-mountainous suburban area, in order to identify and determine the size and causes of forest land use changes. The problem of recording land uses of older years is solved only with the use of photogrammetry and old aerial photographs. Thus, in the framework of this paper, maps of land use of past years and modern years were compared, with the help of aerial photographs and a digital photogrammetric instrument, in the suburban area of Lagyna Lagada in the Prefecture of Thessaloniki. From the comparison of the maps, conclusions about the prevailing land use and the shaped land use trends were drawn.*

Key words: *sustainability, viable development, forest maps, land use maps, monitoring, recording.*

1. Introduction

Changes in land use and land cover date back to prehistoric times and are the direct and indirect consequence of human actions to secure the necessary livelihood resources.

With the discovery of fire, the invention of the possibility of cultivating plants, the creation of the first settlements and the

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development of the first tools, man acquired the ability to intentionally affect large extents of the earth, with drastic and intensive effects on the biological and ecological balance of different ecosystems of the environment.

The use of land and natural resources in the past, as an expression of the natural environment, was based solely on the highest economic gain without taking into account the effects on the natural environment.

The use of land, through time, has gone through various stages, so its current form is a consequence of historical, social, economic, and cultural developments. Thus, man first used the land for hunting, then for cultivation, later the industrial use of the land was added, along with various other uses (settlements, roads, etc.), depending on the social, economic, and cultural level of each country. This land use depends on the degree of satisfaction of human needs, the quality of the soil, and the ability to access it [12].

The earth has been the basis of most human activities since antiquity. Human intervention shapes its use and often changes its cover (natural meadows, forests, wetlands, rivers, lakes, and other hydrographic features, barren and rocky areas, deserts, etc.) [32].

Larger land cover changes have resulted in past transformations of forests and meadows into arable lands and pastures. Arable lands and pastures have increased in the last 300 years by 460 and 560%, respectively [20]. Satellite information for the compilation of global and regional land cover and land cover changes can be used [33].

According to Meyer [28], land cover in geography is defined as the natural state of the soil as well as agricultural lands, forests, mountains - and also includes some artificial constructions, such as houses and roads.

The two terms “land use” and “land cover” are often used in the same sense. It is possible to derive land use from land cover and vice versa, but the connection is not always so obvious. In contrast to land cover, land use is difficult to “observe”. For example, it is often difficult to decide whether or not pastures are used or not for agricultural purposes. The distinctions between land cover and land use and the interpretation of their concepts influence the development of classification systems, data collection and information systems [17]. The combined term land cover / use were redefined in the following years by several researchers [1, 4, 18, 29, 30, 37], and is considered more complete and flexible.

Change detection is used to determine differences in the appearance of an object or phenomenon when observing successive images from different time periods [25, 35]. A systematic description of the environment for the detection of environmental changes, as well as the factors that caused them, is necessary in studies concerning changes in land cover and land uses. By sharing land cover and land use data, the place where the change took place, the type of change, and the way in which this change took place can be detected [21].

Accurate and up-to-date information on land cover changes is essential in understanding and assessing the environmental consequences of these changes [19, 34]. The temporal and spatial changes in a specific area can provide future trends and can be evaluated accordingly.

The information on these changes can be an indicator of the increase in the population, of water consumption, waste production, hospital facilities, schools, expansion of the road network, etc. Determining land uses and their changes in an area requires knowledge of land cover types [5].

Many studies have discussed the issue of land cover changes and land uses in barren, semi-arid, and agricultural productive areas. Changes in land uses primarily threaten forest ecosystems. They mainly concern the expansion of economic activities in the natural space, but also the change of the form of vegetation. Expansion of agricultural land, pressures from tourism and the unregulated building activity, often result in the location of the burned forest "mushrooming" cement.

A constant monitoring of forests and changes in land uses is necessary, but also to make this information widely known. Taking legal and political action in order to address any illegality is also required.

The most important effect of land use since 1750 has been the deforestation of temperate regions. More recent consequences of land use are urbanization, soil erosion and degradation, and desertification. It is characteristic that the way of land use is not decided mainly by those who can use it more efficiently, but by an administrative process that, many times, excludes certain users of the land, in the name of public interest [27].

Assessing land use change helps make decisions about integrated land management and achieving its sustainable development. The exploitation of natural resources must be rational, and the management of the natural environment must be based on the principles of sustainability. Sustainability is now a primary goal of ecosystem management worldwide and these results in the need for a continuous and accurate up-to-date data source [6]. The timely and accurate detection of changes of various features on the Earth's surface is extremely important for understanding the relationships and interactions between human and natural phenomena in order to better manage and use of natural resources [26].

Land management refers to the procedures required to prepare and monitor the implementation of plans for the organization of human activities on land [17]. Apart from its value as a natural good and an area for the development of fauna and flora, land is an object with an economic dimension, which, based on a legal framework, is subject to property and use rights. These rights are subject to purchase, sale, and taxation procedures and thus form the basis of the national economy in free market countries. Land rights are therefore equally important and in fact they comprise an integral part of it, just like its physical features and constructions that exist on its surface [8]. The modern management and storage of the above information presupposes the existence of a cadastral system (or as it is often referred to in the international literature: A Land Administration System), which provides the necessary data quickly and reliably.

Land management needs reliable information about its current status and its resources, as well as its legal status [38]. Cadaster provides the files for this information and is the core of a land management system. It is a form of land registration system which is supported by a cartographic infrastructure. Cadaster occupies all the countries in the world as an institution of economic and fiscal policy. The economic development of a country is based on spatial planning, the distribution of land uses, and the investigation of the possibilities of development and the exploitation of its natural resources [9]. In particular, Forest Cadaster is a tool for the protection of forest areas, the necessary background and the most effective means for drawing up and exercising the State's Forest Policy in the forest area [9]. Cadastral systems are the modern form of the cadastral institution. Their implementation began in the middle of the 19th century [10].

The research at that time resulted in the publication of numerous scientific articles and studies and the writing, by a United Nations Committee (UN / ECE Working Party on Land Administration), of an issue of guidelines for good land management with the general conclusions of the researches. According to the above, the formed opinion is that, despite the innumerable existing differences among the cadastral systems, the basic information managed by most development cadastral systems in the free economy is: a) property status and other rights, b) land use, and c) value of land, uniquely linked to the unit area of land which is the property [36].

Depending on the applicable legislation at any given time, the areas defined as forest and forest area are changing, resulting in different forest maps being created. This is also true at the international level, where the definitions of forest and forest areas differ, a fact that brings about changes in the total percentage of forests and forest areas that are finally mapped [39].

Therefore, from all the above, it is considered imperative to identify and detect changes in land cover / use and their clear delimitation, with land use maps, with the ultimate goal of rational programming - planning to take administrative and organizational measures to consolidate activities by a coordinating body, so as to find the golden section of uses for the development of the countryside. This process of delimitation and classification will lead inevitably to the development of forests and reserves as categories of both nature and state power.

The purpose of this study is to monitor and record the inter-temporal evolution of land cover / land use changes in a semi-mountainous suburban area, in order to identify and determine the size and causes of forest land use changes.

2. Material and Methods

2.1. Study Area

The forest property of Lagyna, with an area of 600 ha, is located southwest of the homonymous semi-mountainous town of the prefecture of Thessaloniki (altitude from 130 m to 280 m) which was owned by Law 2074/1920 [22] and according to No. 9583 / 14-03-1996 decision of recognition of the Multi-Member Court of First Instance of Thessaloniki and to No. 53/6400 / 31-12-1998 certificate of the Lagada mortgage office (Regional Operational Program (ROP) of Central Macedonia 2000-2006). It belongs to the municipality of Lagada and is 13 km away from Thessaloniki (Figures 1 and 2).

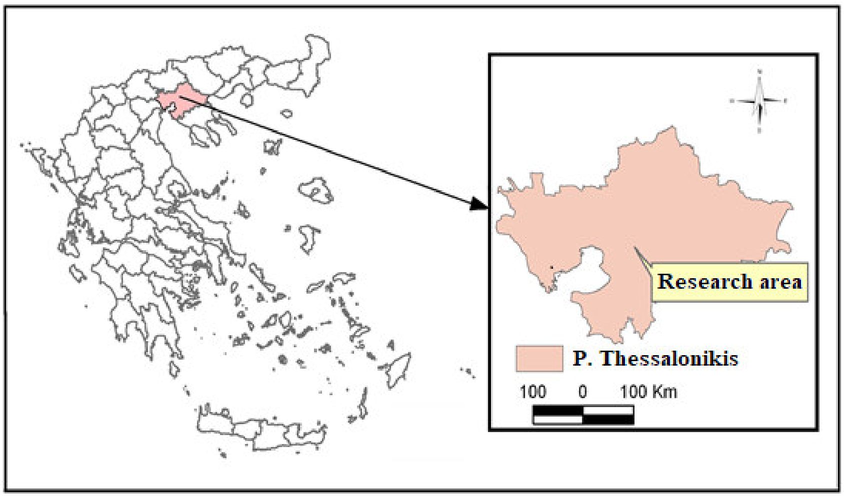

Fig. 1. *Orientation map of the research area*

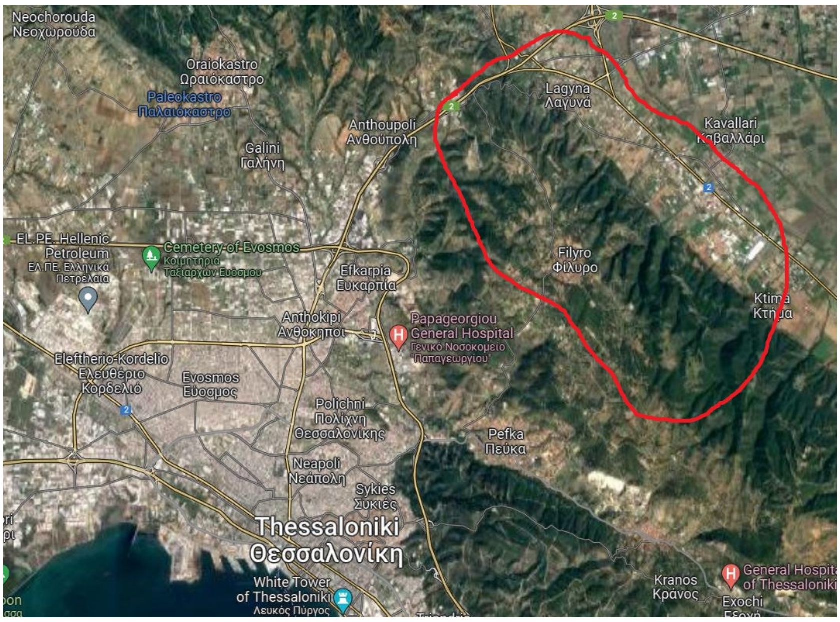

Fig. 2. *The location map of the study area (in red) shows the proximity to Thessaloniki*

Lagyna was a settlement and a fortress during antiquity, which, due to its position, was important for the wider area. The ancient settlement was probably in its current location, while the fort named "Pylon" was closer to Derveni. The word Lagyna comes from the word "Lagynas" and lagina, i.e., clay vessels.

The wider area to which the forest belongs together with the lakes (Koronia and Volvi), lakes - remnants of the old Mygdonia lake, is called the basin of Mygdonia. The area is a rare complex of ecosystems with lakes (Koronia and Volvi), rivers, riparian forests (lakeside forest of Apollonia, Rentina forest), reeds, wetlands, shrubs, and agricultural areas that form an important wetland and especially protected as "Aquatic Bird Habitats", according to the Ramsar International Convention (which Greece has ratified as a member, with LD (Legislative Decree) 191/20.11.74, Government Gazette 350a / 74 [24]), as well as to the Community Directive 79/409 [7].

The area is composed of strongly cracked crystalline background, which is tectonically part of the Serbo-Macedonian mass, with the exception of the western part of the basin (Lagada sub-basin), which is the boundary between the Serbo-Macedonian mass and the Axios zone.

The rocks of the forest are sedimentary of the section Melissochori - Holomonta (Triadic Middle Jurassic) with quartzite reddish-brown to fine-grained, fine-grained iron, and darker calcareous quartz sandstones with layers of sandstone with layers. Locally there are granite shales and darker strips of sandstone limestone. There are also tertiary deposits with steep slopes and rounded peaks, as well as clay shales. It has moderate ravine erosion and the slopes are small to moderate (15-20%), the relief is relatively gentle while the exposures vary (north, south, north and south, south and north).

The vegetation of the area belongs to the Mediterranean vegetation zone and especially to the growing area of deciduous oaks *Quercetalia pubescentis* (hilly semi-mountainous area) [2]. The 500 stremmata consist of an artificial pine forest (*Pinus brutia* Ten.) classified into the type of scrub pastures, evergreen species of the row of oaks (*Quercus coccifera* L.) and the type of grass pastures dominated by thermophilic grasses and gorcia individuals with a coverage of less than 10% (*Pyrus amygdaliformis* Vill., *Phillyrea latifolia* L., *Quercus pubescens* Wild., *Paliurus spina-christi* Mill., *Caprinus orientalis* Mill., *Fraxinus ornus* L., and *Cistus incanus* L.) [31].

2.2. Methodology

In the framework of this work, land uses of past and recent years were recorded and compared, with the help of aerial photographs and a digital photogrammetric instrument. According to article 27 of Law 2664/98 [23], the delimitation of forests and forest areas is done on the basis of the oldest and closest to the time of preparation of the forest aerial photography map. The oldest aerial photography is that of 1945 except for some areas of Attica, where there are aerial photographs of the years 1937 and 1938. These aerial photographs have a scale of 1: 45000, are of poor radiometric quality, and lack the calibration data of the cameras for a reliable photogrammetric performance. To create the temporary forest map of the area, the following steps were followed [3, 15, 16]:

a) The available aerial photographs were photo-interpreted (starting with the aerial photographs of 1945 and then the most recent ones);
b) Extensive ground autopsies were performed to check the results of the photo interpretation on the ground;
c) All the final administrative acts issued by the public services and characterizing certain specific plots of land (e.g., areas that have been declared reforestable, forest areas that have been granted for agricultural use, etc.) were taken into account and recorded, and finally

d) All available information for the recording of land uses was processed with the help of Geographic Information Systems (GIS) and the temporary forest map of the area was created, both in printed and digital form, At the same time, the corresponding databases in form of cadastral tables were created in which each piece of land was registered with the elements that characterize it (for example, the indicative code number and the land use that it belongs i.e., as forest area in 1945 aerial photographs and forest area today, land that was forest in 1945 aerial photographs and then changed its use today, the names of the owners if any, the value of the land, the legal status of the land, etc.)

From the moment the digital forest map was created for an area, a forest engineer can have at his disposal the best modern reliable representation tool (Digital Terrain Model - DTM) for this area to manage it (to organize its fire protection, to plan in space and time the individual interventions, etc.). lso, the creation of reliable DTMs can be done with a laser scanner and can contribute through the land registry to the increase of agricultural and forestry production, to the protection of the environment, to the sustainable development, etc. [11, 13, 14].

3. Results and Discussion

After the output and drawing the temporary cadastral map of the study area and comparing the land uses of 1945 with recent years, the following results were obtained (Figure 3):

- 0.26% of the total area, i.e., 1.56 ha, is the slope of the National Road Thessaloniki – Kavala;
- 0.21% of the total area, i.e., 1.26 ha, has been converted from agricultural land to residential land with its precinct;
- 4.56% of the total area, i.e., 27.36 ha, has been converted from agricultural to forest area;
- 3.20% of the total area, i.e., 19.20 ha, has been converted from forest area to grove;
- 1.38% of the total area, i.e., 8.28 ha, has been converted from forest area to rural area;
- 0.05% of the total area, i.e., 0.30 ha, has been converted from agricultural land to grove;
- 0.01% of the total area, i.e., 0.06 ha, has been converted from forest area to residential area with its enclosure;
- 0.01% of the total area, i.e., 0.06 ha, has been converted from agricultural land to COSMOTE (Telecommunications Company) facilities;
- 0.07% of the total area, i.e., 0.42 ha, has been converted from agricultural land to an orchard with its precincts;
- 0.02% of the total area, i.e., 0.12 ha, has been converted from forest area in a part of the enclosure of a residential area;
- 0.005% of the total area, i.e., 0.03 ha, has been converted from forest area to a fenced area with terraces;
- 0.07% of the total area, i.e., 0.42 ha, has been converted from forest area to livestock facility and agricultural area;
- 0.05% of the total area, i.e., 0.30 ha, has been converted from agricultural land to a livestock facility;
- 0.08% of the total area, i.e., 0.48 ha, has been converted from agricultural land to agricultural facilities (warehouses).

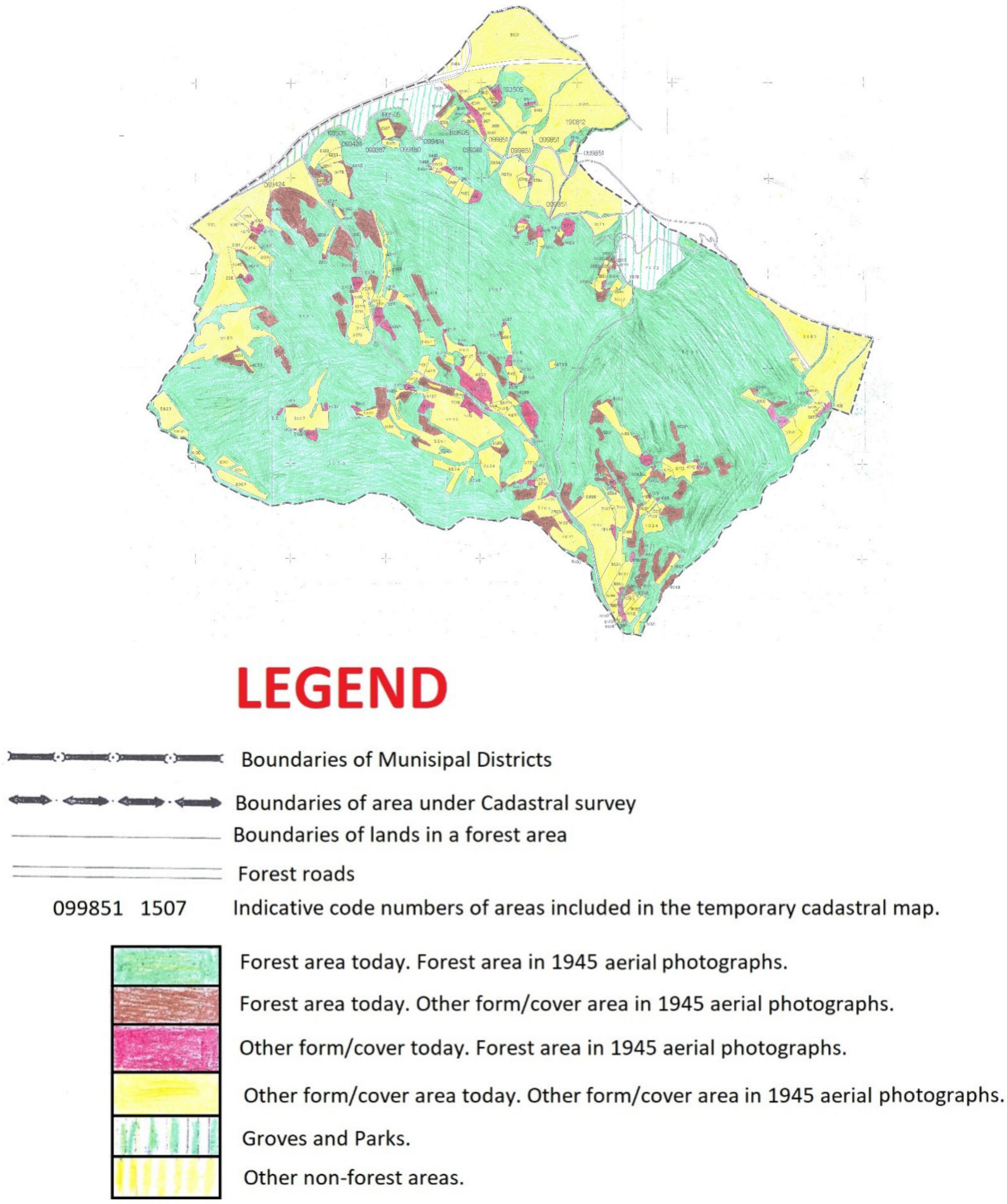

Fig. 3. *Temporary cadastral map of the study area*

As can be observed from the results, 64.78% of the total area remained forest area, i.e., 388.68 ha while 24.95% of the total area remained agricultural area, i.e., 149.70 ha.

Of the 100% of the total forest area, i.e., 416.79 ha, 93.26% remained forest, while 6.74%, i.e., 28.11 ha, underwent changes.

The value of the area is strictly high about 1,000 € per square meter (1 Square Meter = 0.0001 Hectare). The least observed change is 0.03 ha with total cost of 300,000 €.

Urban expansion poses a serious threat to forests and natural resources. This fact has aroused public opinion, which since the second half of the 1990s has shown increased interest in the consequences it may have.

According to a 2006 report by the European Environment Agency, Europe is one of the most urbanized continents on earth, with 75% of the population living in urban centers. It is noted that when the rate of change of land use and consumption for urban uses exceeds the rate of population growth, then there is anarchic urban expansion.

4. Conclusions

The proximity to an urban center (Thessaloniki) created problems. The issue of protection of forest ecosystems in the wider area of Thessaloniki from residential expansion and organized or arbitrary construction is crucial mainly in suburban forests. This disaster is a consequence of the degraded environmental conditions in the urban complex of Thessaloniki and the search for a way out for a first home in the above areas. In recent decades, there has been intense population movement to these privileged areas with a parallel rise in land prices held only by the economic crisis. Consequently, the need to protect the suburban forests of the city of Thessaloniki from landscaping and the rapid spread of the main and second houses is becoming more and more urgent.

Land use is a broad, complex, and constantly evolving field of research, which touches on many aspects of human activities. Especially in the suburban area, land uses show a strong rate of change while the spatial phenomena associated with the changes show an increasingly indeterminate structure and lead to difficult predictable results.

Using digital photogrammetry and GIS (Geographic Information Systems), land use changes and the environmental and spatial effects of arbitrary construction are assessed.

The use of photogrammetric methods to detect changes in land use is considered to give accurate results. Accuracy in photo interpretation in a complex landscape and the ability to better distinguish between different types of land cover and use is due to the high spatial resolution (1-3 m/pixel) of aerial photography. The main disadvantage of aerial photography is the high cost and time-consuming process required. In addition, due to the cost and time required it is difficult to update the data set frequently.

Cadaster and the application of modern technologies, such as digital photogrammetry and geographic information systems, can contribute reliably and efficiently to the recording and assessment of changing trends in land use in the context of a planned spatial planning - development plan.

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MULTI-CRITERIA ASSESSMENT OF THE ENVIRONMENTAL CONSTRUCTION AND OPERATION OF A FOREST ROAD FROM A FOREST TECHNICAL POINT OF VIEW

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Abstract: *A considerable part of the environment in which man lives today is the result of human-made plans and decisions. Design can be found in all sectors of human life. Plans are leading actions not only in the economy but also in politics, administration, and in most of the private matters. The problem of providing quality access to Greek forests and the lack of established direction for carrying out the planning and analysis tasks have led to the creation of a protocol for forest accessibility. The construction of forest roads that began in the Greek forests mainly since 1950 has developed in degree and extent in the last three decades, to satisfy the basic requirements both for the integrated opening-up of the forests and for serving the multiple purposes of forestry. The basic demand is quality access and the cost for providing such high-quality access is potentially high from a security point of view. Past solutions have mostly failed to meet today's needs and requirements. This protocol represents how studies of specific forest areas can be done. Also, it tries to compromise high-quality access, safety, minimum cost, and compatibility with the environment. The aim of this paper is to investigate the impacts of forest road construction on the natural environment. The paper sets the criteria and the parameters affecting a forest road and determines the weights of the intensity and absorption criteria of the ecosystem. The flexibility of the above mentioned criteria enables their wide use according to the needs and features of the area in whichthey are applied, defining global work guidelines, recommended technologies, techniques and method.*

Key words: *absorption, intensity, compatibility, environment, geographical information systems.*

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1. Introduction

One of the biggest investments the Greek State should take under consideration, in order to develop and manage its forests are the forest roads. Constructing forest roads also causes big impacts on the forest itself and its associated values (goods). These two assumptions are good enough reasons to explore the issues of forest roads construction, aiming to provide reasonable guidance on how to minimize the impact of forest roads on the one hand, and the cost of forest roads on the other, in order to obtain a more sustainable forest ecology and more viable forest use/exploitation.

Forest access infrastructure should generally be planned as a permanent facility for the management of a forest, and so its construction should be looked at as a long-term investment covering several silvicultural interventions.

A forest can become exploitable only through a reliable network of roads.

According to the definition, a forest road is considered an artificial strip of land formed by the morphological characteristics of the terrain and the mobility needs of the users, with the purpose of protecting the forest and providing economic and social use, while simultaneously meeting the requirements of natural conservation [1].

The construction of forest roads began mainly in the 1950s in Greece. In the last three decades forest roads have been developed to such a degree and extent so as to satisfy, on the one hand, the requirements of the overall opening of the forest and, on the other hand, to serve the multiple purposes of forestry.

Forest roads should provide safe access, but the cost of building such a safe road in the mountains is high, from a safety point of view.

The main requirement is quality access. Unfortunately, providing high-quality access is very money consuming, from a security perspective. Solutions already taken into practice more or less failed to meet today's needs and expectations.

For every construction of a forest road, an environmental impact assessment (EIA) must be carried out to demonstrate the impacts during the construction as well as during the operation phase of the road.

It tries to combine the potential of high-quality access, safety, and minimum costs, on the one hand, and the environmental compatibility on the other.

The construction of forest roads in mountainous and semi-mountainous forest areas results in a series of negative impacts on the physiognomy and harmony of the natural environment, which cannot be completely avoided.

These impacts can be divided into short-term damages and alterations of the landscape that remain permanently.

The negative impacts of forest roads construction on the economy of nature (in the soil, water, air, climate, fauna, and flora) have as result the change or disruption of the normal structure of the site factors (air, water conditions, habitat and soil).

The main causes of the negative impacts of forest roads are the erosion and leaching of the forest road slopes and of the road surface, and ditches.

This typical surface corrosion takes place especially during the construction phase and during the first years of use of the forest road, and it is reduced by taking appropriate protection measures.

The road network is an infrastructure project, contributing significantly to the sustainable growth and utilization of mountains and their surroundings [4].

The purpose of this paper is to highlight, evaluate and assess the effects of forest roads on the natural environment and to apply an appropriate method of assessing them.

2. Material and Methods

2.1. Research Area

The existing B΄ category forest road "Kerasochori-Arkoudorema" of the "DRYMO" forest complex of Xanthi prefecture, which is 5,000 meters long, perfectly serves the need for the fire protection of the wider area of the forest complex. It also serves the rational management of the surrounding forest and reforestations of a total area of 4.000 acres, the movement of forest workers to carry out work as well as the facilitation of the area's livestock farmers (Figure 1).

The area is located on the north-eastern side of the Erymanthou Forest settlement or forest village, at an altitude of 1,350 meters with 10 wooden houses with tiled roofs operated by the municipal development company "Nestos-Rodopi" of the Municipality of Stavroupoli. The forest complex "Drymou" took its name from the variety and magnificence of its vegetation. It also bears the old name "Haidou" from the past, an honorary name from "Hamidie", who was a squire of the area of the village of Leviditis. The forest in question unfolds on the southern slopes of the Rhodope massif with gentle to strong slopes and with an altitude of 1,610 (army post) to 1,000 meters. The total area of the complex is 3,058.01 ha and it is covered by 2,403.59 ha of forest, or 78.60%, 39.80 ha of partially forested land, or 1.30%, 604.87 ha of bare land, or 19.78%, and 9.74 ha of barren land, or 0.32%.

2.2. Methodology

Before planning the forest road in an area, the site must also be studied (relief, landscape, position in relation to archaeological sites, etc.), and its ability to overcome (absorb) the intervention must be assessed so that the forest ecosystem can balance again with the least possible damage to the forest and the social surroundings.

The environmental compatibility depends on the grading of two categories of criteria defined as intensity and absorptioncriteria. The grading of these criteria depends on the following principle: we accept a situation as ideal (=100%) for forest protection with road construction. The percentage deviation from this ideal situation is subtracted from 100%. The result will be the grading of the criteria. For this reason, the following steps were taken:

A. As far as absorption (A) is concerned:

The absorption criteria were divided into three categories:

a. In forestry;
b. In topographic, and
c. In social.

From the literature and from the opinions of expert scientists in a questionnaire, it was found that the weights of the absorption criteria are 3 for forestry, 2 for topographic, and 1 for social [7]. Grading of the absorption capacity of the ecosystem is done based on data collected from the management plan of the research area and from the on-site observations and measurements. The absorption criteria, the way of their assessment and their weights are presented in Tables 1, 2 and 3 for the forestry, topographic, and social criteria, respectively.

Fig. 1. *A view from the forest road in question in autumn*

B. As far as intensity (I) is concerned:

The intensity criteria have been set based on the literature and on a questionnaire. The questionnaire was drafted with the help of experts and the literature, and includes the intensity criteria. The employees of forestry technical offices in Greece were asked to evaluate the criteria in order to derive their weights and express their views and observations [2, 3, 5, 8, 9, 10] (Table 4).

The intensity criteria were divided into layout and construction criteria.

The grading was carried out as follows [6]:

1. To calculate the mean absorption value (C_A), we multiplied the grade of each criterion by its weight and in the end, we divided the sum of the products by the total sum of weights. This value is the mean absorption value on a scale of 100 (%), as barycentric mean (Eq.(1)):

$$C_A(\%) = \frac{\sum(A \cdot W_A)}{\sum W_A} \qquad (1)$$

where: $\sum(A \times W_A)$ and $\sum W_A$ are the sum of the absorption's productsand the total sum of the weights, respectively, in %.

Form of assessment of the forestry criteria of the absorption (capacity) of the ecosystem

Table 1

1. Land cover/uses	a. Forest	100
	b. Forested land	25-50
	c. Bare land	15
2. Forestry species	a. Mixed Forest	100
	b. Conifer Forest	75
	c. Broadleaf Forest	50-80 (depending on the season when measurements are carried out if they have leaves or not)
3. Management form	a. Seedling (high) forest	100
	b. Mixed sprout and seed origin forest	75-100 (depending on the seedling-coppice forest rate, 100 if there are two stories, overstory with light demanding species (photophytes) understory with shadetolerant species)
	c. Coppice Forest	50
4. Age (forestry form)	a. Irregular shelterwood (multiage) managed forest	100
	b. Uneven-aged managed forest	75
	c. Even-aged managed forest	50
5. Tree height	a. High trees > 20 m	100
	b. Medium size trees 10 – 20 m	75
	c. Small trees < 10 m	25-50
6. Site quality	a. Good	100 (first and second site quality)
	b. Medium	50 (third and fourth site quality)
	c. Poor	25 (fifth and sixth site quality)
7. Forest productivity (Annual allowable harvest)	a. Category I (over $3m^3$/year/ha)	100
	b. Category II ($1\text{-}3m^3$/year/ha)	50
	c. Category III (less than 1 m^3/year/ha)	25

Table 2

Form of assessment of the topographic criteria of the absorption (capacity) of the ecosystem

1. Cross slope of the ground	a. Gentle slopes < 8%	100
	b. Moderate slopes 8% - 20%	50
	c. Steep slopes > 20%	5-25
2. Aspect:		
2.A. Less than 1,000 m	a. Northern	100
	b. Eastern-Western	75
	c. Southern	50
2.B. Over 1,000 m	a. Northern	70 (because there is snow)
	b. Eastern-Western	100
	c. Southern	70 (because they are very degraded)
3. Terrain relief	a. Mild relief	100
	b. Varied relief	50
	c. Multifarious relief	15

Table 3

Form of assessment of the social criteria of the absorption (capacity) of the ecosystem

1. Distance from tourist resort (Since tourism is seasonal and is culminated during the peak season, each kilometre of the distance from the resort increases grading e.g., distance 0-1 km is graded with 0, 1 – 2 km with 10, 2 – 3 km with 30, etc.).
2. Distance from national and country road network (the same as with the tourist resort).
3. Distance from railway (it has no direct impact but if one sees the road from the train, one might want to visit the forest by car. However, ithasimpactduetonoise).
4. Distance from archaeological and monument sites (the same as with the tourist resort).
5. Distance from adjacent big city (the same as with the tourist resort).
6. Distance from adjacent village (the same as with the tourist resort).
7. Distance from European path (Every time the road crosses the path, its grading is reduced; e.g., if it crosses the path once, it is graded with 80, if twice, with 60, 3 times with 40 etc.).
8. Distance from natural or artificial lake or river (the same as with the tourist resort).

They depend on the number of humans affected by the road. In these cases, the road is graded with 25% when there are many humans affected by the road, with 50% when few humans are affected, and with 100% when no one is affected.

Assessment of the intensity criteria weights based on the questionnaire Table 4

	Intensity Criteria	Intensity Criteria Weights
	Layout	
1.	Earthworksallocation	
1.1	What weight is given to the radius of curvature (R) (effect on embankments)	2.1 ± 0.15
1.2	What weight is given to the height of the embankments (layout of the red line)	2.01 ± 0.06
1.3	What weight is given to the height of the embankments (cross section)	2.25 ± 0.06
2.	What weight is given to the width of the road surface (impact on living space, animal movement, water balance, micro-scale, etc.)	2.04 ± 0.18
3.	What weight is given to the longitudinal slope of the road (effect on erosion, drainage)	2.52 ± 0.18
4.	What weight is given to the distances between two hairpin bends (effect on earthworks)	2.13 ± 0.18
5.	What weight is given to the position of the forest road	
5.1	Distancefromstreams	1.83 ± 0.09
5.2	Distancefromforestboundaries	1.65 ± 0.06
5.3	Distancefromdangeroussites	2.4 ± 0.06
6.	What weight is given to the view from the forest road	
6.1	In morphologicalformations	1.83 ± 0.09
6.2	In vegetation	1.8 ± 0.09
6.3	In visual field (space projection)	1.7 ± 0.06
6.4	In compatibleconstructions	1.6 ± 0.06
6.5	Inwatersurfaces	1.65 ±0.09
7.	What weight is given to the adaptation (concealment) of the forest road to the relief	1.77 ± 0.09
	Construction	
8.	Construction method of forest road	
8.1	What weight is given to the forest road construction machinery	2.16 ± 0.21
8.2	What weight is given to the construction materials	2.07 ± 1.21
8.3	What weight is given to monitoring the slopes of the forest roads	1.38 ± 0.09
8.4	What weight is given to the drainage systems of forest the roads (ditches, culverts, surface grooves transverse to the road)	2.31 ± 0.24

Similarly, the grade of each intensity criterion (I) was multiplied by its weight (W_I) and in the end, the sum of the products was divided by the total sum of the weights to extract the average intensity value (C_I) as barycentric mean (Eq.(2)):

$$C_I(\%) = \frac{\sum(I \cdot W_I)}{\sum W_I} \qquad (2)$$

where $\sum(I \times W_I)$ and $\sum W_I$ are the sum of the intensity's products and the total sum of the weights, respectively, in %.

Provided that weights are not subjective, the figures C_I and C_A, indicate the approximate protection degree of the natural environment from the construction of the forest road.

2. To calculate the forest road's *compatibility coefficient* (C_C), we multiplied the mean absorption value by the mean intensity value.

If the compatibility coefficient (C_C) is:

- C_C> 60% or C_C = 60%, the construction is accepted under no special conditions;
- 50% < C_C< 60%, the construction is accepted under conditions;
- C_C< 50%, the construction is accepted provided that works to restore the natural environment are carried out.

3. Results and Discussion

The study of the forest road and the grading of the ecosystem's absorption and intensity resulted as follows in Tables 5 and 6.

The forest road's compatibility coefficient, to the environment is calculated as follows:

$$C_C = C_A \cdot C_I = 74.91 \cdot 84.35 = 63.19\%$$

Table 5 shows the grading of the absorption criteria from the construction of the forest road in the forest ecosystem. Its worth paying attention to the following criteria:

As far as the cross slope of the ground, the aspects and the terrain relief are concerned, the grading is low. These topographic criteria cannot be improved because they need millennia or millions of years to be changed by mother nature or less by human intervention, but not for such scale projects. Another alternative is the redrawing of the road's layout, but this is a very expensive undertaking.

As for the social criteria, there is a tourist resort near the road and nearby the road are the villages of Oraio, Evmiro, and Saia. Thus, the grading of these criteria is thirty and ten, respectively. Also, there is ariver in the area so the criterion is graded with 60.

Its worth paying attention to the following intensity criteria (Table 6):

A. The radius of curvature

The grading of this criterion is 64.58 because in the first 1,000 m the result was 71.3, in the next 1,000 m 73.9, in the next 1,000 m 71.2, in the next 1,000 m 30.5, and in the last 1,000 m 76. So, the final grading is 30.5+76 +71.3+73.9+71.2/5 = 64.58%.

B. The layout of the red line

The grading of this criterion is 35.6 because in the first 1,000m the result was 24, in the next 1,000 m it was 26, in the next 1,000 m 22, in the next 1,000 m 64, and in the last 1,000 m 62. So, the final grading is 24+26+22+64+42/5 = 35.6%.

C. The cross section

The grading of this criterion is 43.6 because in the first 1,000 m the result was 34, in the next 1,000 m it was 46, in the next 1,000 m 26, in the next 1,000 m 56, and in the last 1,000 m 56. So, the final grading is 56+56+26+46+34/5 = 43.6%.

Evaluation of the absorption criteria Table 5

Criteria	Weights	Grade [%]	Sum
Forestry criteria			
1. Terrain conditions			
1.1. Land cover/uses	3	100	300
1.2. Forestry species	3	100	300
1.3. Forest management form	3	97	291
1.4. Age (Forestry form)	3	100	300
1.5. Tree height	3	75	225
1.6. Site quality	3	87	261
1.7. Forest productivity (Annual cut)	3	100	300
Topographic criteria			
1.8. The cross slope of the ground	2	27.5	55
1.9. Aspect	2	70	140
1.10. The terrain relief	2	15	30
Social criteria			
2. Distance from			
2.1.Tourist resort	1	10	10
2.2. National and country road network	1	30	30
2.3. Railway	1	100	100
2.4. Archaeological and monument sites	1	100	100
2.5. Adjacent big city	1	100	100
2.6. Adjacent village	1	10	10
2.7. European path	1	100	100
2.8. Natural or artificial lake or river	1	60	60
Total	35		2,622
Mean absorption value	$C_A = \sum(A \times W_A) / \sum W_A$		**74.91 %**

D. The hairpin turns distance

The hairpin turns distance is between 200 – 100 m, which is short. The grading of this criterion is 32 because in the first 1,000 m the result was 40, in the next 1,000 m it was 60, in the next 1,000 m 28, in the next 1,000 m 16, and in the last 1,000 m 16. So, the final score is 40+60+28+16+16/5=32%.

Finally, according to the construction criteria, the lack of technical works which are necessary for the drainage system of the road led to the grading of this criterion with 70%.

The compatibility coefficient of the forest road is 63.19%. Because $C_C > 60\%$, the construction is accepted under no special conditions.

Evaluation of the intensity criteria Table 6

Criteria	Weights	Grade [%]	Sum
Layout			
1. Earthworks allocation			
1.1. Radiusof curvature	2.10	64.58	135.618
1.2. Layout of the red line	2.01	35.60	71.556
1.3. Cross section	2.25	43.60	98.10
2. Road width- widening	2.04	80	163.20
3. Longitudinal road gradient	2.52	100	252
4. Distance of hairpin turns or bends	2.13	32	68.16
5. Position of the forest road			
5.1. Distance from water courses	1.83	99.16	181.4628
5.2. Distance from forest boundaries	1.65	100	165
5.3. Distance from dangerous sites	2.40	100	240
6. Picture of landscape			
6.1. Morphological formations	1.83	100	183
6.2. Vegetation	1.80	100	180
6.3. Space projection	1.70	100	170
6.4. Compatible constructions	1.60	100	160
6.5. View of water surfaces	1.65	100	165
7. Visual absorption capability	1.77	100	177
Construction			
8. Construction method of forest road (only for existing road)			
8.1. Machinery of earth works	2.16	100	216
8.2. Construction materials	2.08	100	208
8.3. Seeding and mulching of side slope	1.38	100	138
8.4. Road drainage system	2.31	70	161.70
Total	37.21		3,138.8068
Mean intensity value	$C_I = \sum(I \times W_I) / \sum W_I$		**84.35 %**

4. Conclusions

Because the compatibility coefficient is over 0.60 there are not any impacts to the natural environment. So, the road is compatible with the natural environment.

The road in several places is well above the grade line (red line) set out on the ground and is constructd in such a way that in some cases even small trapezoidal section have been created (transeres).

A digital terrain model can be used to derive measurements of terrain relief.

By using this method to characterize the road network, we can assess the road or alternative routes and alignments so we can calculate which road has the least impact on the environment. Doing this, we can improve the settings that indicate the larger impact on the environment. Constructing a forest road depends on three (3) parameters:

1. the cost of construction and rehabilitation of the natural environment;
2. the intensity of the effect that is not negative, and
3. the absorption of the forest ecosystem.

Therefore, it is a matter of political will on the availability of funds for the construction or maintenance of a road network compatible with the natural environment.

We can recognize failings during the assessment of the consequences on the natural environment. These failings are caused by the determination of the direct consequences, the expectation of future consequences, and the objective assessment of the size of the direct consequences.

The interventions of the specialist sciences for the restoration of the environment from the consequences must be proportional to the absorbency of the natural environment.

The method of calculating the compatibility coefficient of forest roads in the environment assessess not only individual forest roads and alternative routes for a road in order to find the road that will have the smallest environmental impact.

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RATIONAL FOREST OPENING-UP AS A TOOL FOR SUSTAINABLE DEVELOPMENT AND EXPLOITATION OF THE SEMI MOUNTAINOUS AREAS IN GREECE

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Abstract: *Investigation, reliable knowledge, integrated and accurate inventory, mapping, and monitoring of natural resources are a fundamental infrastructure for their proper management and utilization, but also for any design and development and environmental protection program. The problem of optimization of a transportation network, more specifically the road network, has been the subject of intense study on account of the essential importance involving the plan of development policy among different countries. The integrated opening-up of a semi-mountainous forest area (the basic opening-up-in German Basiserschließung- with forest roads and the skidding tracks opening-up -in German Feinerschließung- with skidding trails, tractor roads, hauling roads, ropeways, and slides) causes a significant intervention in the natural environment that must be examined very critically from an ecological point of view because of its impacts on it. However, since the opening-up of forests is necessary and inevitable to achieve the rational management of forest ecosystems, with their simultaneous protection, for the sustainable development of semi-mountainous areas, a golden intersection must be found between these two different functions. A comprehensive evaluation including all the points of view could be attempted by the method of cost-benefit-analysis. This paper aims to improve forest road network and the skidding and transport conditions of timber to meet the conditions for a rational management of the forest. The research area is the public forest of Trigono, prefecture of Evrosin, North Greece. Based on the relevant processing of the data that have been received, the necessary improvements to the road network are determined, and opening-up of the forest, improvements to the existing roads, and maintenance of the existing roads are proposed.*

Key words: *improvement, management, forest operations, environment, skidding, transport.*

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1. Introduction

A forest is exploitable only through a good road network. Until not so long ago, the opening-up of forests was carried out with the machinery of the time, based on purely technical and financial criteria. Recently and following a worldwide lobbying on the degradation of the environment, countries have been forced to impose laws for the protection of the environment. Investigation, reliable knowledge, integrated and accurate inventory, mapping, and monitoring of natural resources are a fundamental infrastructure for their proper management and utilization, but also for any design and development and environmental protection program.

Forest opening-up is the total number of installations and works whose goals are:

1. The access to isolated forests areas;
2. The transport of staff, means, materials, and machineries which are meant for exploitation, cultivation, and protection of forest;
3. The skidding, move, and transport of timber from trunk landing areas to consumption and processing areas.

This was the definition of opening-up some years ago. Nowadays we have to add the circulation of visitors and travelers in the forest.

The opening-up must satisfy the following demands [3]:

1. The access to every stand and department of the forest;
2. The means of transport (machineries, tools, materials), which are used for the exploitation of the forest as well as for the construction of technical works, control of torrents, utilization of mountainous pasture and areas for construction, and function works of development and culture;
3. The extraction of products, especially timber, and its transportation from trunk landing areas to the final processing and consumption areas;
4. The proximity of laborers to areas where forest works take place;
5. The transport of staff who deal with the protection and supervision of the forest;
6. The collection and processing of timber on a forest road (allocation of areas where the timber is collected);
7. The exploitation of the forest in functions which are mentioned in tourism and recreation as well as agricultural exploitation of the land found in forest areas;
8. Space order and division of the forest in the frame of the forestry plan;
9. The aquatic economy;
10. The public transportation of people who live in mountainous areas;
11. The defense of the country.

The above demands for the opening-up have as goal the economic development of an area.

The characteristic elements of a forest opening-up are mainly the following:

1. Road density;
2. Road distance;
3. Skidding distance;
4. Opening-up percentage.

These elements are also expressed in characteristic numbers that show the size magnitude of their effect on a forest opening-up.

The rational development and utilization of forests is achieved not only to increase production but also by creating favorable conditions for the movement, with speed and as little expense as possible, of forest products, to the places of their processing or consumption.

Forest opening-up is one of the most important interventions in a forest ecosystem and is carried out by planning and constructing a transport network (forest roads, skidding tracks etc.), satisfying not only the need for skidding and transporting of forest products, but also forest protection and recreation activities [1, 11]. However, in addition to the above positive effects, opening-up burdens the environment and causes damage to the landscape, which can be partially reversed, but most of the time it is impossible to restore.

The problem of optimization of a transportation network and more specifically the road network has been the subject of intense study on account of the essential importance involving the plan of development policy among different countries [2, 7]. The integrated opening-up of a semi-mountainous forest area (the basic opening-up-in German Basiserschließung- with forest roads and the skidding tracks opening-up -in German Feinerschließung- with skidding trails, tractor roads, hauling roads, ropeways, and slides) causes a significant intervention in the natural environment that must be examined very critically from an ecological point of view because of its impacts on it [5]. However, since the opening-up of forests is considered necessary and inevitable to achieve the rational management of forest ecosystems, with their simultaneous protection, for the sustainable development of semi-mountainous and mountainous areas, a golden intersection must be found between these two different functions [4, 6].

Integrated development can only be achieved with a comprehensive and interdisciplinary approach, analysis, recording, monitoring, and utilization of the real forces and potentials of each specific physical and socio-economic reality, as they are multi-dimensionally related, interdependent and mutually influencing [9, 10], and this approach and methodology should be followed in development planning.

A comprehensive evaluation including all the points of view could be attempted by the method of cost-benefit-analysis.

The purpose of the paper is the optimization of the road network and of the conditions for the movement of timber in a semi mountainous area in order to meet the modern demands of forest exploitation.

2. Material and Methods

2.1. Study Area

The studied forest of Trigono is located in the northwest of the Evros Prefecture in the north-eastern edges of the Rhodope Mountains, in Greece. It is included between geographical coordinates: longitude from 26°4′ to 26°14′ East and latitude from 41°34′ to 41°43′ North. The region has an altitude above sea level that ranges from 80 m to 611 m. The slopes are gentle and the aspects are various. The total area is 10,199.56 Ha and the forests and partially forested areas cover 76.14%; the grasslands 1.03%; the barren lands 0.03%, and the agricultural lands 22.8% (Figure 1). The total road length is 332,767.43 m.

Fig. 1. *View of the oak forest in the research area*

2.2. Methodology

The existing road density can be calculated as follows:

Having calculated the total length of the road network (L) and knowing the area (F) of the forest complex, the existing road density (D_{ex}) derives from the Equation (1):

$$D_{ex} = \frac{L}{F} \tag{1}$$

Road distance (S) and road density (D) are inversely proportional quantities and are related to each other by the Equation (2):

$$S = \frac{1}{D} = \frac{10.000}{D} \quad [m] \tag{2}$$

The calculation of the theoretical optimum (D_{th}) and the economical optimum road density (D_{ec}) are based on the application of the Kroth method [8].

Data and equations for the calculation of the economical (D_{ec}) and theoretical (D_{th}) optimum road density using the Kroth method are:

Construction and maintenance costs of forest roads (K_W) – Equations (3) and (4):

$$K_R = \frac{A}{H} \cdot \frac{1.0p^n \cdot 0.0p}{1.0p^n - 1} \tag{3}$$

$$K_{Su} = \frac{Su}{H} \cdot D \tag{4}$$

Skidding costs of timber (K_r) can be determined with the Equation (5):

C_F and

$$C_V \cdot RE_t = C_V \cdot RE_m \cdot F \cdot W = \frac{2500}{D} \cdot F \cdot W \quad (5)$$

where:

p is the interest rate [%];
D – the road density [m/ha];
K_R – the annual interest amortization of forest road construction costs;
A – the road construction cost [€/m];
n – the years of amortization [year];
H – the annual allowable cut [m^3/ha];
K_{Su} – the annual interest amortization of forest road maintenance costs;
Su – the road maintenance cost [€/m];
C_F – the fixed skidding cost [€/m^3];
C_V – the variable skidding cost [€/m/m^3];
RE_m – the theoretical mean skidding distance [m]; for one-side skidding the numerator of the fraction is 5000 while for the two-side skidding is 2500;
RE_t – the true mean skidding distance [m];
W – the coefficient of sinuosity or mean skidding distance correction coefficient;
F – the coefficient of opening-up or road network correction coefficient.

Economical optimum road density (D_{ec}) is achieved when the cost of the road network K_W (negative effects of road construction) is equated with the skidding cost of wood K_r (positive effects of road construction), and is expressed by the Equation (6):

$$K_w = Kr \longleftrightarrow K_R + K_{Su} = C_F + C_V \cdot RE_t = C_F + C_V \cdot RE_m \cdot W \cdot F \quad (6)$$

By replacing the quantities in the previous equality (6) with the Equations (3), (4), and (5), a quadratic equation is obtained; its positive solution constitutes D_{ec} while its negative solution is rejected.

Theoretical optimum road density (D_{th}) is achieved when the cost of the road network K_W (construction and maintenance costs) with the skidding cost of timber K_r become minimal, i.e., it is the point where total costs (K_S) are minimized:

$$K_S = K_W + K_r = K_R + K_{Su} + C_F + C_V \cdot RE_t = C_F + C_V \cdot RE_m \cdot W \cdot F = \text{minimum} \quad (7)$$

The value of the theoretical optimum road density (D_{th}) results from the above equation when its first derivative becomes equal to zero. The negative root of equality is rejected.

The determination of the mean vertical skidding distance as well as the coefficients of mean skidding distance correction and road network correction was achieved using GIS taking into account the means of skidding (for animals: one-sided skidding from uphill to downhill, for tractors: two-sided skidding).

The mean inclined skidding distance for inclination ≤ 25% RE_m^{inc} [m] is skidding distance reduced to slope ≤ 25%.L_κ' g ≤ $14^o.03624$ g > $14^o.03624$ then $L_\kappa' = L_\kappa$ then L_κ' = DH / $\sin 14^o.03624$, where DH is the height difference.

3. Results and Discussion

The total length of the road network L is 332,767.43 m and the total area is 10,199.56 ha. The existing road density is 32.34 m/ha.

The road distance (S) is 309,215 m.

Data for the application of the Kroth method from the forest complex of Trigono of Evros Prefecture are the following:

1. Annual allowable cut: 0.02 m^3/year/hectare;
2. Road construction cost for B category forest road: 11.29 €/m;
3. Road maintenance cost: 0.195 €/m;
4. Fixed skidding costs: 3.62 €/m^3;
5. Variable skidding costs: 1.05 €/m/m^3;
6. Theoretical mean skidding distance: 77.305 m;
7. True mean skidding distance: 511.91 m;
8. Years of amortization: 30 years;
9. Interest rate: 3%;
10. Road network correction factor (F): 3.848588;
11. Mean skidding distance correction factor (W): 1.7234789;
12. Mean inclined skidding distance RE_m^{inc}: 297.52 m;

According to the above-mentioned data and the Equations (6) and (7), the economical and the theoretical optimum road density are calculated. The calculated values for the forest complex are:

D_{ec} = 29.97 m/ha

and

D_{th} = 30.03 m/ha.

Alternatively, D_{ec} = 13.08 m/ha and D_{th} = 15.79 m/ha if taking into account 0,11 €/ha land revenue and 10 m the width of the occupation zone by forest roads.

For years in the area of the forest complex of “Trigono” there has been a very extensive exploitation based mainly on animal husbandry and agriculture. The energy coverage of the residents with firewood, the logging for technical timber for constructions, the grazing of the livestock, the agricultural exploitation with the clearing of forest lands, were considered and were necessary interventions for the livelihood of the forest population. Many times, the exercise of social policy by the state is done through its mechanisms without taking into account the effects of such a policy of exploitation on the natural resources.

Under such conditions, many times foresters are asked to be judged for the measures they propose, for the management and silvicultural methods they have applied, when there are realities opposed to science. It is estimated that the colleagues who studied the management of the forest made a great and substantial effort in the service contexts, in order to give the best. Besides, it seems that they wish to satisfy all the activities for the survival of the forest-living population (grazing, wood burning, etc.), which are a priority in the prioritization of the options.

The implementation of the specific management studies becomes difficult and directs the forest service from a forest political surveillance body, to a policing body, without practical possibilities, due to a lack of personnel and appropriate means of control. The staff of the forest service are consumed, without seeking it in roles, beyond and outside the role of protection and improvement of the forest.

Thus, if the evolution of the forest is evaluated through the "scientific" organized interventions, one can claim that according to the current general productive situation, the applied measures are judged with a positive sign.

4. Conclusions

From the calculation of the economical optimum road density (30.03 m/ha) and the theoretical optimum road density (29.97 m/ha) it follows that these are lower than the existing road density (32.34 m/ha) of the road network of the forest complex of "Trigono".

Therefore, it is concluded that the length of the existing road network is enough and forest roads should not be added to the existing road network. In order to meet the requirements of modern forest exploitation and transport, it is considered necessary to improve, by positions, the geometrical elements of the forest road for the better execution of harvesting and skidding, both with animals and with machines. An improvement of the spatial distribution of the forest roads is required, which is necessary in case of possible mechanization of the works in the future.

The standardization of the opening-up of the forest areas is non-feasible since every forest area is unique and requires special management. The economical-technical opening-up of every forest area is accomplished via thorough study of the traffic, soil-climatic, forest-economic and ecological conditions of the region.

The rational development and exploitation of forests is achieved not only to increase production but also to create favorable conditions for the movement of forest products to the places of their processing or consumption with speed and as little expense as possible.

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DISTRIBUTION AND POPULATION OF TAWNY OWL (*STRIX ALUCO*) AND URAL OWL (*STRIX URALENSIS*) IN DECIDUOUS FORESTS FROM CENTRAL ROMANIA

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Abstract: *This paper studies the distribution, population size, and abundance of two owl species – the Tawny Owl (Strix aluco - TO) and the Ural Owl (Strix uralensis - UO) within a low and medium altitude mountain from the central part of Romania. Măgura Codlei is a part of the Perșani Mountains with an altitude of 560-1,292 m, covered by about 2000 ha of forests. This area is included in the Dumbrăvița-Rotbav-Măgura Codlei Natura 2000 Site (ROSPA0037), designated to protect forest and water bird species. During the 2020 – 2021 monitoring season,observations were conducted using playback from fixed census points, randomly pre-established within the boundaries of the Natura 2000 Site forest. Based on these two monitoring years, both species were relatively evenly spread over the studied area in different types of stands bycomposition, age, and forest management. The Tawny Owl was more frequently identified in the study area. The number of individuals detected in 2020 was similar for the two species (54% for TO and 46% for UO), but this situation was completely different in 2021 (63% for TO and 37% for UO). Concerning their density, TO has 0.8-1.0 breeding pairs bp/km^2 and UO 0.2-0.5 bp/ km^2. Regarding the breeding population size within the study area, TO has 16-20 bp and UO has 4-10 bp. Our results contribute to the monitoring program of UO as a species of community interest. In terms of further management measures, these results will contribute to the species conservation measures to achieve a favorable conservation status for this Natura 2000 Site.*

Key words: owls, density, distribution, deciduous forests, Romania.

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1. Introduction

Owls are indicators of the quality and complexity of ecosystems as top predators [15]. At the same time, they can be selected as indicators for monitoring sustainable forest management [17]. Also, some forest owl species indicate habitats with mature and old trees, with hollow, dead wood (snags) of different sizes.

Among the owl species in Romania, the genus *Strix* includes two species: the Tawny Owl (*Strix aluco*) – TO and the Ural Owl (*Strix uralensis*) – UO, characterizing different types of forest. TO is widespread in Europe, with some discontinuities of its range in the eastern part and in Turkey [20]. Its European breeding population is large: 500,000-1,000,000 pairs [20]. UO has two main breeding areas at the European level, one in northern Europe and the second in central and Eastern Europe [20]. Its European breeding population is estimated at 50,000-143,000 pairs [20] Regarding Romania, TO has a nationwide distribution, occupying mostly plain and hill forests, but also the mountain area [14]. Romania has an average of over 80,000 TO breeding pairs [14]. UO has a narrower distribution, overlapping with the forests of the hill and mountain area [14]. Romania has an average of over 20,000 UO breeding pairs [14].

From the conservation point of view, many of the European owl species (eight species, about 62% of the total European owl species) are of community interest being included in Annex I of the Birds Directive 2009 [1]). Of the two species studied, UO is included in Annex I of the directive [1].

Considering the European species, Romania has a great diversity of owls, but studies on these species are very scarce. There are some studies in Eastern Romania [8-10], but they are in a limited area, in a hilly region with a low density of the forest. Considering that the Romanian owl population is very high, according to the European Bird Breeding Atlas [20], we need more studies to clarify their habitat preference and ecological requirements to ensure suitable conservation measures.

The aims of this study were: *(1)* to investigate the occurrence, distribution, and densityof TO and UO in a deciduous forest from a low and medium mountain area, and *(2)* to find out the actual breeding population of the studied species (especially of UO as a species of Community interest) within the Natura 2000 Site ROSPA0037.

2. Material and Methods

2.1. Study Area

The study area is part of central Romania, Transylvania, Perșani Mountains in the Oriental Carpathians. Concerning the altitude, they are part of the group of low mountains in Romania, except for the regionwith an altitude of over 1000 m. This is called Măgura Codlei (MC) and is included in a Natura 2000 Site – ROSPA0037 Dumbrăvița-Rotbav-Măgura Codlei. The total area of the Natura 2000 Site is 4,434.1 ha [6], and MC area is almost half, 2,152.1 ha. The forest of the MC area covers 1,946 ha (Figure 1).

Deciduous forests cover the whole forested area, except some coniferous plantation stands. The primary forest type in the MC area is beech forest (*Fagus sylvatica* (L.) is the dominant tree species), then mixed sessile oak – beech stands and pure sessile oak stands (*Quercus petraea* ((Mattuschka) Liebl.) is the dominant tree species) partially with hornbeam (*Carpinus betulus* (L.)). Other deciduous tree species as components of the forest are Norway maple (*Acer platanoides* (L.)), European ash (*Fraxinus excelsior* (L.)), etc. The coniferous plantations in MC are mainly represented by Scots pine (*Pinus sylvatica* (L.)) and Black pine (*Pinus nigra* (J.F. Arnold.)).

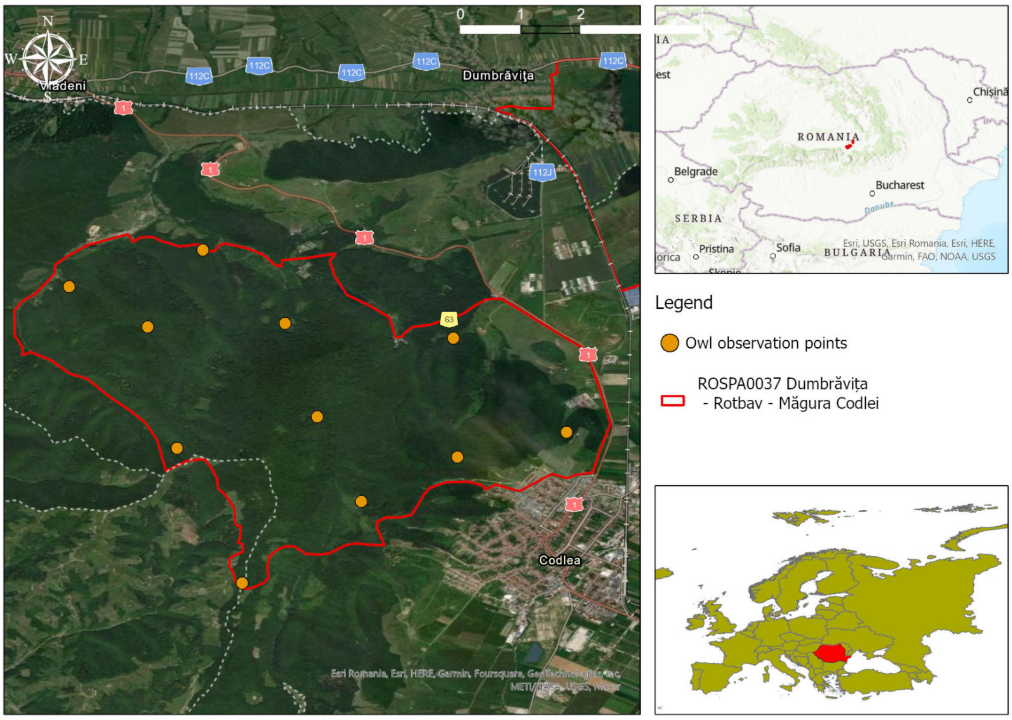

Fig. 1. *Study area and observation points for owl monitoring in ROSPA0037 Dumbrăvița-Rotbav-Măgura Codlei*

Concerning the forest age [2], there are both even-aged and uneven-aged stands. The area is covered mainly by mature stands (forests over 80 years) – 1,167 ha (60% MC of MC total forested area). Almost 300 ha on the steep of MC have been studied from the point of view of stand naturalness, being identified as old-growth quasi-virgin stands [18].

Concerning the forest management in the study area, it is applied tomost of the forest area but with different cutting types and intensities [2]. The most frequently used forest treatment (cutting) in mature/old stands is shelterwood cutting based on regeneration gaps within stands. On steep slopes and other stands with protection aims, conservation cuts were made, similar in technique and purpose to shelterwood. Within pine stands, clear-cuttings were applied. Some of the mature stands are not subject to main cuttings, but sanitation harvestings (sanitary cuttings) are applied to them. In this case, especially dead standing trees are cut down. The management plan of the

Natura 2000 Site provides some restrictions on such cuts to keep some of the essential trees for biodiversity (e.g., 10 trees / ha of the categories such as snags, hollow trees, etc.; [4]. Repeated thinning is applied for the young stands that have not reached the age of harvesting. There will be other changes regarding the forest management within the Natura 2000 Site, such as changing the types of cuttings in several forest units (e.g., only sanitary cuttings instead of some shelterwood).

2.2. Study Design and Owl Data Collection

For this study, we used the TO and UO national monitoring scheme [3, 5] with some adaptations for the small areas survey. The method uses playback and point monitoring (fixed point). A total of 11 points were randomly selected in the forest of MC (Figure 1). All points overlap with forest habitats or are near woodlands (Figure 2).

The method was applied in 2020 and 2021. All observations were made from October-November. Because of difficult conditions for accessing the observation points at night, most were relocated on the nearest forest road or tourist trail at a maximum of 300 m from the initial point and a minimum of 1,000 m from any other point. The method was conducted atnight, starting with dusk when it is almost dark and only in favorable weather conditions using playback by playing a standard, recorded call of the target species. At each point, we stayed for 20 min.

Fig. 2. *A typical habitat of Ural Owl in Măgura Codlei*

3. Results

3.1. TO and UO Occurrence in the Study Area

For 2020, the identification frequency of TO from the total accessed points was 78%, and for UO, 56%. The situation is different for 2021; only in slightly more than half of the points was TO detected (54%), and UO only in 27% (Table 1). In 2020, both species were identified together in three points (33% of the total observation points), and in 2021 in two points (18% of the total observationpoints). In 2020, the number of points where only TO was identified was four, and where only UO was identified, two. In 2021, there were only four points with TO, and one with UO.

Table 1

The occurrence of TO and UO and the frequency of identificationin the two years

Year	Species	No. of points where the species was identified*	Frequency of detection [%]**
2020	TO	7	78
	UO	5	56
2021	TO	6	54
	UO	3	27

** the ratio between the number of points where the species was observed and the total number of points accessed in that year

3.2. OWL Density and Number of Pairs in the Natura 2000 Site

Although nine out of 11 points were accessed in 2020, the total number of specimens of TO and UO was 24, almost double that of 2021 (14 specimens from both species).

The number of individuals detected in 2020 was relatively similar for the two species (54% for TO and 46% for UO), but this situation was completely different in 2021 (63% for TO and 37% for UO). Almost four times fewer UOs were detected in 2021 compared to the previous year.

TO was the most abundant species in the two years and the number of pairs was double to four times higher compared to UO (Table 2).

Density and breeding pairs (bp) of TO and UO in the studied area Table2

Species	Density [no. of pairs /100 ha]	No. of pairs [bp] within Natura 2000 Site
TO	0.8-1.0 bp /100 ha	16-20
UO	0.2-0.5 bp /100 ha	4-10

4. Discussions

4.1. TO and UO Occurrence in the Study Area

There is an apparent difference between the number of points where the two species were identified in 2020 and the one in 2021. The number of identification points in 2021, almost twice as low as in 2020 for UO, may have several causes. These differences could be caused by the accessibility and abundance of prey (small rodents), considering that the habitats did not undergo essential changes during this period under the action of natural or anthropogenic factors. For example, it is known that UO can have significant population variations in different periods depending on available prey [23, 29]. TO is also influenced by prey availability, and small mammal abundance and distribution (e.g., mice) are very important during winter and early spring [16]. Considering that our study covers a short period (only two years), we cannot say that these species are declining. To have a suitable population trend, we need further long-term studies.

4.2. TO and UO Density

During the 2020 – 2021 survey in Măgura Codlei, we found a density of 0.8-1.0 breeding pairs (bp) / km^2 for TO and 0.2-0.5 bp / km^2 for UO. There are very few studies on TO and UO in Romania. In the scientific literature available, studies have been published on both species distribution and abundance in the eastern part of Romania, Moldova Province [8, 10]. Thus, in the Eastern Moldova region, on a total forest area of 3,185.5 km^2, the highest densities of TO were found in large old-growth forests (1.02 bp/km^2), and the lowest densities in fragmented river meadows (0.32 bp/km^2). The medium density was 0.83 bp/km^2 [8]. Compared to our results, the densities are similar, in our case the minimum value being higher than the minimum in Moldova. In the same region (Moldova) but in a larger area (46,123.36 km^2), UO had a minimum occupancy density for the forested study area of 0.24 individuals/km^2, similar toour results [10].

Numerous studies have focused on determining the densities of TO and UO in Europe. It is difficult to compare bird densities across Europe, even if the habitat type and management, as well as the climatic conditions are similar, due to differences in survey methods and study area coverage. However, we will compare our data mainly with some European populations, where forest structure and climatic conditions are closer to those from our study area.

For TO, different densities were calculated in Europe. In the central-eastern Alps, Italy (55 km^2), the density was 0.12 – 0.6 bp/km^2, from a 200-1,560 m altitude with different woodland types (*Quercus-Tilia*-Acer; *Fagus-Abies*; *Picea*) [24]. Compared to our results, much higher densities were calculated in central Italy (Latium and Abrusso) from coastal thermophilus oak woods (*Quercus*) to mountain beech woods (*Fagus*), in stands (10-1,500 m) between 100-500 ha with only a few beingmore than 2,000 ha. In this area, the lowest densities were recorded in mountain beech woods with a range of 0.8-5.2 bp/km^2, and the highest in thermophilus oak woods: 2.0-14.3 territories on a square km [27]. Densities of 0.4 bp/km^2 were calculated in central

Slovenia, in the North Dinaric Alps (290-1,107 m), on a 140 km^2 area dominated by *Abies alba*, *Picea abies* and *Fagus sylvatica* [31]. In the Balkan Peninsula, Central Montenegro, in a medium-sized mountain (two localities) covered by *Quercus* and *Fagus-Abies* woodlands, the density was 0.6 bp/km^2 [32]. In an area of 10,602 ha of lowland floodplain forest along the Danube and Morava River in northeastern Austria, the TO density was 0.5 – 0.78 bp/km^2 [26]. Similar densities have been reported inthe Carpathians foothills (200-430 m) of south Poland on a total area of 490 km^2 with forest predominated by *Pinus* and *Fagus*: 0.82-0.97 bp/km^2 [19]. In different forest types (*Pinus pinaster*, *Quercus spp*.) in eastern Spain in a 115 km^2 study area, a density of 0.76 owls/km^2 [22] was estimated. Much lower densities of 0.08 bp/km^2 were recorded in forests from semi-arid landscapes (2,182 km^2 of forests with a few *Pinus* and *Quercus* species) insouth-eastern Spain [28]. Regarding the size of the species territory, the area of the Tawny Owl usually occupies 0.35–0,50 km^2 [13, 19, 25]. In prime habitats, the average of its territory, it is 0.10-0.12 km^2, but in poorer habitats is 0.60-0.70 km^2 [16]. The species densities we found are similar to those in European forest types, such as beech and some oak forests. However, our densities are lower than those calculated in thermophilus oak woods from central Italy [27].

5. Discussion

Considering south-eastern, eastern, and central Europe, different breeding densities of UO were recorded, as shown below. In an area of 2,325 ha from the Pieniny Mountain National Park (420-982 m), south Poland, where the forest is predominantly *Abies*, *Fagus,* and *Picea*, a density of 0.09-0.17 bp/km^2 [12] was calculated. In optimal habitats of *Fagus* stands in eastern Slovakia (320-1100 m), the density was 0.2 males/km^2, but the highest density was 1 or sometimes 3 bp/km^2 [21]. Lowland forests of *Carpinus-Quercus*, *Quercus,* and *Quercus-Pinus* stands in an area of 7,108 ha in western Ukraine (Roztochchya area, 300-350 m) and support 0.17-0.2 bp/km^2 [7]. Considering the Balkan Peninsula, the densities were similar in two different areas. Thus, in a 140 km^2 in the North Dinaric Alps (290-1,107 m) in central Slovenia, where dominant tree species are *Abies alba*, *Picea abies*, *Fagus sylvatica*, a density of 0.22 bp/km^2 [31] was calculated. In a survey area of 1,070 km^2 in Croatia, the majority of the population (80%) was found in *Fagus-Abies* forests from the mountain area, with 0.11-0.54 bp/km^2 density [30]. Considering the UO territory, it is known to cover on average 4 km^2 of forests and adjacent areas [11, 13, 19, 25]. As can be seen, the UO densities we found are comparable to many of those calculated in deciduous or mixed forests from different areas of central, eastern, and south-eastern Europe. At the same time, in the area we studied, the species densities suggest an average breeding territory of 4 km^2, as described by relevant studies [11, 13, 19, 25].

6. Conclusions

The densities of the two species are similar to those found in other areas of Europe, requiring a long-term study in larger areas to know the trend of their populations.The forests in the studied area provide optimal breeding conditions for TO and UO.

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DENSITY AND DISTRIBUTION OF SEVEN WOODPECKER SPECIES IN A DECIDUOUS FOREST FROM CENTRAL ROMANIA

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Abstract: *This paper presents a study on the distribution, population size, and abundance of seven woodpecker species in a low and medium altitude mountain from the central part of Romania (Măgura Codlei as part of Perșani Mountains, 560-1,292 m). The study area is included in Dumbrăvița – Rotbav – Măgura Codlei a Natura 2000 Site (ROSPA0037). Covering 1,946 ha of predominantly deciduous forest, the area contains managed and unmanaged stands (about 300 ha of quasi-virgin stands). In addition, a separate body of oak forest and a wood pasture with a total of 87 ha (530-570 m) from the same protected area were analyzed. For the survey, we used the playback method from fixed census points within the boundaries of the Natura 2000 forest. The most frequently identified species was the Great-spotted woodpecker (Dendrocopos major) - GSW, then the Middle-spotted woodpecker (Leiopicus medius) - MSW. The rarest was the Green woodpecker (Picus viridis) - GW. The most abundant species in breeding pairs (bp) were GSW (0.6-0.8 bp/10 ha; 122-163 bp) and MSW (0.4-0.7 bp/10 ha; 81-142 bp). Two woodpecker species of community interest also had high densities, which are generally relatively equal to or greater than those known at the Central European level: the White-backed woodpecker (Dendrocopos leucotos): 1-3 bp/100 ha and the Grey-headed woodpecker (Picus canus) - GHW: 2-3 bp/100 ha.For GSW and MSW, the densities are comparable to or lower than those at the Central European level. Compared to the studies conducted in deciduous forests from the central part of Romania (Transylvania), our densities are obviously higher for GSW and GHW but relatively similar for MSW.*

Key words: *woodpeckers, density, distribution, deciduous forests, Romania.*

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1. Introduction

Birds are suitable indicators of natural habitats, such as forests, that can signal different changes in them [24]. They are among the most frequently used indicators of forest habitat biodiversity and environmental change at the level of forests subjected to significant global pressures [24], but also at the European level where forest management is applied [21].

Woodpeckers, as a specialized systematic group of birds, can indicate diversity in birds at the landscape level, such as in the forest [19], as well as forest habitat quality [18].

Studies on forest woodpeckers in Romania are very few [8, 10, 11] and were usually conducted in small areas. Most of them do not present data on species density or their relationship with the forest management. Only one of the three cited publications presents data on the density of woodpecker species in forest habitats [10].

The aims of this study were: *(1)* to investigate the occurrence, distribution, and density of woodpecker species in a deciduous forest from a low and medium mountain area in central Romania; *(2)* to calculate the actual breeding population of the studied species (especially those of community interest) within the Dumbrăvița-Rotbav-Măgura Codlei Natura 2000 Site ROSPA0037; *(3)* to find any differences in woodpecker density and distribution depending on the forest management.

It is important to stress that up to now, the national studies on woodpecker have analyzed the relationship between woodpecker numbers and forest management.

2. Material and Methods

2.1. Study Area

The study area is part of central Romania, Transylvania Province, Perșani Mountains, the Oriental Carpathians (45°43'N 25°22'E). Concerning altitude, the site belongs to the group of low mountains in Romania, except for the part over 1,000 m. This is called Măgura Codlei (MC) and is included in a Natura 2000 Site – ROSPA0037 Dumbrăvița-Rotbav-Măgura Codlei (Figure 1). The total area of the Natura 2000 Site is 4,434.1 ha [5], and MC area is 2,152.1 ha. The forest of the MC area covers 1,946 ha. Dumbrăvița area (D) is also partially surrounded by forest (77.5 ha) and wood pasture (8.5 ha). Thus, the total forested area of D is 87 ha.

Deciduous forests cover the whole forested area except some coniferous plantation stands. The primary forest type in the MC area is beech forest (*Fagus sylvatica* (L.) is the dominant tree species), then mixed sessile oak – beech stands and pure sessile oak stands (*Quercus petraea* ((Mattuschka) Liebl.) is the dominant tree species) partially with hornbeam (*Carpinus betulus* (L.)). Other deciduous tree species as components of the forest are Norway maple (*Acer platanoides* (L.)), European ash (*Fraxinus excelsior* L.), etc. The coniferous plantations in MC are mainly represented by Scots pine (*Pinus sylvatica* (L.)) and Black pine (*Pinus nigra* (J.F. Arnold)). Concerning the forest age [1], there are both even-aged and uneven-aged stands. The area is covered mainly by mature stands (forests over 80 years) – 1,167 ha (60% of MC total forested area).

Almost 300 ha on the steep of MC have been studied from the point of view of stand naturalness, being identified as old-growth quasi-virgin stands [15]. Dumbrăvița forest is a pure Pedunculate oak (*Quercus robur* (L.)) stand over 120-130 years old. Next to this stand, there is also a wood pasture with large and old oaks (over 200 years).

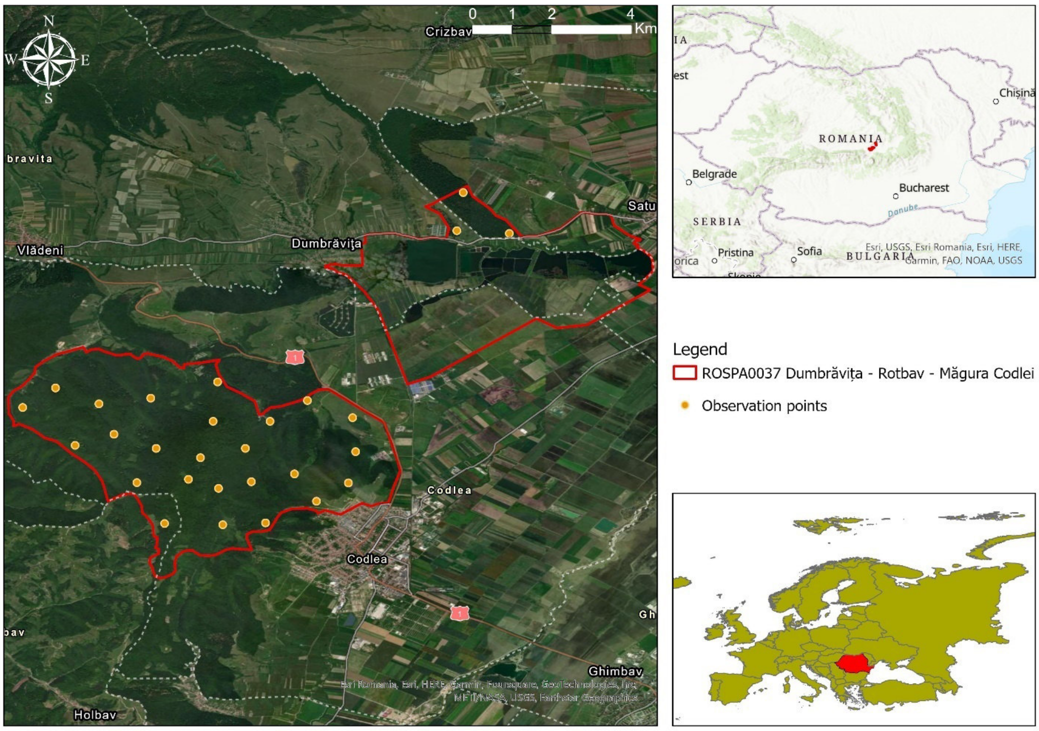

Fig. 1. *Study area and observation points for woodpecker monitoring in ROSPA0037 Dumbrăvița – Rotbav – Măgura Codlei*

The forest management applied in Romania at the level of the hill and mountain areas of the Carpathians includes several types of cutting. For mature stands to be harvested, shelterwood and conservation cuttings are applied to the most significant areas (mainly in deciduous and mixed forests). Through these cuttings, all the old trees are gradually eliminated. Before or during cutting, dead wood is also removed. Clear cuttings are practiced in coniferous stands (e.g., spruce, pines). In addition, in any type of stand, the forestry rules provide for sanitary cuttings, removing even fully or partially dead wood (e.g., snags). The most relevant habitat structures for woodpeckers can be eliminated through all these cuttings, especially through sanitary cuttings.

Concerning the forest management within the study area, it is applied to most of the forest area but with different cutting types and intensities [1]. The most used forest treatment (cutting) in mature/old stands is that of shelterwood cutting based on regeneration gaps within stands. Conservation cuts were made on steep slopes and in other stands with protection aims, similar in technique and purpose to shelterwood. Within the pine stands, clear-cuttings were applied. Some of the mature stands are not subject to main cuttings, but sanitation harvestings (sanitary cuttings) are used on them. In this case, especially dead-standing trees are cut down. The management plan of the Natura 2000 Site provides some restrictions on such cuts to keep some of the essential trees for biodiversity (e.g., trees/ha/ ha of the categories such as snags, hollow trees, etc.) [3]. For the young stands which have yet to reach the age of harvesting, repeated thinning is applied. There will be other changes regarding the forest management in this Natura 2000 Site, such as changing the types of cuttings in several forest units (e.g., only sanitary cuttings instead of some shelterwood).

2.2. Study Design and Woodpecker Data Collection

For this study, we followed the national woodpecker monitoring scheme [4] to build the data collection protocol. The method is based on point monitoring (vantage point), with a minimum distance of 500 m between observation points. The observation points were randomly selected in the study area. According to the size of the study site, 25 points were selected (Figure 1). We considered a radius of 250 m around each monitoring point as the general maximum detection limit of woodpeckers during the application of the method. In this regard, we separated the points according to the type of forest management into two main categories: without management or only with low-intensity cuttings (e.g., sanitary cuttings or accidental cuttings; see the explanations from the study area, forest management) and with management (main cuttings of mature stands or thinning). Thus, there are only two points with forest stands that are strictly unmanaged (old-growth quasi-virgin stands) in the upper area of MC. Another 11 points are located in the forest, where predominantly (> 50-100% of the circle surface) low intensity cuttings were done during the last decades. In the rest of the points (14), the forest was partially (more than 50% of the circle surface) or totally covered with main cuttings, such as shelterwood, conservation cuttings and thinning, depending on forest composition, age, accessibility, the primary purpose, etc. All the points overlap proportionally with forest habitats, in all forest types in terms of composition and age. Two points were selected in an oak stand and one in a wood-pasture. The other 25 points were randomly selected in the forest area of ROSPA0037 Dumbrăvița-Rotbav-Măgura Codlei.

For each point, one visit was conducted per breeding season. The method was applied in two consecutive years, 2021 and 2022. All observations were made during March-April. Only in the case of 2022, due to the weather conditions, the observations were made at the beginning of May for the points above 1,100 m. In case of difficult conditions for accessing the points, they were relocated to a maximum of 400 m from the initial point and a minimum of 500 m from any other point. The observations were conducted during morning hours, between 6 and 12 o'clock and only in favorable weather conditions, using the playback method. For playback, standard recorded calls and/or drumming (about 20 minutes / each point) of the target species were used.

Eight species of woodpeckers were investigated: the Lesser Spotted Woodpecker - LSW (*Dryobates minor*), the Middle Spotted Woodpecker - MSW (*Leiopicus medius*), the Great Spotted Woodpecker - GSW (*Dendrocopos major*), the White-backed Woodpecker - WBW *(Dendrocopos leucotos*), the Black Woodpecker – BW (*Dryocopus martius*), the Eurasian Three-toed Woodpecker – TTW (*Picoides tridactylus*), the Grey-headed Woodpecker - GHW (*Picus canus*), and the Green Woodpecker – GW (*Picus viridis*).

During the observations, all woodpecker species were recorded. For each individual, we recorded the age class, sex (if possible), observation time, position, and behavior. All the observations were integrated into an ArcGIS database, using the marked location for each woodpecker.

The differences in the woodpecker populations between unmanaged and managed forests were analyzed using the Mann-Whitney U test in R statistical software v.4.1 [23].

3. Results

3.1. General Information

During the field observation, seven woodpecker target species were identified. The Three-toed Woodpecker is the only species that was not identified alone in the observation points.

3.2. Woodpecker Occurrence / Distribution in the Study Area

For both years (MC area), the maximum number of identification points and the maximum identification frequency (%) were reported for GSW, with 18 points where the species was identified and a frequency of identification of 50% for 2021 and 32% for 2022.MSW follows with a total of 16 points where the species was identified and a frequency of identification of 30% for 2021 and 40% for 2022 (Table 1). For 2022, WBW also had a high frequency of identification - 40% (Table 1). Regarding the D area (Table 2), only GSW was identified in all 3 points, followed by MSW, with 66% for 2022. In what regards the altitude of the observation points (MC area), the woodpeckers were identified from 570 m to 1,230 m as the highest observation point (Table 1).

3.3. Woodpecker Density and Number of Pairs in the Natura 2000 Site

The most abundant species from the Măgura Codlei forest area was GSW, followed by MSW. At the same time, WBW and GHW have relatively equal densities.

Of the total number of individuals identified for both years, 36.21% were GSW, 24.14% MSW, 13.79% WBW, 12.93% GHW, 6.03% BW, 4.31% LSW, and 2.59% GW. Considering the year 2022, when we had a complete inventory in all 28 points, the highest number of individuals was also GSW (29.58%), followed by MSW (28.17%), and WBW (18.31%). BW (5.63%), LSW (4.23%), and GW (1.41%) had the lowest number of individuals. The density could be calculated for four species (Table 3), according to which the number of breeding pairs (bp) from the Natura 2000 site resulted.

Table 1

The occurrence of woodpecker species, frequency of identification, and some primary data about stand-in point (MC area)

Year	Species	No. of points where the species was identified*	Frequency of detection [%]**	Some basic data about the stand (forest unit) in points***		
				Altitude – average and range [m]	Forest type	Age - average and range [years]
2021	LSW	1	5	660	Pure Sessile Oak	110
	MSW	6	30	715 (570-900)	Pure Sessile Oak, Mixed deciduous forest (*Quercus* + *Fagus* + *Carpinus*), Pure Beech	127 (65-170)
	GSW	10	50	702 (570-800)	Pure Sessile Oak, Mixed deciduous forest (*Quercus* + *Fagus* + *Carpinus*), Pure beech	110 (55-150)
	WBW	2	10	750 (600-900)	Almost pure beech with *Quercus* + *Carpinus* + *Acer pseudoplatanus*	140 (110-170)
	BW	2	10	750 (725-775)	Dominant beech forest with *Quercus*	130 (120-140)
	GHW	4	20	775 (700-900)	Almost pure or dominant beech with *Quercus* + *Carpinus*	124 (65-170)
	GW	1	5	700	Almost pure beech	65
2022	LSW	3	12	760 (660-900)	Pure Sessile Oak, pure beech, Mixed deciduous forest (*Quercus* + *Fagus*)	127 (120-140)
	MSW	10	40	767 (570-1,100)	Pure Sessile Oak, pure beech, Mixed deciduous forest (*Quercus* + *Fagus* + *Carpinus*)	122 (70-140)
	GSW	8	32	725 (570-900)	Pure Sessile Oak, pure beech, Mixed deciduous forest (*Quercus* + *Fagus* + *Carpinus*)	120 (70-150)
	WBW	10	40	860 (625-1,230)	Pure beech, dominant beech with *Quercus* + *Carpinus* + *Acer pseudoplatanus*	100 (55-170)
	BW	3	12	725 (700-775)	Mixed deciduous forest (*Quercus* + *Fagus* + *Carpinus*)	108 (60-140)
	GHW	7	28	770 (600-990)	Pure Sessile Oak, Mixed deciduous forest (*Quercus* + *Fagus* + *Carpinus*), Pure beech	98 (5-140)

Table 2

The occurrence of woodpecker species, frequency of identification, and some primary data about stand-in point (D area)

Year	Species	No. of points where the species was identified*	Frequency of detection [%]**	Some basic data about the stand (forest or wood-pasture unit) in points***		
				Altitude – average and range [m]	Forest type	Age - average and range [years]
2021	LSW	1	33	565	Pedunculate oak	120
	MSW	1	33	540	Pedunculate oak	130
	GSW	3	100	548 (540-565)	Pedunculate oak, wood-pasture with Pedunculate oak	133 (120-150)
	GHW	1	33	540	Wood-pasture with Pedunculate oak	150
	GW	1	33	540	Wood-pasture with Pedunculate oak	150
2022	MSW	2	66.6	553 (540-565)	Pedunculate oak	125 (120-130)
	GSW	3	100	548 (540-565)	Pedunculate oak, wood-pasture with Pedunculate oak	133 (120-150)
	GHW	1	33	565	Pedunculate oak	120
	GW	1	33	540	Wood-pasture with Pedunculate oak	150

** - the ratio between the number of points where the species was observed and the total number of points accessed in that year;
*** - the data were taken from the [1].

We could not calculate the density for LSW, BW, and GW, due to a small number of detections in the field during the study period. However, according to the data collected in the area, we can approximate the population for BW at 3-6 bp, for LSW at 5-8 bp, and for GW at 1-3 bp for the study area.

Density and breeding pairs (bp) of four woodpecker species in the studied forests Table 3

Species	Density [no. of pairs / surface unit, e.g., /10 ha, /100 ha]*	No. of pairs [bp] within Natura 2000 Site
GSW	0.6-0.8 bp / 10 ha	122-163 bp
MSW	0.4-0.7 bp / 10 ha	81-142 bp
WBW	1-3 /100 ha	20-61 bp
GHW	2-3 / 100 ha	41-61 bp

* - the area in which the report was made depends on the species

3.4. The Number of Woodpeckers Depending on the Forest Management

Considering the forest management system, during the field studies, more specimens were recorded in unmanaged stands or with reduced silvicultural interventions compared to those where mainly main cuttings were practiced. Here are three of the community interest species: MSW, WBW, and GHW. In the case of GSW, the number of specimens identified in the two types of management is almost the same (Table 4).

Table 4

The relationship between the number of woodpeckers and the forest management

Main forest management type	Number of woodpeckers / points							
	WBW	GSW	MSW	LSW	BW	GHW	GW	Total
Type A	11	19	19	2	4	10	-	65
Type B	5	21	9	3	3	4	1	46

Type A – unmanaged or low-intensity cuttings
Type B – managed stands with predominantly main cuttings

However, using the Mann – Whitney test, we did not find any statistically significant difference between woodpecker populations from unmanaged or low-intensity cuttings and managed stands with predominantly main cuttings ($Z = 1.0807$, $P = 0.2814$). Analyzing the presence of each woodpecker species in unmanaged and managed forests, we found no significant difference (all $P>0.05$).

4. Discussions

4.1. Woodpecker Occurrence / Distribution in the Study Area

During the field work, surveys recorded seven woodpecker species. Only one species was not observed, but the absence of TTW seems normal due to the lack of characteristic habitat - old spruce forests at high altitudes [14]. In the study area, there is a small stand with old spruce and dead wood from this tree species (about 1.5 ha) above 1,200 m. Considering our observations, these stands are not enough for TTW breeding or feeding.

Woodpeckers were widespread in the main types of deciduous forests, both pure and mixed. Regarding the age of the trees, the preferences were, as expected, for mature / old stands. Some specimens of WBW, BW, and GHW reacted from younger stands, apparently uncharacteristic as breeding habitat for them. These reactions came from woodpeckers whose initial position was in much older stands. The composition and age of the stands (according to Table 1) should be different from the breeding habitat of the woodpecker species. Habitat structure and species preferences for diverse forest elements in this area are the subjects of another study.

Within the D area, it was found that three of the woodpecker species (GSW, GHW, and GW) were identified both in the oak forest and the oak wood-pasture. The other two species (LSW and MSW) were only detected in the forest. In a study on woodpecker assemblage of six species in southern Transylvania, Romania [11], no difference in the number of species between forests and wood pastures was found. At the same time, GW preferred wood pasture and LSW, the forest.

Concerning the observation altitude, the maximum identification altitude of MSW (1,100 m) is somewhat surprising. It usually breeds at altitudes of 300-600 m [14] or between 200-600 m [2], but sometimes also at higher altitudes [9], as in the case of Slovakia (700-950 m). At the same time, all points where MSW was detected at altitudes of 900 m or above are pure beech forests or points where beech is dominant in >90% of the stand composition. In addition to MSW, WBW was identified in two points above 1,100 m and 1,200 m, where the species typically breeds [14].

The distribution of woodpecker species may be of local conservation importance through possibly proposing forest management measures, if necessary, even at the level of stands / forest units.

4.2. Woodpecker Density

Comparing the densities we found with those reported for Romania, Niraj valley, Transylvanian Plateau, the central part of the country within forest fragments, mainly deciduous – *Carpino-Quercetum petraea* [10], there are differences, but also some similarities. Thus, in the case of GSW, our densities are ten times higher than those in Niraj valley. Similarly, for WBW, the minimum value in the area we studied is ten times higher than the one found in Niraj valley. The explanation for WBW may consist in the considerable difference between the surfaces / percentages of the beech stands in the two areas, WBW being advantageous in our site by the domination of beech. For GHW, the density we found is more than five times higher than in Niraj valley. Almost the same values were calculated only in the case of MSW. The existence of comparable types of forests can partly explain these similarities. However, the surface of oak stands or mixed stands with oak is smaller in our case than in Niraj valley. Furthermore, MSW also occupies pure beeches in the MC area.

Numerous studies have focused on determining the densities of woodpecker species in Europe. It is not easy to compare bird densities across Europe, even if the habitat type and management and climatic conditions are similar, due to differences in survey methods and study area coverage. However, we will compare our data to Central European populations, where forest structure and climatic conditions are closer to those from our study area.

For GSW, we found a density of 0.6-0.8 bp/10 ha. This is similar to the European densities for this species, but generally at the lower limits for forest stands, similarly to our study area. In a synthesis of the European status of GSW, Hagemeijer and Blair [14] show that the density was 0.1-6.6 bp/10 ha, with a mean of 1.1 (maximum 5.5) in *Carpinus betulus-Quercus* and a mean of 2.0 (maximum 5.3) in mixed oak-beech and lowland beech from Germany. For western Poland, the density was 1.4-3.3 bp/10 ha in 186 ha of *Quercus-Fraxinus-Ulmus* and *Quercus-Carpinus* stands with 64% over 80 years old [16]. Lower densities were reported in different forest types, especially from mountain areas in Austria [25]. Thus, in the mountain forests of the Upper Austrian and Styrian Northern Limestone Alps, the density was 0.13-0.15 bp/10 ha when computed over all plots (7,656 ha), but the value was 0.14-0.17 bp/10 ha only for plots in which the species was found. For Slovakia [9], as a synthesis, the density varied between 0.3-5 bp/10 ha, depending on the habitat.

For MSW, we found a density of 0.4-0.7 bp/10 ha. According to the atlas of European breeding birds, its density is between 0.3-2.4 bp/10 ha in central Europe, and in most oak stands, the average is about one bp/10 ha [14]. Also, as a synthesis at the European level, the species has variable densities between 0.01-3.9 bp/10 ha [22]. For different types of Spanish oak forests, its density was 0.1-1.3 bp/10 ha [22]. For western Poland, the density was 1.6-2.0 bp/10 ha in 186 ha of *Quercus-Fraxinus-Ulmus* and *Quercus-Carpinus* stands with 64% over 80 years old [16]. In another study from Poland on an extensive forest area of 222.6 ha of remnants of semi-natural flood-plain forest (*Quercus-Fraxinus-Ulmus* and *Quercus-Carpinus*), the density was 1.6-2.5 bp/10 ha and 0.8-2.0 bp/10 ha for 630.8 ha of an isolated *Quercus robur* stand [17]. In a synthesis for Slovakia [9], MSW density in intact natural oak forests was 2.0-2.9 bp/10 ha, while in most oak stands it was 0.2-1 bp/10 ha. Our density is between some of the European forests but generally at the lower limits. These values, below 1 bp/10 ha, seem to show that the habitats we analyzed are obviously below many oak stands, especially those unmanaged or intact natural forests from different areas of Europe.

For WBW, we found a density of 1-3 bp/100 ha. The density of optimal deciduous forests from northern and central Europe is 1 bp/100 ha [14]. In the western Pyrenees beech forests from Spain, the density was 0.3-0.5 bp/100 ha on a total area of 3,200 ha [13]. In different forest types (especially deciduous and mixed stands), some primeval forests or National Parks from Austria, the density was 0.1-2.6 bp/100 ha [25]. Higher densities of 0.6 to 0.7 bp/100 ha were found on 7,656 ha in the Upper Austrian and Styrian Limestone Alps [25]. Within old mixed stands in the National Park Kalkalpen (3,242 ha), its density was 1-1.1 bp/100 ha, and in this protected area, the maximal density was 1.9-2.3 bp/10 ha on 309 ha [25]. In a doctoral thesis from Austria, Frank [12] studied WBW in the montane mixed forests of the

Northern Limestone Alps (Lower Austria). He found a density of 1.38 bp/100 ha in an area of 5,094 ha on optimal sub-plots in the Roth wald primeval forest 1.35-2.57 bp/100 ha [12]. Low densities (0.12 territories/100 ha) were also calculated in the Tyrolian Karwendel, on almost 4,800 ha [20]. In Slovakia, the density in favorable forest stands was 3-10 bp/100 ha [9]. In our case, the species has a density comparable to those found in its favorable and optimal habitats at the European level. Therefore, in general, the forest in the MC area can be considered favorable or optimal for breeding this species.

For GHW, we found a density of 2-3 bp/100 ha. In the breeding atlas, Hagemeijer and Blair [14] reported 1 bp/100 ha as a typical central European density over 215 km^{2}and 2.5 bp/100 ha over 200 km^2. In the Northern Limestone Alps of Upper Austria and Styria, densities were evaluated at 0.5-0.6 bp/100 ha over a large area (7,656 ha) in different forest types, some of them National Parks or reserves [25]. Oberwalder et al. [20] calculated a mean density of 0.69-0.82 bp/100 ha for Tyrolian Karwendelon 4,800 ha. High densities were found in western Austria – Klostertal: 2.0 bp/100 ha [25]. In Slovakia, the highest densities in different types of forest (oak, beech, mixed from mountain, spruce) were 1-3.3 bp/100 ha [9]. The species has among the highest densities at the European level. In this sense, it would be suggested that its habitats in the MC area are generally favorable for GWH breeding.

4.3. The Occurrence and Number of Woodpeckers Depending on the Forest Management

The presence or the existence of a greater number of woodpeckers was expected in forest stands where low-intensity cutting or no cutting at all was done in the last decades. The structure of forest stands from unmanaged or low intensity cuttings preserves better and probably in more significant quantities the essential elements for woodpeckers (large and thick trees, dead wood – snags and downed logs, etc.). On the contrary, main cuttings usually lead to significant structural changes in canopy cover, age, sometimes in the composition of the stand, tree diameter and height, amount of dead wood, etc. [6, 7, 16]. For three of the species of Community interest (MSW, WBW, and GHW), we recorded more individuals in stands without management or with low intensity interventions. However, they also occur in forests where various cuttings of higher intensity have been applied for the most part. We did not observe a statistically significant difference between the forest management stands, but this could be an essential issue for a long-term study. An example is that of MSW, which breeds through several pairs in the oak forest of D area. In the previous winter and almost until the date of the application of the method, several trees in that forest stand were cut down (shelterwood cuttings).

5. Conclusion

To maintain the current populations, especially of woodpecker species of community interest, and to perpetuate a favorable conservation status, several measures are necessary. One of the most important measures is maintaining the actual forest management, which is a close-to-nature and integrative one, with the preservation of the current percentages of forests over 80-100 years old. In parts of the forests where species of community interest or with higher densities of some of these species were identified, we are firstly proposing the conservation of quasi-virgin stands (about 250 ha) with no cuttings. For managed forests, shelterwood and conservation cuttings should be prohibited within some mature stands that hold a significant local population of bird species of community interest (e.g., woodpeckers, owls, flycatchers – *Ficedula albicollis*, *Ficedula parva*). Only controlled sanitation cuttings or accidental cuttings (wood resulting from wind, snow or falling ice) should be allowed in these areas. Thus, almost 183 ha belonging to 15 forest units would have a continuous mature forest structure. At the same time, the application of the provisions of the Natura 2000 Site management plan regarding the preservation of a volume of dead wood (mainly snags) and other categories of thick, hollow trees, etc., is necessary. Considering the conservation of habitat structures characteristic of woodpeckers, in order to have a favorable status of conservation at the SPA or national level, ways must be found to preserve at least a quantity of dead wood. In order to know these quantities, studies are necessary on the impact of cuttings on the various species of woodpeckers.

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POPULATION SUSTAINABILITY ANALYSIS OF PRZEWALSKI'S GAZELLE (PROCAPRA PRZEWALSKII) USING THE VORTEX SOFTWARE

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Abstract: *The Przewalski’s gazelle (Procapra przewalskii) is an endemic species of wildlife found only in Tibet's highlands. The present study focused on two populations, the Haergai and the Yanzhe. To predict the probable behavior of a population over 100 years, the Vortex software (version 10) was used to perform a population viability analysis. The results of the recorded demographic data in our study revealed that the species is classified as Critically Endangered (CE) and its viability is determined by demographic and environmental characteristics rather than by carrying capacity. The Yanzhe population is disappearing at a faster rate as a result of increased demographic uncertainty. The mortality of the individuals of the 1st solar class has a greater impact on the viability of populations compared to other age classes. The dispersal of 3% of the Haergai population into the Yanzhe population may enhance the dynamics of the metapopulations. Management policies such as habitat restoration, intensive surveillance, and protection programs from predators, as well as the strengthening and creation of biological pathways, are also important in facilitating the increase of genetic diversity among subpopulations.*

Key words: *carrying capacity, genetic diversity, viability analysis, biological pathways.*

1. Introduction

The fact that global environmental change can have long-term effects on various wildlife populations is important to conservation biology today [16, 17]. Unfortunately, the number of endangered species significantly exceeds the number of the conservation resources available. This situation appears to be deteriorating rapidly, as continued environmental degradation due to anthropogenic factors (e.g., rapid human population growth and overuse of natural resources) is expected to exacerbate biodiversity threats in the

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future. The International Union for Conservation of Nature (IUCN) estimates that more than one in four species are on the verge of extinction [2]. It has been proposed that human activities are responsible for more than 99 percent of recent species extinctions. Species with small and limited populations are particularly vulnerable to extinction [1, 4].

Przewalski's gazelles are endemic to China and between members of the Bovidae family. The gazelle was named after Nikolai Przhevalsky, a Russian explorer who brought back a sample of individuals to St. Petersburg in 1875. Przewalski's gazelles have historically been found in central and northwest China, including Qinghai, Inner Mongolia, Gansu, Ningxia, and Shanxi. The natural distribution of the gazelle is already restricted to nine isolated groups (Yuanzhe, Hudong-Ketu, Haergai N, Haergai S, Tianjum, Talexuanguo, Bird-island, Shadao and Wayu). The populations are separated by geographical barriers or human activities surrounding Qinghai Lake (Figure 1), a huge lake in Qinghai province, resulting in population reduction and, hence, an increased probability of extinction [12, 24, 25].

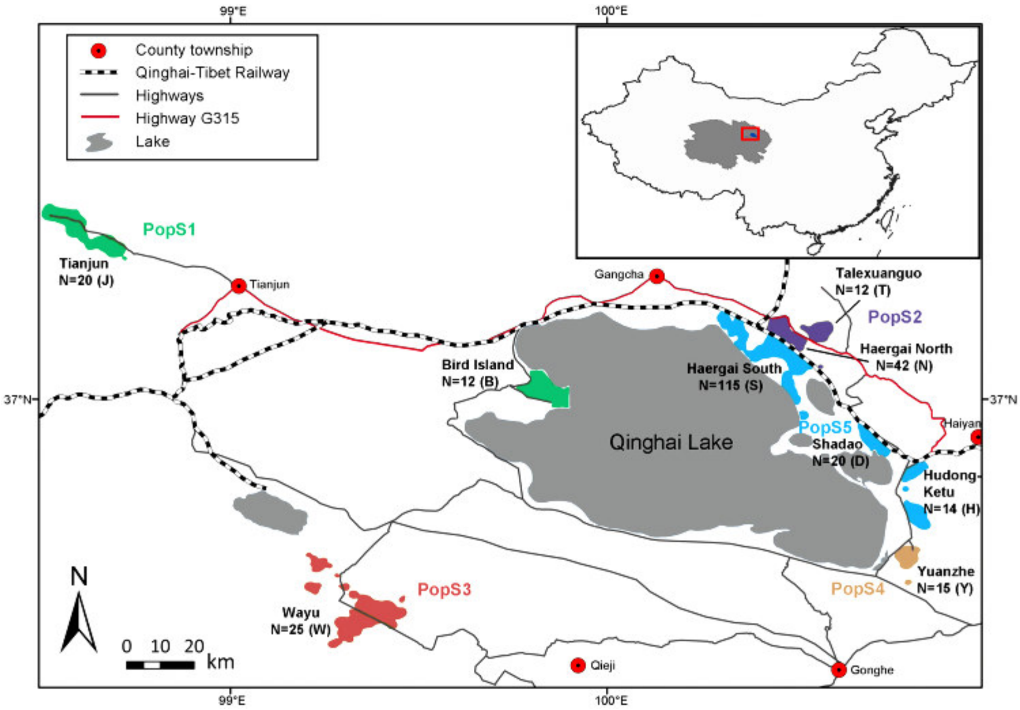

Fig. 1. *Distribution map of the geographically isolated populations of the Przewalski's gazelle along with human structures such as national roads and railways [25]*

More specifically, local economic and construction development, in connection with the development of other infrastructures, not only expanded the geographical fragmentation of the species' natural habitats but also restricted population movement, creating serious problems for the species' sustainable survival [25].

Simulation models to predict the future evolution of a species (Population Viability Analysis (PVA)) [11, 21], especially those with limited populations, have been widely used in conservation biology and the management of threatened and endangered species. More specifically, they are a set of tools that can be used to assess the threats faced by populations, predict whether they will disappear or reduce, and predict their recovery as well [10]. Simulation models for population viability analysis wheel the fate of individuals through generations and provide information on the future course of the population, such as its size, sex ratio, distribution of individuals in different age classes and genetic diversity. The analysis of the population viability depends on the availability of data, the basic characteristics of the ecology of the species or population. The course of the population through simulations is checked several times to indicate the frequency distribution for its disappearance or survival [15].

The present study on analyzing the viability of Przewalski's gazelle populations (Haergai and Yanzhe) using the Vortex software (version 10) provides information about the extinction risk of the two populations and identifies the factors that have the most influence on their conservation and recovery.

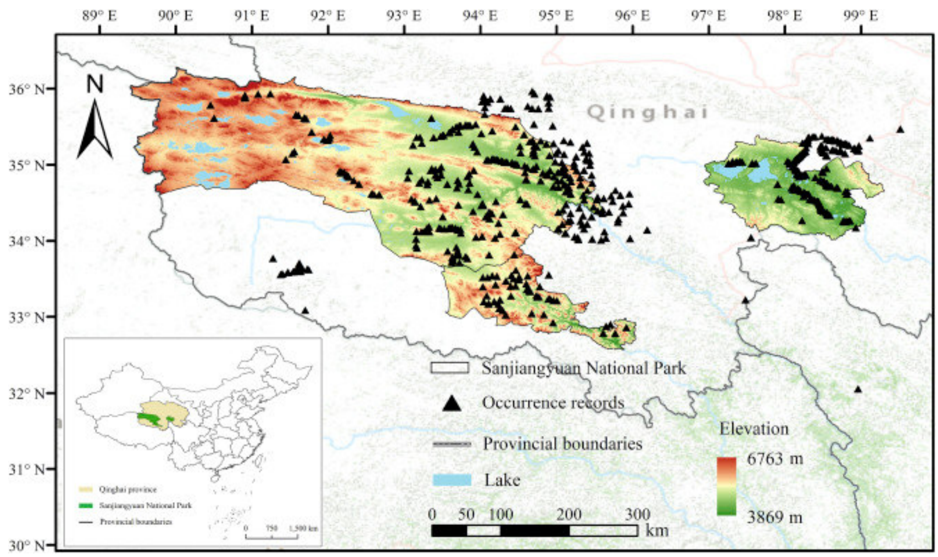

Fig. 2. *Map of Sanjiangyuan National Park showing gazelle populations on the Tibetan Plateau [5]*

2. Material and Methods

2.1. Research Area

The study area is the area around Qinghai Lake in the northeastern part of the Qinghai-Tibet Plateau in China, which is inhabited by the endangered Przewalski’s gazelle (*Procapra przewalskii*) species, namely the two populations Haergai and Yanzhe. As shown in Figure 2, the area has a latitude (N) of 35°56′-37°50′ and a longitude (E) of 97°57′-101°17′. The altitude ranges between 2,100 and 5,300 m. The area has a plateau continental climate with cold and long winters, cool and short rainy summers, and significant diurnal temperature ranges. The average annual temperature is 0.5°C, with the highest at 25°C and the lowest at -31°C [13]. The vegetation types include alpine meadow, alpine grassland, alpine shrub-steppe, and desert grassland [14].

2.2. Material

Simulation models have been shown to provide an unbiased assessment of the extinction risk for well-studied mammals and birds, such as the gazelle population, when using the Vortex software.

Demographic parameters of the Haergai and Yanzhe populations Table 1

	Haergai	Yanzhe
Inbreeding depression		
Lethal equivalents	3.14	3.14
% due to recessive lethal alleles [%]	50	50
Reproductive system		
Reproductive system	polygynous	polygynous
Age of first offspring females [years]	3	3
Age of first offspring males[years]	3	3
Maximum age of female/male reproduction [years]	10	10
Sex ratio at birth – in % males [%]	50	50
Reproductive rates		
Maximum number of breeding periods per year	1	1
Maximum number of broods periods per year	2	2
% adult females breeding [%]	50	50
Average number of offspring per litter following a normal distribution	0.58	0.51
Standard deviation	0.02	0.035
Mortality rates		
Mortality from age 0 to 1		
Average [%]	25	40
Standard deviation [%]	6	12.5
Mortality from age 1 to 2		
Average [%]	8	10
Standard deviation [%]	4	5
Mortality after age 2		
Average [%]	2	2
Standard deviation [%]	0.5	0.5
% males in breeding pool [%]	60	60
Reproduction and mortality rates are correlated		
Initial population size	170	50
Carrying Capacity (K)		
Average	300	200
Standard deviation	30	20

The Vortex software is a powerful tool for researching a wide range of ecological and genetic issues. Developed in the early 1990s [11], it quickly gained popularity as a free, highly versatile, and simple-to-use software. Version 10 includes an almost fully automated sensitivity control unit, which is one of the most significant upgrades. The user can now set value ranges for the parameters to be included in the sensitivity test, and Vortex will generate the relevant combinations automatically. In this way, it is possible to test the effect of individual parameters and the interactions between them in prediction models quickly and easily [17].

2.3. Methodology

The information is from research studies on the gazelle population between 1994 and 2008. Since the 1990s, research and conservation efforts on the Przewalski's gazelle (*Procapra przewalskii*) population have resulted in increasing studies and population estimates [6, 8, 23]. Based on these extensive on-site surveys of the remaining Haergai and Yanzhe gazelle populations conducted from 1994 to 2008, the values for the main input demographics were determined (Table 1).

The viability of the gazelle populations over a 100-year period was compared by entering the demographic data into the Vortex software. To generate more reliable risk estimations, the simulation of the population evolution was estimated with 1,000 different repetitions.

The analysis of population viability allows the prediction of the likely behavior of a population in response to various factors. The effectiveness of specific management strategies can be assessed by simulating extinction processes with different scenarios.

3. Results

After analyzing the viability of the population using the Vortex software, the results are the following.

The estimated average growth rates (r) of the Haergai (N=170) and Yanzhe (N=50) populations are -0.082 and -0.015, respectively (Figure 3). Based on the results with 1,000 simulated populations, only one was preserved in 100 years (Pr. Extinction=1.00) with an estimated extinction probability of 99.9% (for both populations).

The Haergai and Yanzhe populations' viability curves are type I, indicating that the populations' viability will decline to 50% in 28 and 48 years, respectively, resulting in the Haergai population becoming extinct approximately 23 years later (Figure 4).

To determine the viability of the Yanzhe population in relation to the carrying capacity of the habitat, four alternative scenarios with 1,000 different replicates/scenarios were tested. All demographic factors except the carrying capacity mean value (r_K) and standard deviation ($SD_{(K)}$) were constant. For each scenario, the Yanzhe population's mean growth rate (r) and standard deviation ($SD_{(r)}$) were estimated (Table 2).

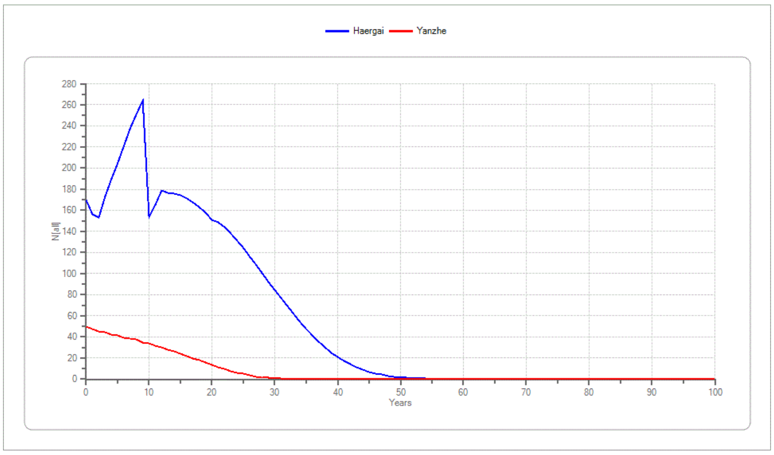

Fig. 3. *The estimated size of the two gazelle populations for the next 100 years*

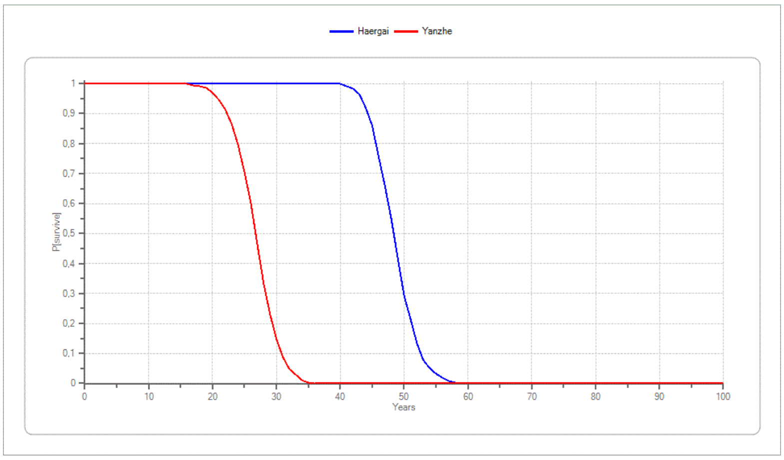

Fig. 4. *Extinction probability of the two gazelle populations in 100 years*

Different carrying capacity scenarios of the Yanzhe population Table 2

Scenarios	$r_K(SD_{(K)})$	$r\ (SD_{(r)})$
Yanzhe	200(20)	- 0.105(0.146)
Yanzhe_K300	300(30)	- 0.105(0.146)
Yanzhe_K400	400(40)	- 0.104(0.146)
Yanzhe_K500	500(50)	- 0.104(0.146)

According to the Vortex software, there are no differences in the development and viability of the Yanzhe population for all four scenarios, demonstrating that the carrying capacity has no effect on population evolution (Figure 5) or species viability (Figure 6).

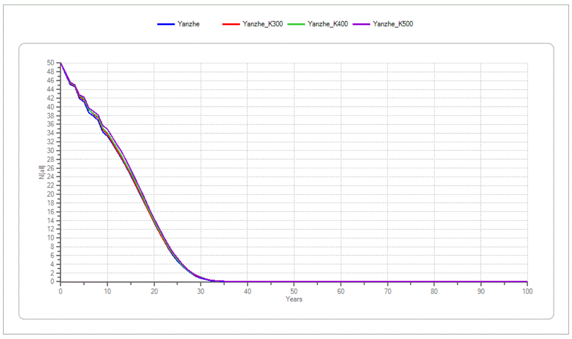

Fig. 5. *Probability of the Yanzhe population extinction for each scenario for 100 years*

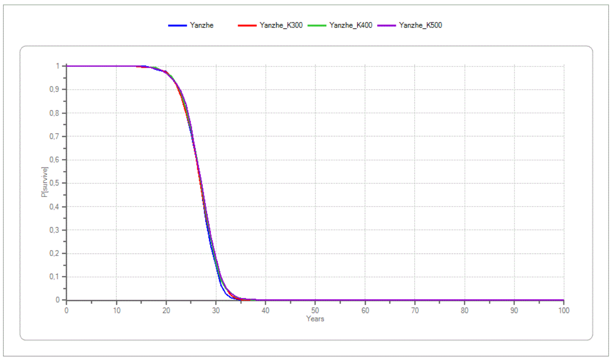

Fig. 6. *Estimated sustainability of the Yanzhe population by scenario for 100 years*

We tested four different scenarios (1,000 simulations per scenario) on the Yanzhe population to determine how mortality rates affect the population (elasticity analysis). For each scenario, the mortality rates for a different age group varied while the demographic factors remained constant (Table 3).

The results showed that the mortality of the 1st age group, as it turns out, has a greater effect on the population of the species whose extinction will take place at a later time (Figures 7 and 8).

Mortality rates by age group for female and male Table 3

Scenarios	Age groups			
	0-1 years	1-2 years	2-3 years	>3 years
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Yanzhe	40(12.5)	10(5)	2(0.5)	2(0.5)
Yanzhe-mortality0	36(12.5)	10(5)	2(0.5)	2(0.5)
Yanzhe-mortality1	40(12.5)	9(5)	2(0.5)	2(0.5)
Yanzhe-mortality2	40(12.5)	10(5)	1(0.5)	2(0.5)
Yanzhe-mortality3	40(12.5)	10(5)	2(0.5)	1(0.5)

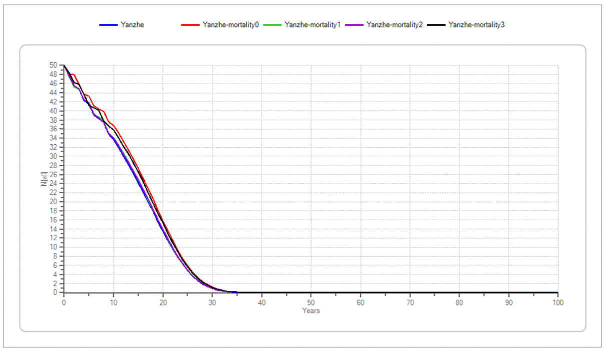

Fig. 7. *Probability of extinction of the Yanzhe population as a function of mortality per age group in 100 years*

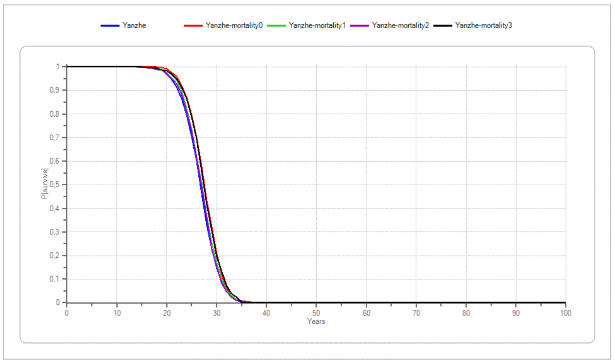

Fig. 8. *Estimated viability of the Yanzhe population as a function of mortality per age group in 100 years*

Through the use of scenarios (1,000 simulations per scenario), this paper examined how inbreeding depression affects the viability of the two populations by measuring the inbreeding of the depression with lethal equivalents. The lethal equivalents are harmful genes that affect the survival and reproduction of offspring from crosses between related individuals (Table 4).

Based on our results, as individuals' inbreeding depression decreases in both populations, the growth rate shows a slight improvement (more obvious in the Haergai population), it delays the risk of the extinction of the populations (Figure 9), and prolongs viability (Figure 10).

Furthermore, the effect of the dispersion of individuals on metapopulation viability was estimated. A total of seven various scenarios concerning the migrations of individuals between populations were analyzed (Table 5).

Based on the data, the most prevalent scenario for the viability of the metapopulations is the Haergai/Yanzhe3 scenario, with individuals (3%) relocating from the Haergai population to the Yanzhe population, which is more maintained (Figure 11) with minimal increment in viability (Figure 12).

Lethal equivalents change as a function of growth rate per scenario Table 4

Scenarios	Lethal equivalent	r(SD)
Haergai	3.14	-0.082(0.154)
HaergaiLE1.54	1.54	-0.073(0.143)
HaergaiLE6.29	6.29	-0.089(0.166)
Yanzhe	3.14	- 0.105(0.146)
YanzheLE1.54	1.54	-0.102(0.144)
YanzheLE6.29	6.29	-0.106(0.147)

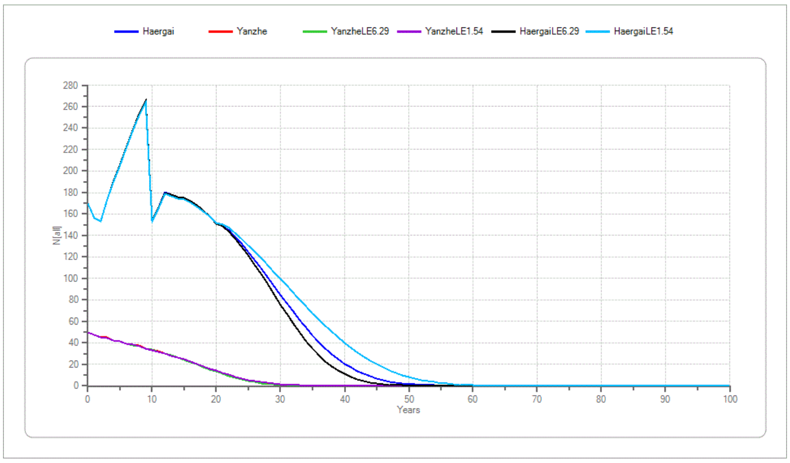

Fig. 9. *As a function of changes in lethal equivalent, the Haengai and Yanzhe populations are at risk of extinction in 100 years*

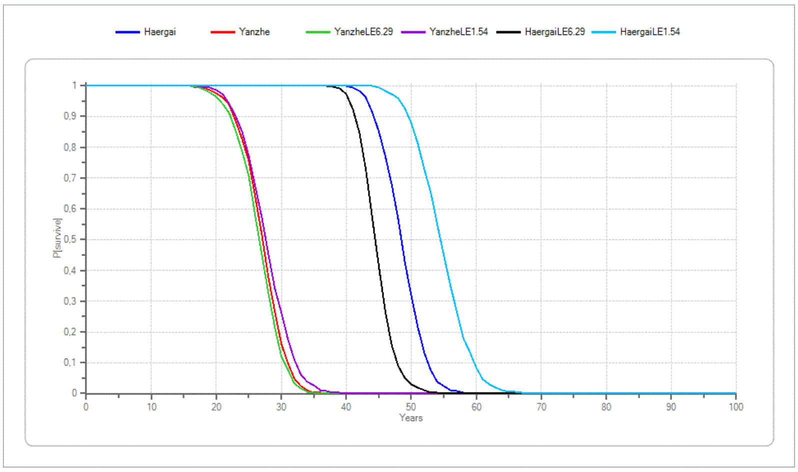

Fig. 10. *Estimated viability of the Haengel and Yanzhe populations as a function of change of lethal equivalent in 100-year*

Dispersal scenarios of individuals (%) between populations Table 5

Scenario	Migration of individuals [%]	
	Haergai	*Yanzhe*
Haergai/ Yanzhe	0	0
Haergai/ Yanzhe1	1	0
Haergai/ Yanzhe2	2	0
Haergai/ Yanzhe3	3	0
Haergai/ Yanzhe4	0	1
Haergai/ Yanzhe5	0	3
Haergai/ Yanzhe6	3	3

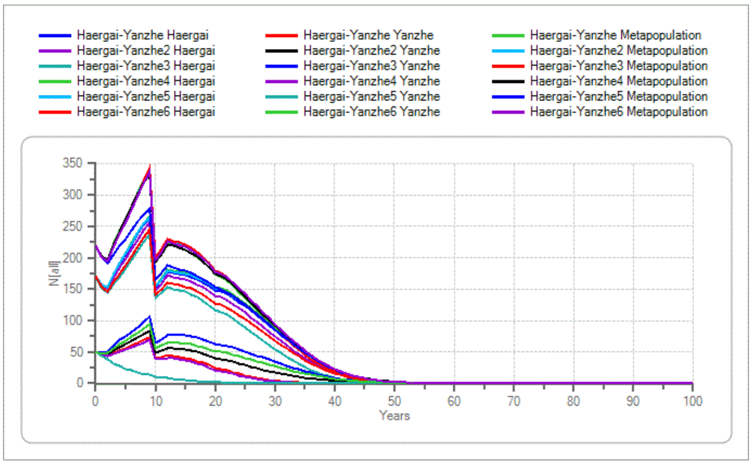

Fig. 11. *Estimated risk of the metapopulations’ extinction based on different dispersal scenarios for 100 years*

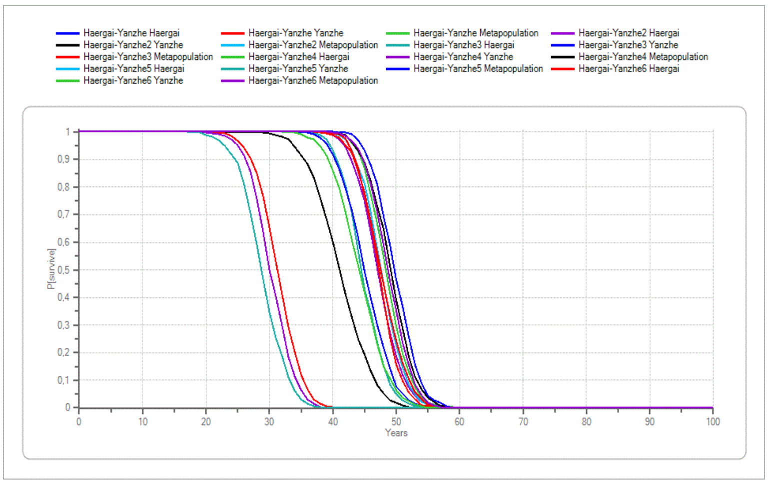

Fig. 12. *Estimated sustainability of the metapopulations based on different dispersal scenarios for 100 years*

4. Discussion

Based on the results presented in this research, the role of homomictic deterioration in gazelle populations is significant, especially in smaller populations such as the Yanzhe population. This population may be isolated for many generations since they do not accept other immigrating individuals to enrich their pool of allelic genes, thus keeping the levels of genetic variability low. More specifically, the populations under study are fragmented and isolated due to geographical (mountains, lakes, deserts) and anthropogenic (railways, roads, human settlements, pastures) factors [13]. Already burdened with demographic factors, they tend to become extinct faster when the lethal equivalents are doubled (relative to the Haergai population) through increased homozygosity in the specific heteromict gazelle population.

Connecting two populations would improve their viability through the dispersion of robust individuals (genetic benefits) and reduce the intensity of phenomena such as demographic uncertainty and the Allee effect. The dispersion of Haergai individuals (3%) in the Yanzhe population is the most feasible scenario for the (temporary) increase in the viability of the metapopulations. In the process of dispersion, individuals are exposed to risks as they move from one habitat to another. Of course, the social behavior of individuals upon their arrival in the new habitat also plays an important role (new individuals are not always accepted).

According to studies published in the 1990s, hunting is not a major threat (after widespread government gun confiscations) [3]. However, the mortality of mainly migrating young females due to the increase of wolf (*Canis lupus*) populations around Qinghai Lake has become one of the most serious threats to the survival of Przewalski's gazelle [9]. Przewalski's gazelle has been protected by law as a category I species in China since 1988. In 2001, it was designated as one of the 15 species in urgent need of protection in China. Several new approaches were developed to police the forests. The gazelle species are now considered a protection priority by national and provincial governments. The population growth of Przewalski's gazelle since the 1980s can be attributed mainly to the establishment of protected areas and a national hunting ban [14]. Four habitats (Bird Island, Shadao, Ganzihe & Haergai) with about 59% of the total Przewalski's gazelle population, are protected in the Qinghai Lake National Reserve and, except for Bird Island, have increased over the past two decades [7, 24]. It is feasible to increase the viability of gazelle subpopulations by combining their spatial and genetic characteristics.

Despite these efforts, the species continues to be threatened by habitat loss and fragmentation, barriers to the movement of individuals between metapopulations, increased competition with domesticated livestock, and increased predation [14]. These risks are exacerbated by human expansion and overgrazing. According to reports, there are about 2.9 million animals around Qinghai Lake [19], which has caused the result that in a period of 100 years they will become extinct due to limited demographic factors (such as small population size, low growth rate, low reproduction and mortality in small class ages). The Yanzhe population become extinct 20 years earlier than the Haergai population possibly due to a decreased population size and growth rate (demographic uncertainty). Also, the survival rate in the Yanzhe population is lower which may indicate a habitat with difficult conditions (lack of food, predation, intense competition). Remarkably, both populations appear to have stable viability over 10 years. The probability of extinction is estimated at 99.9% in 100 years (1,000 simulated populations), while based on the IUCN criteria, the isolated populations are of low size (N < 250 + decline) and with a negative growth rate so that the species can be characterized as Critically Endangered (CE). It is important to mention that a small population even in ideal environments can become extinct due to stochastic threats. That is, even in the ideal case of removing the causal threats, the probability of survival of a low population density does not increase, since random fluctuations in its size can lead to its extinction [20]. For the sustainability of the Yanzhe population, the carrying capacity is not a limiting factor since its changes do not affect the size of the subpopulations.

A small population with mortality in older age classes, such as the Yanzhe population, faces the risk of extinction since females of reproductive age may have little opportunity of meeting males of the same reproductive status, resulting in many females being infertile and average fertility decreasing. Furthermore, small populations may be sufficient to elicit the social behavior required for reproductive activity.

5. Conclusions

The Przewalski's gazelle is one of the world's most endangered large ungulate mammals.The sustainability of the gazelle appears to be negatively affected by low demographic factors such as high mortality and low fertility. Therefore, the species meets the thresholds and conditions as threatened. The conservation status remains serious and regular monitoring of population numbers and trends is essential, in addition to improving connectivity between subpopulations. It is feasible to increase the viability of gazelle subpopulations by combining their spatial and genetic characteristics.

Conservation measures such as habitat restoration and cooperation with local growers are possible to encourage the conservation and renewal of the species' habitats even within pastures to maintain carrying capacity (in this study it is not the limiting factor for sustainability) and to facilitate population recovery. The above practice can be applied to each subpopulation separately to reduce demographic and environmental uncertainty more quickly. Habitat protection is one of the most effective protection measures because the ecological profile of the species concerns remote areas with complex terrain and little human impact. Through intensive programs, the management and strengthening of the supervision and protection (creating and improving an anti-poaching system and preventing illegal commercial activities of wild programs, the management and strengthening of the supervision and protection (creating and improving an anti-poaching system and preventing illegal commercial activities of wild animals) of the habitats can take place to create a harmonious and mild natural environment for the subpopulations. Management may also include controlling the wolf population, which is the gazelle's main predators. It is also important to identify and establish ecological (biological) corridors between subpopulations (e.g., underground wildlife corridors) to facilitate the maintenance and increase of genetic diversity. For this reason, suitable habitats should be protected and restored where necessary to achieve migration by natural predators or non-predators, and thus gene flow. It is therefore important to minimize the impact of anthropogenic landscape features such as human settlements, roads and railways, which have greatly increased fragmentation and affected genetic differentiation between subpopulations.

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RUT DEPTH DETERMINING TO ASSESS THE NEGATIVE IMPACT OF FOREST MACHINES ON THE GROUND SURFACE OF MOVEMENT

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Oleg STYRANIVSKYY[1]

Abstract: *The principles of the forest industry sustainable development largely cover the problems of logging, in particular, harvested wood transportation. The forest machine engine power is mainly spent on overcoming various resistance forces. Such costs are manifested in various types of destruction of the soil surface, as well as in thermal transformations of mechanical energy. Therefore, a higher level of resistance forces requires more power spent to overcome them which leads to a greater level of destructive effects on the soil and the environment, and the greater the fuel consumption, the more material resources must be spent on maintaining forest sustainability. The way to reduce such losses is by selecting rational operating modes - speed and load capacity. The determination of the operational modes outlined above energy approach implemented. These are primarily processes in the soil volume: viscous flow of moisture-saturated soil, soil compaction, etc. In addition, it is the soil volume destruction, breaking off particles due to stickiness. By applying the exergy-anergy approach to the above mentioned processes, the theoretical dependence of the rut depth on contact time, speed and load was established, which to a certain extent coincides with experimental data. In the future, a rational mode of movement can be established under the condition of minimizing the track depth and energy losses for each specific case.*

Key words: *energy approach, sustainable development, overcoming resistance forces, rational operating modes.*

1. Introduction

The interaction of a wheeled or crawler mover with the supporting surface of the movement – the ground – is a rather complex problem that arises in real conditions. As a result of such interaction – single or multiple – compaction of the soil surface is formed, which is manifested by the formation of ruts and other related negative consequences.

The mechanical behavior of soils is an extremely complex and multifaceted problem. Soil, as a continuous deformable

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medium, is characterized by a rich set of rheological properties. Depending on the conditions of external force influence, elastic deformation properties are found in soils; compaction associated with a change in phase composition; plastic deformation; viscous flow; ability to degradation processes associated with wear, chipping, cutting of near-surface or intra-volume soil masses [17, 32].

We owe the study of the interaction of technological transport drivers with soil masses to works [1, 5, 21, 27, 31] and many others. However, the research process is far from over. Attempts to determine the real parameters of the interaction of the driver with the soil, taking into account the phenomena of creep and relaxation, are accompanied by significant methodological and technical difficulties [11, 12].

The article proposes the use of an energy approach to obtain an engineering assessment of the characteristics of the process of forming irreversible residual soil deformations [6]. The theoretical results were subsequently compared with predictive and experimental data [7, 22, 23].

2. Materials and Methods

Let us consider the process of the mover rolling on the soil surface (Figure 1), taking into account the various mechanisms of soil rheological behavior described above.

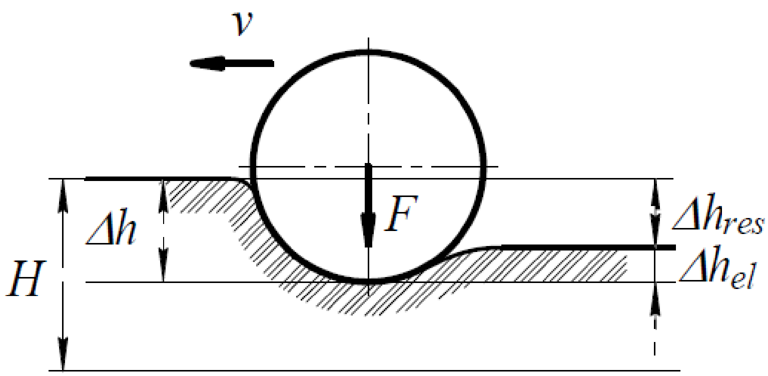


Fig. 1. *Scheme of the mover with the soil interaction; vector $\vec{v}$ indicates the movement direction*

The mover of the vehicle acts with a force F on the contact pad with an area of S_k. As a result of this action, the soil is deformed, and the supporting surface is displaced by the amount Δh. After removal of the external load, displacements from elastic deformation Δh_{el} disappear, and displacements from residual deformations Δh_{res} caused by various rheological processes remain. Among the remaining deflections, it can distinguish the following, indicated by equation (1):

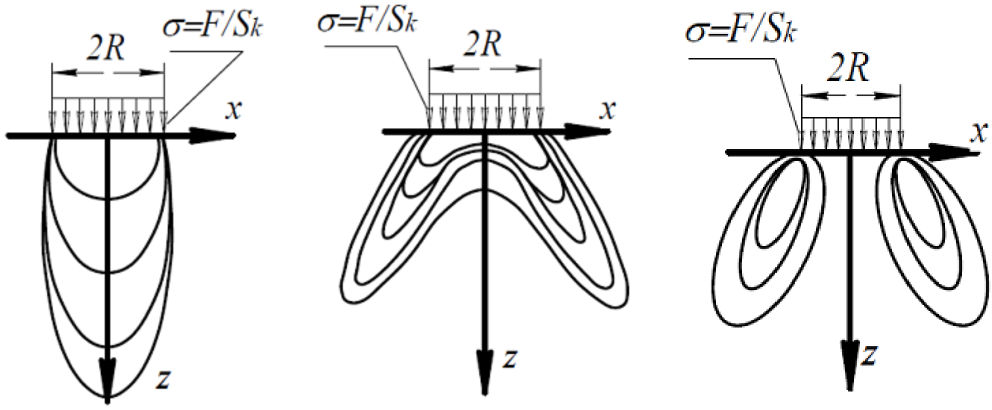
$$\Delta h_{rem} = \Delta h_{\sigma T} + \Delta h_{\mu} + \Delta h_{chip} + \Delta h_{cut} + \Delta h_{slip} + \Delta h_{lat.slip} \quad (1)$$

where:

- $\Delta h_{\sigma T}$ is the residual deflections caused by plastic deformation of soil masses;
- Δh_{μ} – the residual deflections caused by the viscous flow of soil masses;
- Δh_{chip}, Δh_{cut}, Δh_{slip}, $\Delta h_{lat.slip}$ – the residual deflections caused by the processes of chipping, cutting, and wear as a result of longitudinal and lateral sliding of the driver.

All these processes can be modeled within the energy approach, but a complete analysis of such a problem can be the subject of a separate study. The article applies an engineering approach to building the characteristics of the rutting process, taking into account the plastic and viscous properties of the soil.

Following [32], we will use the results of solving the classical Boussinesq problem regarding the influence of a distributed force on an elastic half-space [4]. In this case, the stress distribution will have the form graphically presented in Figure 2. Mathematical expressions of the specified quantities are given in [4]. From the analysis of the stress distribution, it follows that the growth of the external load beyond a certain limit leads to the formation of an area of vertical compaction of the plastic type directly under the driver, the size of which depends on the contact area and the external force. Regions of horizontal compaction and viscous flow are formed in a similar way. According to the shape of the curves presented in Figure 2, it is proposed to approximate these areas in the form of the corresponding cylinder (σ_z) and tori (σ_x, τ_{xz}).



a. b. c.

Fig. 2. *Lines of equal stress for solving the Boussinesq problem: a. vertical; b. horizontal; c. shear stress*

The exact mathematical notation of the solution to this problem is quite complicated. The paper proposes to obtain an engineering approximation of energy expressions for exergy and anergy of the studied hydro mechanical system. The deformed soil mass is considered as an elastic cylinder of height *H*, which is in a combination of two power factors. The first is compression by vertical forces *F*

(Figure 3), which we consider distributed evenly over the contact area: $\sigma = F / S_k$. The second is the corresponding horizontal all-round compression with stresses s_{sq} (Figure 4).

The potential energy of elastic deformation of such an object, which coincides with its exergy, taking into account the solution of the problem of hydrostatic compression of a cylinder [2], is as follows (eq. (2)):

$$E_{el} = Ex = \frac{F^2}{2S_k} \cdot \frac{2 - \upsilon^2}{E} H \qquad (2)$$

where E, υ are the Young's modulus and Poisson's ratio of the soil environment, and H is the effective soil depth at which elastic deformations due to force *F* are significant.

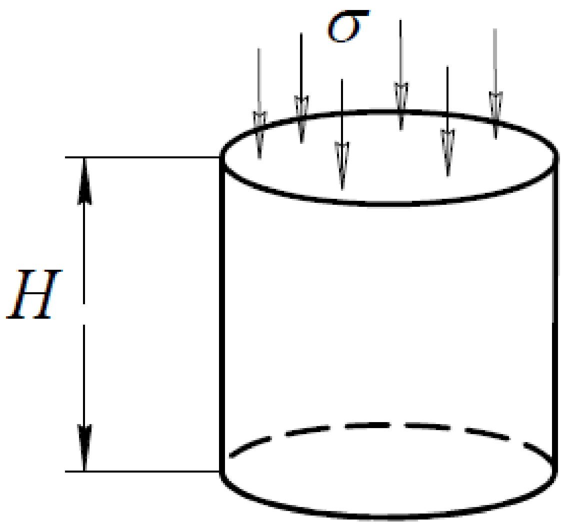


Fig. 3. *Calculation scheme for elastic deformation energy soil base determining*

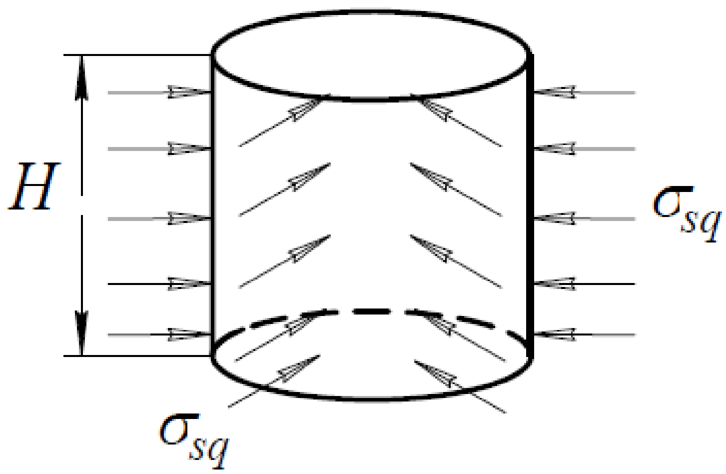


Fig. 4. *Calculation scheme for comprehensive compression*

Performing elementary transformations for the case of elastic deformation, we express the external load *F* in terms of the vertical displacement *w* of the point of force *F* application (eq. (3)):

$$F = w\frac{E \cdot S_k}{H} \tag{3}$$

Taking equation (3) into account, equation (2) can be rendered as follows:

$$E_{el} = Ex = w^2 \cdot \frac{E \cdot S_k}{H} \cdot \frac{2 - \upsilon^2}{2} \tag{4}$$

Applying simplified configurations for areas of plastic deformation in the form of a corresponding cylinder and a torus, we will write down the energy expressions for the considered dissipative processes, which for a cylindrical region of plastic deformation in the vertical direction take the form of equation (5):

$$E_{\sigma T} = \sigma_T \cdot w \cdot S_k \tag{5}$$

For a torus-shaped area of plastic deformation in the horizontal plane, taking into account the expression for the torus volume (Eq. (6)):

$$E_{\sigma P} = \sigma_T \cdot \frac{w}{H} \cdot \frac{8k_1^2}{\sqrt{\pi}} \cdot S_k^{3/2} \tag{6}$$

For a torus-shaped area of viscous flow (Eq. (7)):

$$E_\mu = \mu\pi \cdot \frac{w^2}{S_k \cdot t} \cdot \frac{8k_2^2}{\sqrt{\pi}} \cdot S_k^{3/2} \tag{7}$$

where:

σ_T is the yield strength of soil;

μ – the dynamic viscosity;

k_1, k_2 – the correction factors that take into account the deviation of the real volume of viscous or plastic deformation from the torus.

The anergy expression for the case under consideration will take the form of equation (8):

$$An = E_{\sigma T} + E_{\sigma P} + E_\mu \tag{8}$$

Using equations (4) – (8) in the main variational inequality [33], we obtain for the case of residual deformations of the contact surface the following formula (9), where *t* is the interaction time of the mover and the movement contact surface.

$$w = w(t) = \frac{\frac{F}{S_k} + \sigma_T\left(1 + \frac{4k_1^2}{\sqrt{\pi}} \cdot \frac{\sqrt{S_k}}{H}\right)}{\frac{E}{H}\left(2 - \upsilon^2\right) + \frac{2\pi\mu}{t} \cdot k_1^2} \tag{9}$$

Analyzing the expression on the right-hand side of equation (9), we note the slowing of the growth of the movement surface residual deformation over time, which may indicate a gradual compaction of the soil mass. The residual deformation is significantly affected by viscosity μ and yield strength σ_T. The obtained ratio can be used within certain limits for theoretical and experimental studies of the compaction process and parameters of the contact interaction of the mobile machine mover with the working environment, in this case the supporting surface – the soil.

Figure 5 shows the amount of total (due to plastic deformation and flow) residual deflections *w = w(t)* of the soil contact surface, determined from relation (9), in the case of a HSM-type mobile machine movement at speed *v* = 3.6 km/hour over a wetted soil surface with parameters corresponding to State standard of Ukraine B B.2.1-4 -96 and conditions of known experiments (BHATU-2016) [27]. It should be noted that the obtained theoretical results qualitatively and quantitatively (30% closer to the experimental points in the figure) cover the experimental data more fully in comparison with other theoretical results.

Therefore, the theoretically obtained equation (9) can serve to predict the process of rut development depending on the load of the forest machine, the contact time and, accordingly, the speed of its movement.

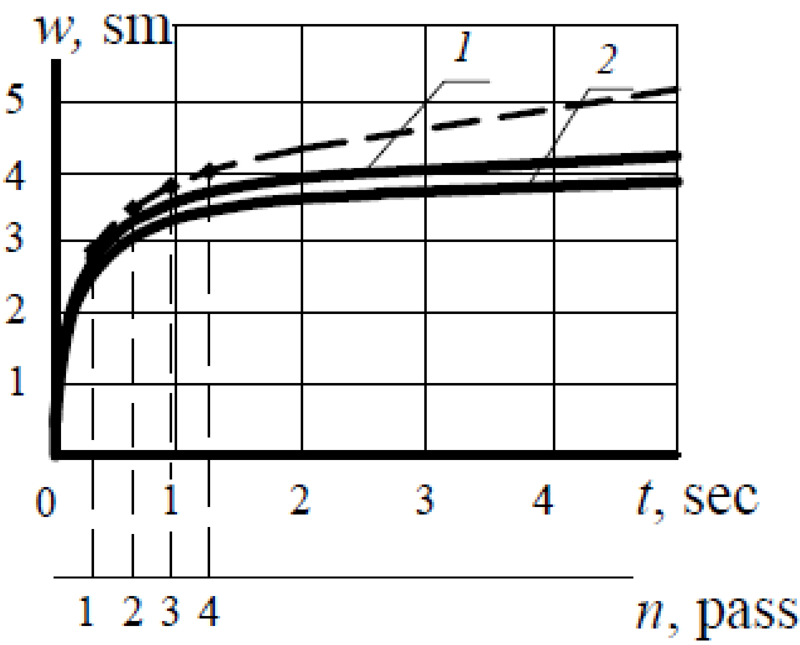


Fig. 5. *Dependence of the residual deflections of the movement surface points on time and the number of passes for different values of soil viscosity μ.*
Legend: *1. E = 5 x 10^6 Pa; μ = 3.835 x 10^6 Pa x s (moistened soils);*
2. E = 2 x 10^7 Pa; μ = 2.902 x 10^6 Pa x s (hard soils); dash-dotted line – over moistened pliable soils corresponding to the conditions of the experiments (points in the figure)

3. Results and Discussion

The range of theoretical studies of rutting is quite wide. The state of the problem in 2015 was characterized in a scientific review [8], and some aspects of the rutting process are presented below.

Paper [12] describes the method of determining the depth of the rut, taking into account the variability of the modulus of elasticity and soil creep cores after each passage of the machine. A comparative analysis of the track depth using similar methods for the case of paving the traffic route with auxiliary materials is presented in [13]. However, obtaining results for specific cases of soil-machine interaction is quite complicated and difficult for practical application. On the other hand, an oversimplified approach using only variable resistance coefficients gives only an approximate assessment of the process and is often far from reality.

In work [27] it is proposed to use the probabilistic approach of statistical physics. Despite the methodological complexity, the obtained results are suitable for the analysis of the experimental data of the same authors. The construction of numerical models for determining the depth of "subsidence" using finite element methods [16] is quite impressive. In particular, a numerical model of the interaction of a rolling or pressing into the soil cylinder has been developed. However, this approach is difficult for the machine operation practice.

Experimental studies of the rutting process are associated with the implementation of expensive field studies in natural conditions. Work [7] describes the results of various stages of field research, starting from the formation of the polygon, to the analysis of the geometric and temporal characteristics of rutting. However, these results are descriptive in nature, which makes it difficult to predict rutting in conditions different from experimental ones. The materials presented in work [27] also have a similar imperfection.

On the basis of a comprehensive analysis, [25] sets out the principles of recommendations for the operation of forest wetland roads in Canada, and in [28] - the risks of soil erosion as a result of economic activity in South Africa. Work [10] analyzed the general state of empirical studies of the rutting process and formulated general recommendations for the operation of freight transport on soil surfaces. A detailed analysis of research related to the study of various aspects of the impact of vehicles on forest soils is presented in review article [8].

In work [18] it was established that the consequences of logging lead to the destruction of the soil area of transportation. Different methods of reclamation do not give the desired effect, so it is necessary to find ways to reduce rutting. Reclamation [9] and maintenance of old forest roads, related, in particular, to the drainage of roads and their recreational use, requires significant financial costs. It was established [15] that forest roads are a source of sediment on land, which is very worrying for areas with a slope. It describes a method of combating the erosion of forest roads by using Word Excelsior mats, which are quite expensive. Damage to forest roads in mountainous areas is caused by full mountain rivers, which are a source of erosion and deposits of stones of various sizes and configurations [30].

Work [24] substantiates the possibility of an energy approach in the study of component mechanical processes, in particular, rutting processes. Modes of interaction of forest machines with the soil should be chosen based on the minimization of environmental risks and excess energy resources that lead to such risks [3].

In article [29], the concentration coefficient was used to adapt the stress distribution equations in the half-space under a point load on its surface. The concentration factor in the Boussinesq equation was introduced by Fröhlich [14] to take into account that the soil is not a truly elastic material and that the stresses are more or less concentrated around the loading axis, depending on the strength of the soil. Research was conducted for volcanic ash soil. These conditions are not typical for the forest machines operation. Therefore, the use of the modified Boussinesq equation with the concentration coefficient and elliptical coordinates requires experimental confirmation.

Modeling of soil compaction [19] showed that the stress distribution at the tire-soil interface is very uneven and significantly affects the stress in the soil. Along with this, such simulation models for the interaction of the tire with the soil serve for planning and decision-making regarding the choice of the maximum force that is applied to the support surface of a given humidity, as well as the determination of the permissible number of vehicle passes to achieve the critical density.

Studies [20] have shown that stress transmission in structured, undisturbed soil can be qualitatively described by the Boussinesq–Fröhlich equation. The effect of load and contact area on vertical stresses in the soil profile was determined and the stress concentration along the load axis was estimated. However, in this study, the accuracy of the prediction of soil compaction at high loads was unsatisfactory even with the adjustment of the concentration factor.

In [26], the calculation of the final volume density profile for the vertical stress distribution on the soil surface was performed using a new approach in PLAXIS. The influence of the change in the mechanical parameters of the soil, caused by the difference in the texture or water content in the soil, on the plastic behavior of the soil was confirmed. The change in the water content in the given soil can also change the form of vertical stress distribution. This approach can be used to calculate an appropriate vertical stress distribution for compaction modeling given the soil type described by the mechanical parameters, beam bending stiffness, and applied uniform vertical stress.

The main shortcomings of the above-mentioned studies are descriptiveness and the use of empirical methods or theoretical methods based on complex mathematical models. This makes it difficult to predict the process of rutting in the general case of different types of soil under the action of engines of forest machines or other technological transport, which differ in structure and load.

The methodology of the energy approach to the study of the rutting process and the construction of the mathematical expression of the rut depth is proposed in this work. The results were obtained using engineering evaluation of energy expressions. These results are suitable for practical use in the future.

In order to build the theoretical foundations of mechanical processes that occur during the contact interaction of the wheel with the movement contact surface, this paper developed an energy analysis of the factors of such processes. Since the energy resource is additive for any mechanical system, in particular, for the "machine - ground surface of movement" system, its use makes it possible to summarily and comprehensively take into account all significant phenomena accompanying the progress of the track. The energy approach is proposed to be used in the form of exergy-anergy balance of the system, as described in [33].

4. Conclusions

The application of exergy-anergy analysis for the forest machine mover interaction with the ground surface of the movement makes it possible to combine the main factors of such a complex process into one equation. Namely: elastic deformation, plastic deformation, viscous flow of soil masses and, if necessary, other destructive processes. Each of these processes contributes to the overall picture of track development.

Analytical dependence of the amount of the soil mass residual deformation on the machine load conditions, the state of the mover (the size of the contact pad), the contact time and, accordingly, the speed of the machine was obtained. A theoretical graph of the residual deformation dependence was constructed, which corresponds well with individual experimental data. This match is 30% better than other theoretical methods.

Therefore, the obtained results can serve to predict the intensity of rutting. In addition, these results can be used to determine rational operational modes in specific soil conditions.

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AN OVERVIEW OF THE PHOTO TRAP CAMERA AS A SURVEY TOOL FOR WILDLIFE

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Abstract: *This study provides an historical review of the methodological and technological evolution of camera trapping as a species survey tool. Camera trapping has a long history but, as a wildlife survey and research method, its history is quite recent. Eadweard Muybridge first used what modern biologists would consider a 'camera trap' in the USA between 1878 and 1884. By the mid-twentieth century, smaller photographic equipment and the replacement of the clumsy and dangerous magnesium flash powder with flash bulbs allowed further refinement of remote wildlife photography. In the beginning, the concerns regarding the use of photo trap camera were the achievement of independent and multiple captures of images with the best possible quality. Later, with technological developments, these concerns took second place, the techniques and methods of collection and integrated analysis of data becoming a priority. The scientific publications analyzed highlighted the evolution of the use of photo trap cameras from simple presence-absence studies to more complex monitoring studies that include aspects of population ethology, ecology, and estimation. Current scientific research is concerned with improving and standardizing data collection and analysis methods so that scientifically rigorous results are obtained. The current interest of researchers regarding the use of photo trap cameras is to use more expensive brands that offer higher speed, greater functionality, more reliability and the ability to interconnect with GIS, GPS, and statistical software and data transfer via the internet.*

Key words: *wildlife monitoring, camera trap, data analysis, data collection.*

1. Introduction

Nowadays it is quite uncommon for a researcher or a wildlife manager to have never used camera traps for wildlife monitoring activities. This cost-effective method whose sampling usually implies proper protocols contributes to the collection of dozens of data [23]. A photo contains plenty of information worth

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analyzing [30], and many of them may get lost because of the precarious analysis of the metadata [9]. Revealing the size and evolution of a wildlife population is imperative for its conservation status and management decisions. Consequently, camera trapping as a survey tool should be species and area specific, to provide reliable outcomes [15]. The current review aims: *(1)* to provide perspectives on the evolution of camera trap monitoring; *(2)* to present tools and software for data analysis following camera trapping, and *(3)* to evaluate camera traps as a survey tool for wildlife monitoring.

2. Evolution of Photo Trap Camerasfor Wildlife Monitoring

Eadweard Muybridge is considered the father of motion pictures. In 1878, he developed a system with many cameras which captured a horse while galloping and these were all triggered by the animal breaking the strings [17]. More than a decade later, in 1890, George Shiras III improved the technique and managed to capture wild species using a remotely accessible camera which was pulled by a very long wire. The wire was placed in a way so that the captured individuals took their own pictures [25]. National Geographic Magazine had made public the first wildlife photos received from Shiras and the use of photo trap camera received a humble boost, as some other researchers began to use them for monitoring activities of different species which were poorly known back then and which came from various regions (remote islands belonging to Panama, Africa, Indonesia, India) [24]. Hunters from the USA discovered the opportunity for trophy search by using remote cameras; thus, a small industry began at the end of the 20th century [23]. The industry is in constant development [3]. This is also proven by the number of Web of Science (WoS) indexed studies using camera traps which increased rapidly in recent years. The Results section provides more insight into this fact.

3. Material and Methods

The research articles retrieved for this review were obtained using the WoS database with the following query: ALL=("photo trap" OR "camera trap" AND "wildlife" AND "monitoring"). Therefore, only peer-reviewed research work was included, and the search was conducted in November 2022. The results were refined using the feature of publication year, which was set starting with 2018 until the current year (2022). Inclusion/exclusion criteria were used to further refine the outcomes. A clear inclusion criterion was the data analysis following camera trap monitoring, thus having them eventually listed in this paper. Similar studies were excluded. This paper focuses on the sampling and results sections from research studies which used photo trap cameras as a field tool for several wildlife species. Therefore, the identification of this information was the deciding factor retrieving or excluding the evaluated study.

4. Results

4.1. Retrieved Articles

Figure 1 illustrates the rapid expansion of the number of papers on this topic indexed in WoS. A decade ago, 13 records resulted following the query “photo trap" OR "camera trap" AND "wildlife" AND "monitoring". Meanwhile, the number of records escalated, reaching 77 for the last and current year (2022).

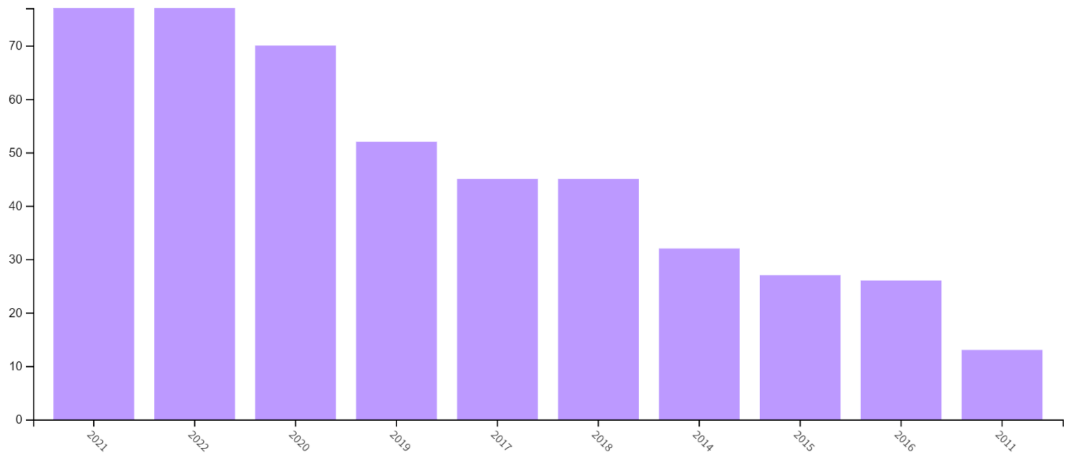

Fig. 1. *Number of articles by year (2011-2022) from Web of Science using the query "photo trap" OR "camera trap" AND "wildlife" AND "monitoring"*

320 articles resulted using the chosen query in the well-known database. Following the inclusion/exclusion criteria, we sorted out 300 articles which did not fit into the field of interest of this review. Many records were similar, using the same tools and software to analyze and model the data gathered using photo trap cameras. The most relevant outcomes retrieved from 20 peer-reviewed research articles are presented in the next section.

4.2. Data Analysis Following the Use of Photo Trap Cameras

There are significant factors which should be taken into account before collecting data with camera traps for research activities. Establishing the type of study (the study scope) that will be conducted is the first step, which is followed by the second step: determining the targeted fauna species. Generally, the most common scopes are species inventory, occupancy, density of one species (via spatially capture recapture-SCR, capture mark recapture-CMR) or density of multispecies (via random encounter model-REM) [24]. Another factor is the number of cameras per sampling site which usually is a compromise influenced by financing resources and human vandalism acts [9]. Moreover, the period of monitoring can significantly impact the captures according to the species and site ecology [18]. Another influencing factor is the sampling period and location which depends on the study scope and often may face trade-offs caused by lack of resources. Sometimes the captures should be maximized, and baiting is used, while other times the sampling should be random. The special features of the camera help to get superior quality images from which metadata can be easily extracted [24].

The study scope and data analysis according to the location and targeted species of the retrieved literature Table 1

Study scope	Data analysis	Location	Targeted species	Reference
Transfer into species management	Relative Abundance Index (RAI)	India	Carnivores and herbivores	[20]
Test effectiveness of baited and un-baited camera trap sites	Recoynx MapView Professional, Presence	North America	Terrestrial Mammals	[2]
Facilitate use of artificial intelligence in wildlife ecology	Wildlife Insights, Machine Learning for Wildlife Image Classification, MegaDetector and Conservation AI, R studio	NA	Animals	[28]
Occupancy estimation of the two species	CamtrapR package, Unmarked package, Vegan package, RSF modelling	Swiss-France	Wild boar, roe deer	[29]
Distribution range, abundance and density estimation, activity patterns analysis, ecological interactions, species inventory	Rstudio (text mining)	Mexico	Mammal and bird species	[19]
Population density estimates, improvement of REM	REM	Spain	Iberian lynx	[7]
Monitoring activity, species management	Spatial capture-recapture (SCR) model, OpenPopSCR, gelman.diag, coda, secr, relative abundance index	Central Europe	Lynx	[21]
Individual identification, population monitoring	Rstudio (betareg)	UK	Urban fox	[4]
Alternative to telemetry, monitoring	R studio (adehabitatHR)	Brazil	Forest deer	[10]
Individual presence	ClassifyMe	NA	Wildlife	[6]
Population monitoring, abundance estimation	ExifPro	NSW, Australia	Feral cat	[26]

Table 1 (continuation)

Study scope	Data analysis	Location	Targeted species	Referenc e
Population monitoring, abundance estimation	SCR model, package SECR and SPACECAP	Namibia	Leopard	[22]
Abundance estimation	Closed CR, spatially explicit capture-recapture (SECR) models, R package (rjags,NIMBLE, mcmcplots, sf, ggplot2)	Canada	Grizzly bear	[14]
Abundance/density estimation	Site-structured, unmarked spatial CR, REM, Space-to-event instantaneous, distance sampling (DS), R package (SiMRiv)	NA	Wildlife	[8]
Species identification	R package (MLWIC2)	USA	Wildlife	[27]
Distribution, diel activity pattern, management decisions	RAI, linear mixed model with a Poisson distribution in R package lme4	Japan	Wild boar	[13]
Species distribution and activity pattern	Data classified “by hand”, Steel-Dwass multiple comparison test	Japan	Brown bears and sika deer	[16]
Activity pattern and behavior against predator analysis	Data classified “by hand”, kernel density estimator, R package (overlap)	USA	White-tailed deer	[12]
Density estimation	REM, DS models, R package (DHARMa)	Germany	Red deer	[11]
Density estimation, evaluation of density fluctuation	SECR model, SPACECAP software, CloseTest, Kruskal-Wallis test, Spearma’'s rank correlation coefficient (SRCC)	Czech-Slovak-Polish	Lynx	[5]

Unfortunately, this can also face trade-offs because of financial reasons and vandalism acts [23].

The main objective/s of the retrieved literature together with the tools and software used to get the results are listed in Table 1. Information referring to the study location and targeted species is also included in Table 1. Almost all the reclaimed research articles put the focus on species management, while the other ones intended to improve the effectiveness of the method. The collected results vary from simple analysis/software which contributes to the image metadata extraction to much more comprehensive analyses. The Akaike Information Criteria score (AIC) was used for ranking the resulted models [2] for over 90% of the cases from the retrieved work and succeeded in filtering the reliable findings.

5. Discussion

The camera trapping method is used as primary or supplementary to other techniques [19]. The captures reveal the most appropriate time when the wildlife is active, so that researchers and managers will know when to organize their work. When studying home range, telemetry is most likely to provide better results than camera trapping, which is also not recommended for habitat use studies especially in extremely heterogenous landscapes [10]. However, individual identification is discussed often when analyzing data gathered via camera trap monitoring [3]. A study on captured snow leopards proved that even the expert individual identification tends to be misleading. The results showed that both the specialists and the non-specialists have the tendency to overestimate the existing population when evaluating the photos by hand [15]. A suggestion is to consider the possible biases, and to supplement the monitoring method with another survey tool [19]. Another study presented a specialist who managed to recognize individuals of urban fox, even if this species presents no prominent features. The conditions were: high quality of the photo and many recaptures of the same individual from different angles. The experience of the specialist is crucial in this situation [4]. Nevertheless, this cannot be generalized, because it is unrealistic to think that a user is capable of detecting unique individuals only by looking at a photo which could also have very poor quality sometimes [15].

Use of bait and/or lure may be a question when surveying wildlife with camera traps. Baited sites usually increase the detection probability for carnivores. Capturing mustelids was most likely in sites where either bait or lure were placed, while generally the carnivores were more attracted to bait and lure used separately only. No significant result can be mentioned regarding the non-carnivores which did not provide any insights during the study conducted by Buyaskas et al. [2]. The camera should be placed by an expert who knows the sampling site as well, because the final results will be impacted by this factor. A reclaimed research proved that when a correction factor is taken into account, REM can still be used even if the cameras are placed in specific spots where the capture probability is the highest (i.e., roads, main tracks) [7]. However, it is suggested to have the REM corrected and tested priorly in a pilot study.

The technology has grown exponentially since the first models of the remote accessed cameras, so that artificial intelligence (AI) has made advances to analyze the imagery data from high-performance instruments. AI platforms developed to analyze images should be chosen according to the purpose they were created for. Their particular use leads to viable results; thus, the prior choice of the platform is dependent on the type of data the user already has [28].

SWOT Analysis of the photo trap method for wildlife monitoring Table 2

Strengths	**Weaknesses**
• Non-invasive and cost-efficient (in most situations) method. • Works continuously (if handled the right way). • The study may have many different purposes: faunal inventories, behavioural studies, occupancy, density estimation using capture-recapture. • Provides objective records of the wildlife population, individual identification, activity pattern. • Succeeds in detecting more fauna species than other methods. • Wireless data transmission of the collected data.	• Needs to be periodically checked-resources consumption (money, fuel, time). • Sensor performance (trigger speed, sensitivity, environmental resistance). • Battery change, data download, replace SD card. • Sometimes gets stolen or destroyed (not only by humans, even by the wildlife) –the technical components can get damaged after a while. • "The universal one" is not always the best, it depends on the study aim. • Individual identification done by hand can be subjective and depends on the specialist's experience.
Opportunities	**Threats**
• The use of cameras usually has the same goal: management and conservation of species. • Combined with other monitoring methods contributes to knowledge enhancement. • More efficient (in some cases) it was compared to a non-invasive genetic method (Italian study on wildcat). • Technology development led to impressive progress of cameras such as Reconyx, Scoutguard, but also to different software to analyse the results. • The cameras development is in progress and the method is constantly improving because of increased research interest and tech boost.	• Still lack of interdisciplinary approaches. • Non-harmonized protocols. • The recorded absence may be a non-detection, thus a biased result, an underestimation. • If using bait in an irregular manner, the results may again be biased. • The factors with a great impact on the results must be considered, otherwise the outcome will be unreliable. • A realistic examination of the data type which is possible to be collected.

Mexico has initiated several programs to survey wildlife using photo trapping (e.g. National Forestry Commission, National Commission of Protected Areas) and projects are conducted to progress this monitoring method, but the protocols are still non-harmonized at the national level, making data analysis difficult [19]. The need for having the same protocols is generally emphasized. This is crucial especially for large scale, transborder camera trap studies [1]. A harmonized protocol facilitates the data transfer and analysis, which strengthens the management and conservation decisions for the wildlife species.

The SWOT analysis in Table 2 sums up the need for using photo trap cameras as a survey tool for wildlife. Being a cost-effective and reliable method, it is recommended as an additional technique or for revealing the presence of the species and their activity patterns.

6. Conclusion

If the limitations of the method are taken into consideration and knowledge is constantly transferred between the specialists and practitioners, chances to have an improved photo trap camera survey tool for wildlife increase significantly, which will further influence the decision-making process related to the biodiversity conservation.

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EVALUATION OF DEFORMATIONS OF THE FOREST ROAD PAVEMENTS BY USING THE FINITE ELEMENT METHOD

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Abstract: *The deformations produced by trucks and other vehicles on forest road pavements play a significant role in sustainable forestry. The Finite Element Method was used for the determination of deformations, for two types of forest trucks, namely Volvo FH 12.A60 and Mercedes – Actros 2646. Surface force was determined and calculated along curb displacement values on the road. The aim of the present study was to analyze the deformations of forest road pavement made of three layers as a function of traffic intensity and type of trucks that are running the forest roads. Based on the findings, it appears that the maximum displacement took place in the middle area of the contact surface between the road and wheel. The results indicate that the maximum residual deformations occurred after the passing of the rear wheel - axel 2. The residual deformations appeared to be higher after the passing of the last wheel and could increase significantly. Data found in this work can be used for a better maintenance of forest road networks and in sustainable forestry.*

Key words: *FEM, pavement, residual deformations, traffic intensity.*

1. Introduction

Forest roads are permanent transport routes of private property [27] which can be used only with the accord of the administrator of a road. Also, bridges anddefense and consolidation works for crossing rivers or streams, or for traffic safety, signaling signs, as well as other facilities are included in any forest road project design. Traffic is steadily increasing both in terms of the number of vehicles involved and tonnage loaded [5, 6, 9, 33]. Thus, the design calculation of a road pavement requires an accurate adaptation to the current situation. In this respect, the most used method to achieve accurate results is the Finite Element

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Method (FEM) [12, 18, 28, 35, 36, 38]. The Finite Element Method is used successfully both for the determination of asphalt mixture cracking and for the evaluation of rutting pavement paths [4, 8, 16, 21, 22, 30-32]. Researchers in the field succeeded in predicting the life cycle of a road by using such an FEM methodological approach [2, 18]. Moreover, the FEM 3D method may be applied to simulate the vertical strain developed as a result of traffic loads for a road pavement which presents linear viscoelastic behavior [29, 32, 37]. It is worth mentioning that by using the 2D FEM method with the help of the Plaxis 2D software, the elastic modulus of the Californian Bearing Ratio (CBR) for the foundation soil can be determined [25]. Some of the most used software for FEM calculation is ANSYS and ABAQUS [17, 18, 37]. The use of the ANSYS software has led to results considered compatible with the ones obtained through other well-established methods of pavement design [7]. The FEM calculation mainly refers to three-dimensional (3D FEM) and axis-symmetric (2D FEM) calculations [11, 12]. Both methods yield similar results, and the 2D variant offers low resource consumption [10, 12]. In general, the first step in validating the FEM 3D calculation of a road pavementis the validation of the 2D method applied on the same structure [14]. It isalso possible to model the dynamic tire-road interaction in a rigorous and realistic way by using FEM [15, 34, 36]. It appears that the FEM analysis with ABAQUS is preferred for rigid pavements made of concrete [20]. But research studies have been performed on block pavements as well [13, 19]. In the case of asphalt layers it is possible to predict their cracking by using the FEM analysis. In Romania, the forest roads are designed in accordance with the national standardized regulations of the forest roads, based on the region geography where they are located, and according to their importance and functionality [27]. This standard stipulates that the load resulting in the tire contact area is uniform. But by using FEM, its non-uniformity has been modeled and predicted [23, 26]. Road pavement consists of three layers in case of a carried-on quantity more than 50,000 tons/year [27]. Such pavement consists of a ballast base layer (protective layer), polygranular stone foundation 0/90 (bearing layer), and a clothing layer made of broken pore stone 0/70 (wear layer). When the ground conditions impose, a foundation substrate can be introduced as an insulating, anti-foaming, antifreeze, drainage, and homogenization layer [1].

The opportunity of the research derives from the technical evolution that led to the increase of the loading capacity in vehicles of transport, currently reaching up to 38 tons, as the maximum authorized mass on the forest road network in Romania [27]. In addition, the fact that the forest transport network in Romania was designed for a maximum total weight allowed of 25 tons, according to AND 582 [3], and currently the loads exceed this value, it is an important attribute for the necessity and opportunity of the research, it being known that degradations are greatly influenced by traffic, tonnage, and mass distribution on the vehicle's axles [5, 9, 23, 37, 38]. According to what was mentioned above, the aim of the presentstudy wasto apply the Finite Element Method to analyze the deformations (elastic and residual) of the forest road pavement made of three-layers as a function of trafficintensity and type of trucks which are running the forest road.

2. Material and methods

2.1. Geometric Modeling of the Representative Road Pavement and Materials Used

A flat portion of the road with dimensions of 5 x 2 x 2 m was taken in consideration for the geometric modeling of the road. Therefore,the overall deformation occurred due to the pressure forces without any influence on the geometric size used for the numerical simulation as illustrated in Figure 1.

The 3D modeling sample was employed for the finite element calculation. With this approach, satisfactory large road surface was considered resulting in no influence of the geometric dimension of the road. The geometric model of the two roads for Finite Element Calculations is shown in Figure 2. The dimensions of the layers of the forest road took into consideration the dimensions of each layerpresented in Figure 1.

The materials used in this studyfor the three-layer pavement design and their properties are presented in Table 1. For the comparative calculation when using the Finite Element Method, the materials are considered homogeneous and only the elastic deformation area is taken into account.

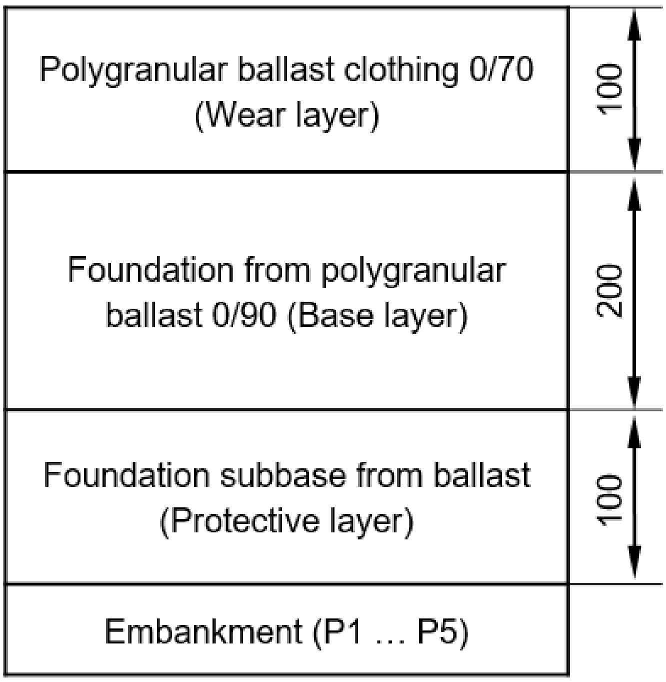

Fig. 1. *The geometric dimensions of the forest road*

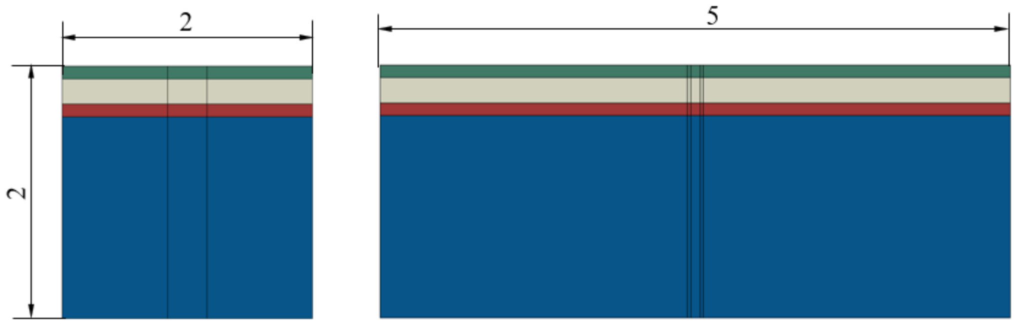

Fig. 2. *The three-layer pavement type*

Material properties used for the pavement Table 1

Type of material	Thickness layer [mm] type 1.x	The modulus of elasticity [MPa] type 1.x	Transverse contraction module ν
Polygranular ballast clothing 0/70 (Wear layer)	100	90	0.27
Foundation of polygranular ballast 0/90 (Base layer)	200	80	0.27
Foundation subbase of ballast (Protective layer)	100	70	0.27
Embankment (P1 … P5)	∞	12	0.27

2.2. Description of the Finite Element Model and application of the Boundary CONDITIONS

The discredited models compiled with the ABAQUS CAE design software (2019 version) of the road are presented in Figure 3. The finite 3D elements by hexadecimal type, which simulate the pavement layers, were attributed to the material properties of each layer. The connection between the layers is achieved by the common nodes between the finite elements.

For a comparative analysis in this study, the maximum load on two forest trucks that support different maximum loads was considered. The characteristics of the two forest trucks commonly used in Romaniaare displayed in Table 2. The total load supported by each axle is distributed on each wheel to obtain the deformation of the road pavement that comes into contact with each wheel at a given time [27, 38]. Thus, the residual deformation that occurs in the road pavement after the passing of a forest truck with a given load can be estimated.

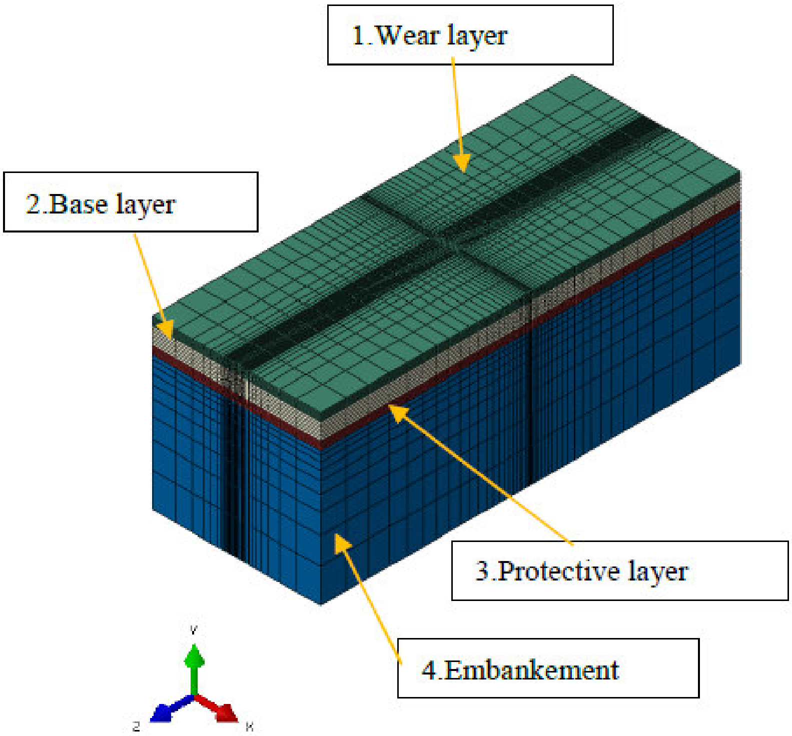

Fig. 3. *Finite element model of the pavement*

Characteristics of the main forest trucks used in Romania Table 2

Brand	Model	Loaded weight [tons]	Axle load [kN]		Load wheel [kN]	
			Front	Rear	Front	Rear
Mercedes	Actros 2646	22.84	60	2x85	30	42.5
Volvo	FH 12.460	47.18	75	2x197.5	37.5	98.75

The contact surface between the wheel and the road is calculated based on the tire size and the wheel pressure, and thus the contact surface is determined (Table 3).

The equivalent contact surfaces between the wheel and the road for each forest truck corresponding to one front andrear wheel are shown in Figure 4.

Figure 5 graphically illustrates the variation of the forces on each wheel pertruck type and the difference between the appliedloads.

The road pavementdesign was established in all directions, based on the embankment layer and the loading force, as presented in Figure 6.

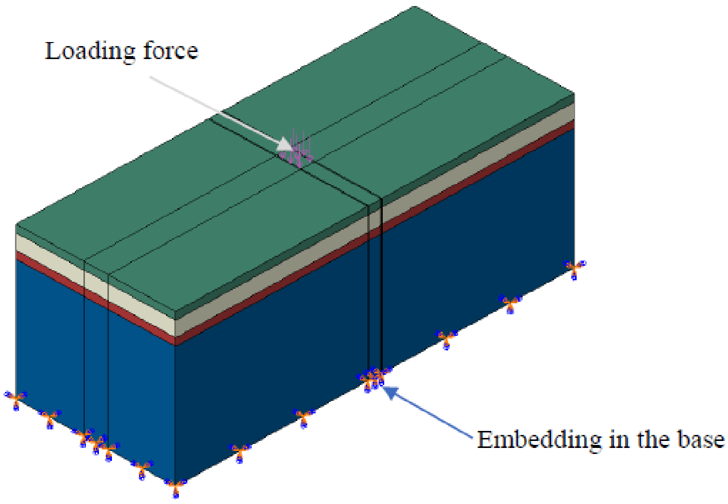

Fig. 6. Boundary conditions

Contact surface between wheel and road Table 3

Brand	Model	Tire size	Equivalent diameter of contact surface [mm]		Contact surface [mm^2]	
			Front wheel	Rear wheel	Front wheel	Rear wheel
Mercedes	Actros 2646	315/70R22.6	226	173	40115.00	23506.18
Volvo	FH 12.460	315/70R22.5	252	272	49875.92	58106.90

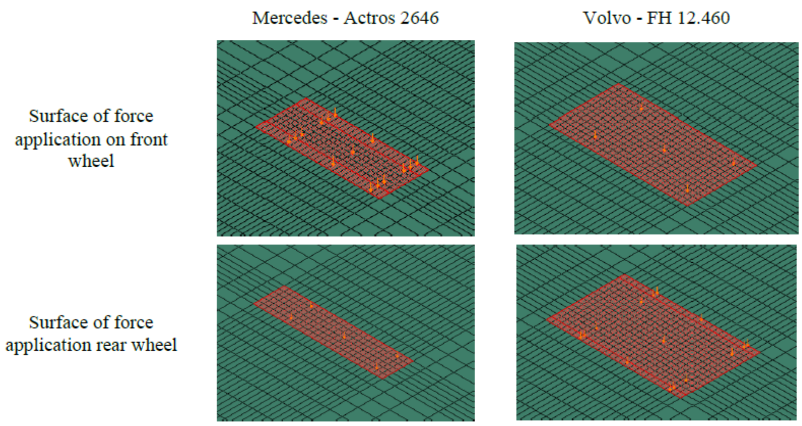

Fig. 4. *Surface of force application for two types of trucks*

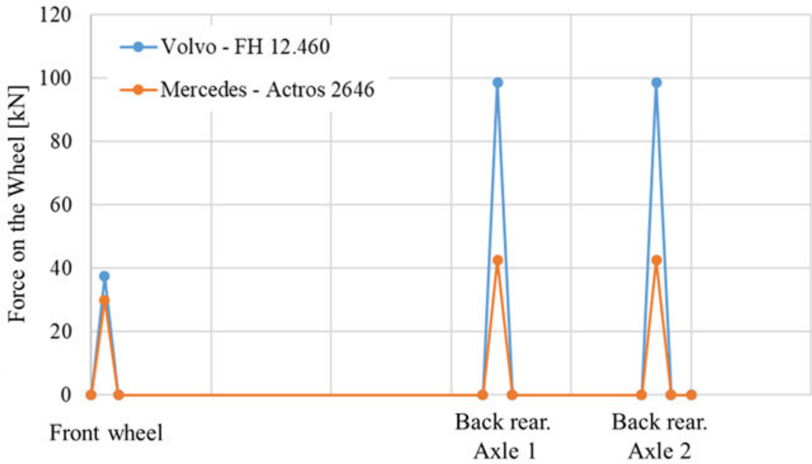

Fig. 5. *Distribution of forces on each wheel for each truck type*

3. Results

The main stresses inducedbythe front wheel – front axle, rear wheel - axle 1 and rear wheel - axle 2 were calculated. The obtained results per wheel and axle were analyzed.The structure displacements in all three cases are presented in Figure 7. It appeared that when running the forest road pavement with a Volvo truck, the structure displacements were higher as compared to the case of using a Mercedes truck on the same forest road; this aspect is a consequence of the technical characteristics of the two trucks (Table 2). Almost similar values for the structure displacement were noticed for the interaction of the rear wheels and their corresponding axles.

The displacement distribution and residual deformations per wheel and axle for each truck type were determined. They are represented in three different graphic ways, such as top view, plan and isometric views, respectively. Two examples of such an approach are presented in Figures 8 and 9.

In all cases, the maximum displacement andresidual deformation were observed in the middle zone of the contact surface between structure and wheel [24]. The maximum residual deformations are displayed in Table 4.

Table 4. *Maximum residual deformations as a function of interaction and truck type*

Type of interaction	Maximum residual deformations [mm]	
	Mercedes - Actros 2646	Volvo - FH 12.460
Front wheel-front axle	2.65e-4	3.35e-4
Rear wheel-axle 1	1.25e-3	2.79e-3
Rear wheel-axle 2	6.09e-3	1.51e-3

By applying the Finite Element Method, the main stresses and displacements for the front wheel – front axle, rear wheel - axle 1 and rear wheel - axle 2 were determined. In the case of front wheel – front axle, the maximum displacements were of approx. 2.87 mm for Mercedes -

Actros 2646 and 3.41 mm for Volvo - FH 12.460. The residual deformations represented approx. 9.23 and 9.82‰ of the elastic deformations for the first and second truck type, respectively.

In the case of rear wheel - axle 1, the maximum displacements were of approx. 4.54 mm for Mercedes - Actros 2646 and 8.64 mm for Volvo - FH 12.460. The residual deformations represented approx. 27.53 and 32.29‰ of the elastic deformations for the first and second truck type, respectively.

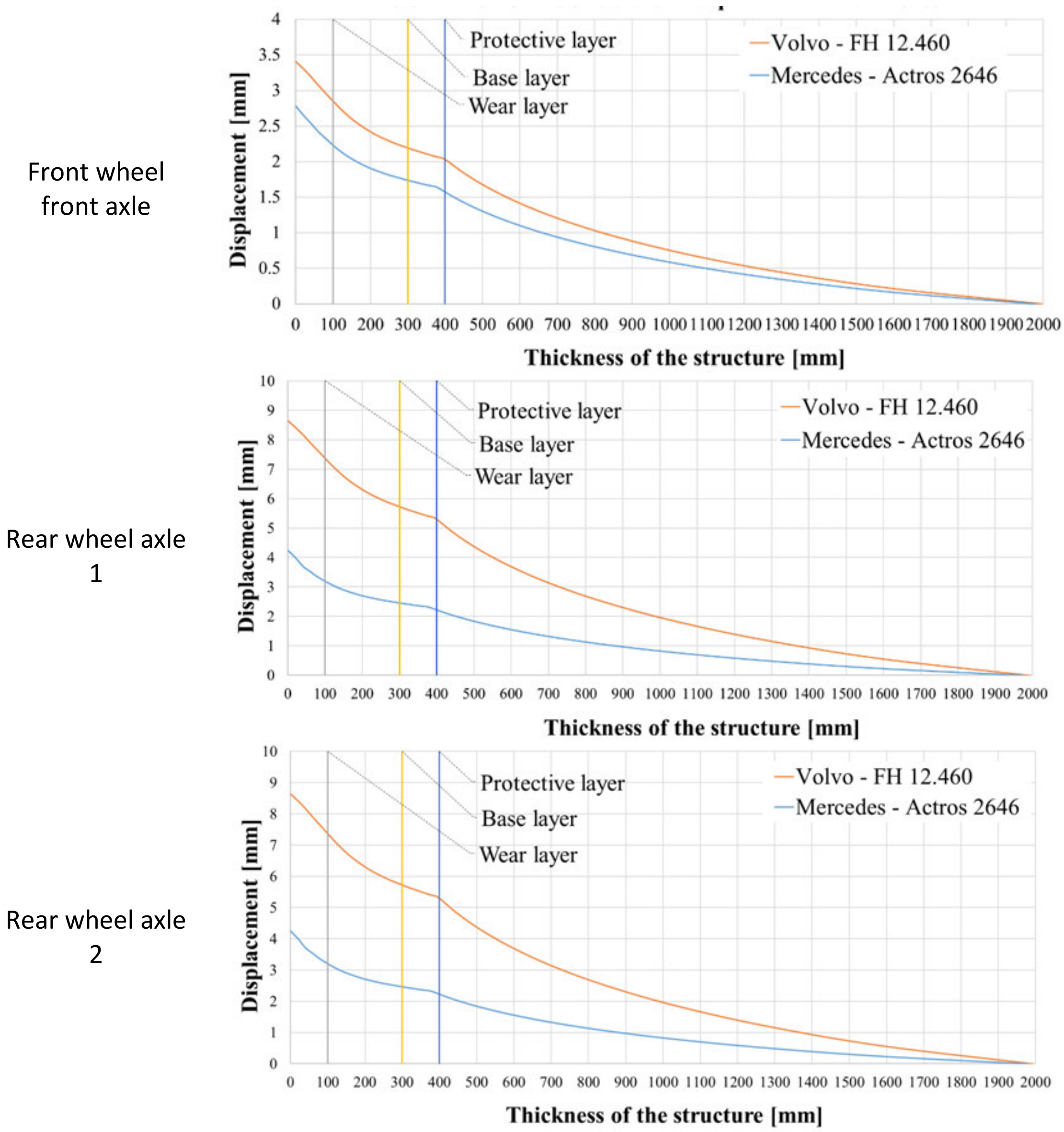

Fig. 7. *Structure displacements into the pavement depth per wheel and axle foreach truck type*

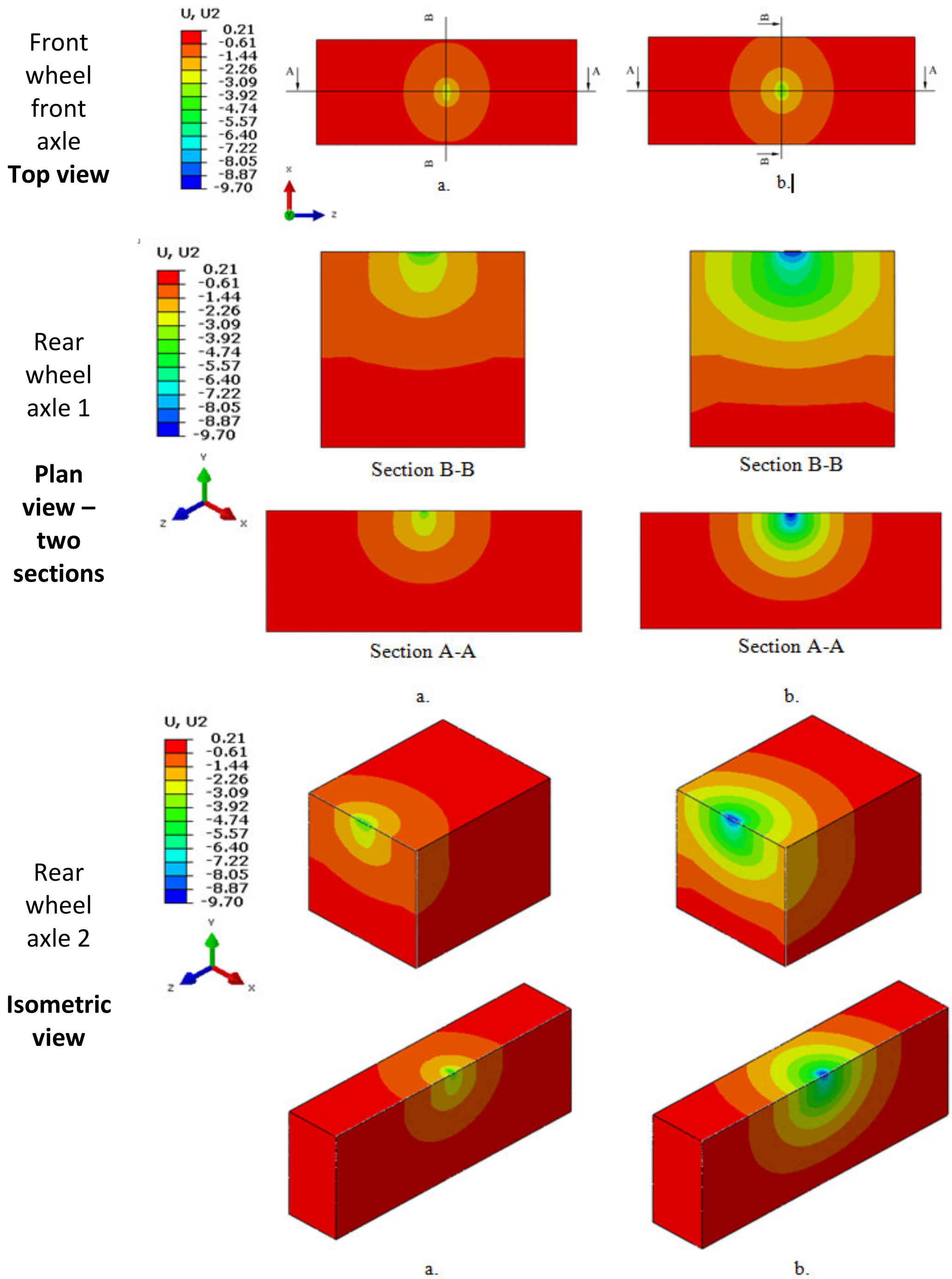

Fig. 8. *Displacement distribution under different graphic representations (top view, plan and isometric views) per wheel and axle for each truck type (a. Mercedes - Actros 2646; b. Volvo - FH 12.460)*

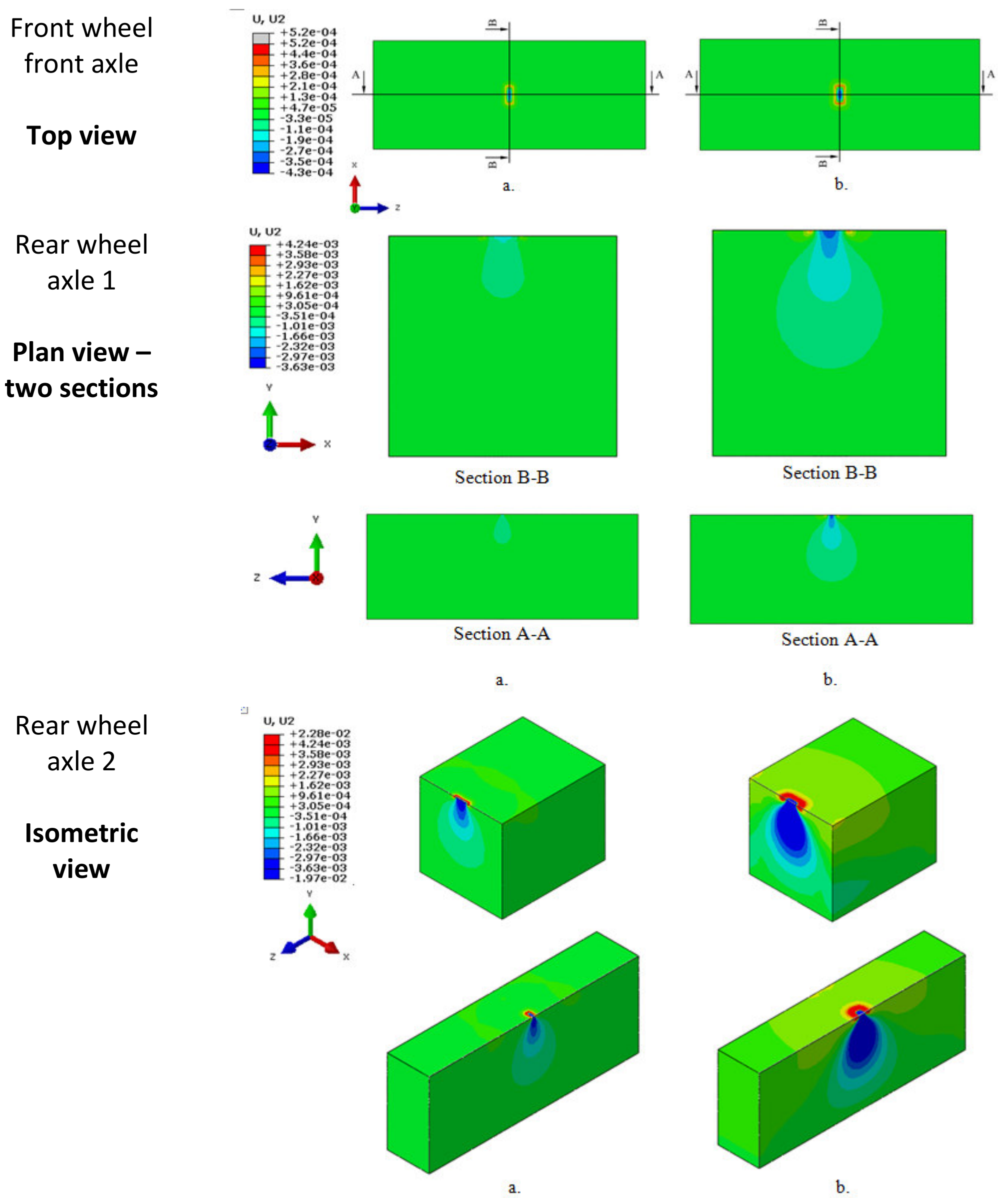

Fig. 9. *Residual deformations under different graphic representations (top view, plan and isometric views) per wheel and axle for each truck type (a. Mercedes - Actros 2646; b. Volvo - FH 12.460)*

In the case of rear wheel - axle 2, the maximum displacements were found to be aprox. 4.55 mm for Mercedes - Actros 2646 and 8.64 mm for Volvo - FH 12.460. The residual deformations represented approx. 13.38 and 17.48% of the elastic deformations for the first and second truck type, respectively.

The average residual deformations were found to be approx. 3.84% of the elastic deformations.

4. Discussion

For simplifying the calculations, the contact surface between structure and wheel, even if it is an ellipse, was considered a circle [24, 27]. The diameter of the equivalent circle varies between 20 and 30 cm in the case of the trucks with single axles and between 30 and 40 cm for those with double axles. The maximum admitted pressure on the contact surface is about 0.6 … 0.7 MPa [27].

Trzciński and Kaczmarzyk [33] state that on the forest roads with a single layer structure of gravel, the deformation modules are influenced in a small part by the thickness of the structure, because the deformations increase both with pressure and carrying capacity as well as with the road embankment or proper pavement construction. The influence of the pressure on the structure can also be easily observed in the present research, where Volvo – FH 12.460 trucks produce higherdisplacements and residual deformations than Actros 2646 trucks, regardless of the axle (front or rear).

Mulungye et al. [23] predicted strains from the Finite Element Model, and mentioned that the single wheel was 2.2 times more than those from the dual tandem pair per unit load in the longitudinal direction and 1.5 times in the transverse direction. Also, they showed that the single steering wheel generates 120% higher strains on average than the dual tandem axles for the same load.

Regarding the most affected point or zone of the structure under the pressure of loading, Leonardi et al. [18] and Musat and Bitir [24] reached the same result as the current study, where all the maximum displacement and residual deformation were observed in the middle zone of the contact surface between structure and wheel. Also, Leonardi et al. [18] mention that the maximum vertical deformations are greater with the increase of the number of carried loadings and the use of geogrid (glass fiber grid) can improve the behavior of the pavement, leading to a longer service period for the forest road.

5. Conclusions

The structure displacement produced into the pavement depth indicated that the maximum displacement was observed based on the values in the middle zone of the contact surface between ground and wheel.

Maximum residual deformations occurred after the passing of the rear wheel - axel 2. The residual deformations are higher after the passing of the last wheel. Therefore, after multiple passes, the residual deformation could increase significantly.

Data found in this work can be used for better maintenance of forest road networks and in sustainable forestry.

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EFFICIENCY OF GROSS FIXED CAPITAL FORMATION IN FORESTRY – DATA ENVELOPMENT ANALYSIS AND MALMQUIST INDEX FOR CROSS-COUNTRY COMPARISON IN EU

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Abstract: *The problem of the economic efficiency of investments in fixed assets is of constant relevance in forestry. The present study aims to analyze the economic efficiency of these assets in the forestry of European Union countries. The methods used are widely accepted non-parametric approaches that sufficiently reflect the advantages and disadvantages of individual countries in managing forestry fixed assets. The results of DEA and the Malmquist index can be applied in practice.*

Key words: *forestry, efficiency, data envelopment analysis.*

1. Introduction

The study of the economic efficiency of forests and forest economic systems is a current topic with constant interest from the scientific community in this direction. Economic efficiency estimation is a powerful instrument in forest management even in the phase of planning [2, 10, 20] or in forest policy [4]. Economic efficiency as a criterion is widely used for entire forest assessment [13, 17]. Some authors implemented the economic efficiency estimation for cross-country forestry comparison [8, 12] until others used it at the level of the forest enterprise or district [6, 11, 17, 18]. One of the most implemented approaches to economic efficiency estimation is Data Envelopment Analysis (DEA). DEA is a non-parametric approach that makes it possible to comparatively estimate the efficiency scores of several basic production components [6] or comparative economic systems. It was introduced by Charnes et al. [5] for the assessment of relative efficiency of similar economic units. According to Li et al. [12] until 2009 the

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share of DEA-based papers dedicated to forestry was only 0.86%, and 4.66% in industry, but the growth of these papers was exponential afterward. In forestry, the DEA approach was successfully implemented by authors [11, 12, 17, 18, 22] who conducted research in forestry. Some of them [15, 22] used DEA, widening the scope of research, estimating the eco-efficiency of forests.

Investments in the economic systems are an important part of their economic growth. Gross fixed capital formation (GFCF) is a macroeconomic concept used in official national accounts [9]. It measures the annual investments in fixed assets like machinery and equipment, which is why some authors put focus on it. Li et al. [13] investigated the efficiency of investments in China forest district through the parametric approach. Others [21] relied on DEA and the Malmquist productivity index (MPI). The Malmquist productivity index is a DEA-based indicator that measures the productivity change between two time spans or moments [16]. Caves et al. [3] decomposed the Malmquist input index [14] to elaborate the so-called Malmquist productivity index.

Gross fixed capital formation does not fall within the scope of previous research dedicated to cross-country forestry efficiency comparison. This is the reason why the main purpose of the current research is to estimate the efficiency of investments in machinery and equipment in some EU countries and to clarify the reasons for improvement. The results reveal the directions for improvement and subsequent recommendations for the forestry sectors in Bulgaria and Romania.

2. Material and Methods

In a similar manner as Kovalcik [12] and Šporčić et al. [18], in the current research are used simultaneously the model with constant returns to scale, or CCR, and the model with variables return to scale, or the BCC model developed by Banker et al. [1].

The CCR output-oriented model with constant returns to scale (Eq. (1)):

$$\max \theta_0^t$$

$$\sum_{j=1}^{m} \lambda_j x_{ij} \le x_{i0}$$

$$\sum_{j=1}^{s} \lambda_j y_{rj} \ge \theta y_{r0} \qquad (1)$$

$\sum_{j=1}^{n} \lambda_j = 1$ for the variable returns to scale (BCC) model.

where:

λ_j are the individual scalars of each j-th DMU;

x_{ij} – the amounts of inputs of type i in DMU j

x_{i0} – the amount of i-th input of DMUo being estimated, indexed with 0.

DMUs are the countries Inputs are Compensation of employees (COE) as vital resource for forestry activities and generation of efficiency and Net value added (NVA) as an indicator for the ability of forestry to add value with labour and good management. Output is Goss fixed capital formation (GFCF) and in particular investments in machinery and equipment.

Caves et al. [3] improved the Malmquist input index to elaborate the so-called Malmquist productivity index. The equations for the index elements are the following (2):

$$MI = EC \cdot TC \qquad (2)$$

where *EC* is pure efficiency changes (3) and *TC* are the technological changes (4).

$$EC = \frac{\theta_0^{2018}\left(x_0^{2018}; y_0^{2018}\right)}{\theta_0^{2008}\left(x_0^{2008}; y_0^{2008}\right)} \qquad (3)$$

$$TC = \left(\frac{\theta_0^{2008}\left(x_0^{2008}; y_0^{2008}\right)\theta_0^{2008}\left(x_0^{2018}; y_0^{2018}\right)}{\theta_0^{2018}\left(x_0^{2008}; y_0^{2008}\right)\theta_0^{2018}\left(x_0^{2018}; y_0^{2018}\right)}\right)^{1/2} \qquad (4)$$

where:

- $\theta_0^{t+1}\left(x_0^{t+1}; y_0^{t+1}\right)$ are the minimum DEA scores from the CCR model with inputs of year *t* + 1 and output of *t*-th year;
- $\theta_0^{t+1}\left(x_0^{t}; y_0^{t}\right)$ are the minimum DEA scores with inputs of year *t* and output of year *t* + 1;
- $\theta_0^{t}\left(x_0^{t}; y_0^{t}\right)$ and $\theta_0^{t+1}\left(x_0^{t+1}; y_0^{t+1}\right)$ are the minimum DEA scores for year *t* and *t* + 1 inputs and outputs.

Data were selected from the Eurostat-Economic aggregates of forestry. The period of research comprises the years from 2008 to 2018. Limitations placed in the current research are due to:

- Data availability: the research includes only countries with full available data for the whole time span – 10 countries with 2 outside EU; they are called DMU in the model;
- Model requirements: the rule of thumb requires the number of inputs and outputs in the model to be at least 3 times lower than the number of DMUs.

3. Results

The results of the estimated efficiencies using the model with constant returns to scale and that with variable returns to scale are presented in Figure 1.

The results in Figure 1 show that the most economically efficient countries are Switzerland, Austria, Luxembourg, and Slovenia. The average CCR scores for all the countries are 0.52 and for BCC, the average scores are 0.64. The economic efficiency of the countries with scores above average is on average 0.84 for CCR and 0.93 for the BBC model. This means very big differences compared to the other countries, which have 0.31 for CCR and 0.35 for BCC. The CCR efficiency reveals the scale effects of the GFCF. Formation of fixed capital is not in the amount that makes most of the countries efficient. They have to invest more. The priorities of the investment policy in each country can be revealed by the 45 degrees curve between the CCR and BCC efficiencies (Figure 2).

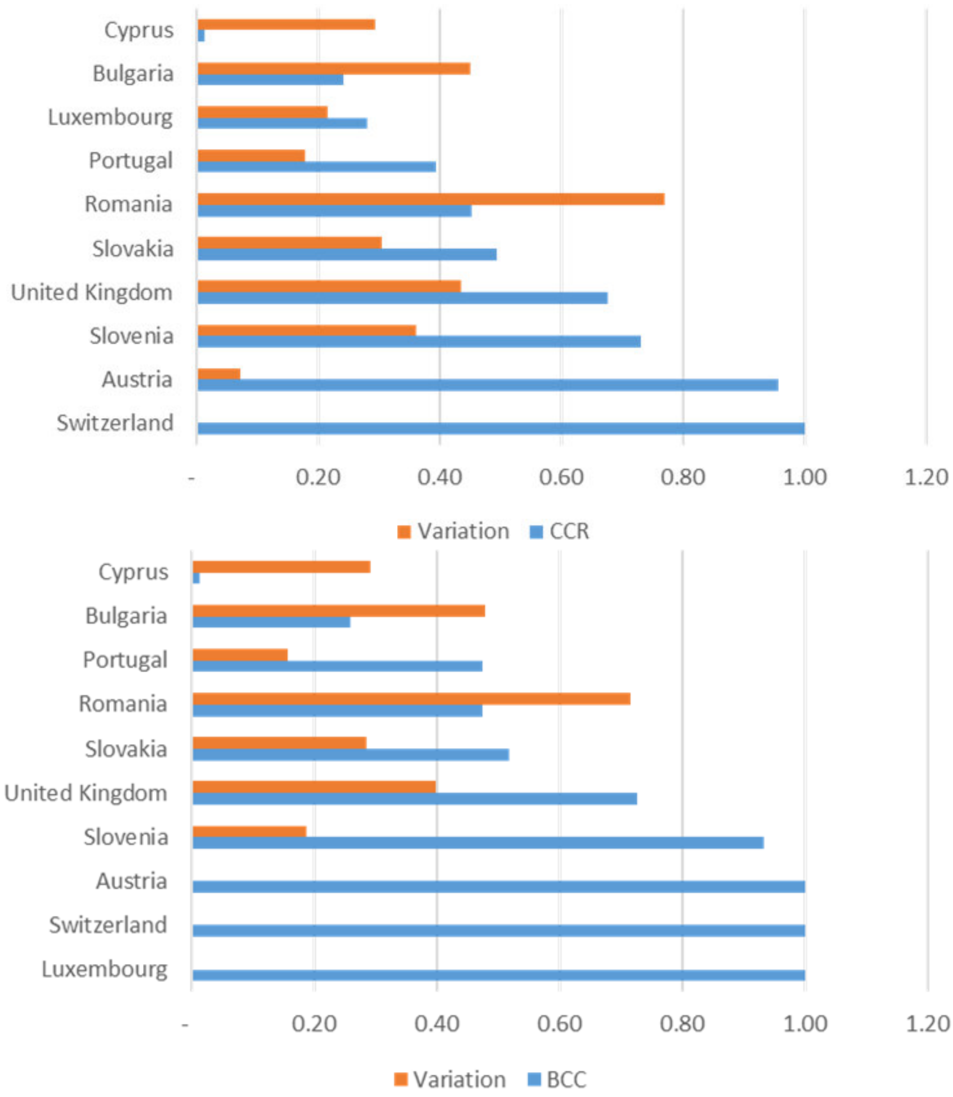

Fig. 1. *Average scores of CCR and BCC efficiency for the time of research*

The curve shows the forestry investment priorities of the surveyed countries. Some of them emphasize the good proportion between added value and investments. These are Luxembourg, Portugal, Austria and Slovenia. For them, during the research period, investments were made at an optimal ratio of sources of income generation and investment costs. The remaining countries invested at scale, without maximizing the investment/value added ratio. Romania and Bulgaria place slightly more emphasis on the technical efficiency than on the scale one. When considering the two countries – Romania and Bulgaria, the efficiency scores over time give information about the quality of the investment management in the forestry sector (Figure 2).

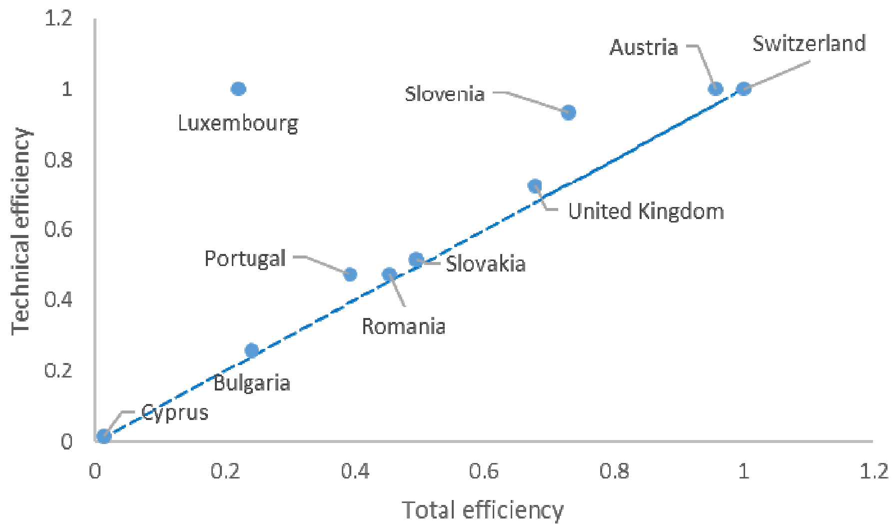

Fig. 2. *The 45 degrees curve comparison between CCR (Total efficiency) and BCC (Technical efficiency)*

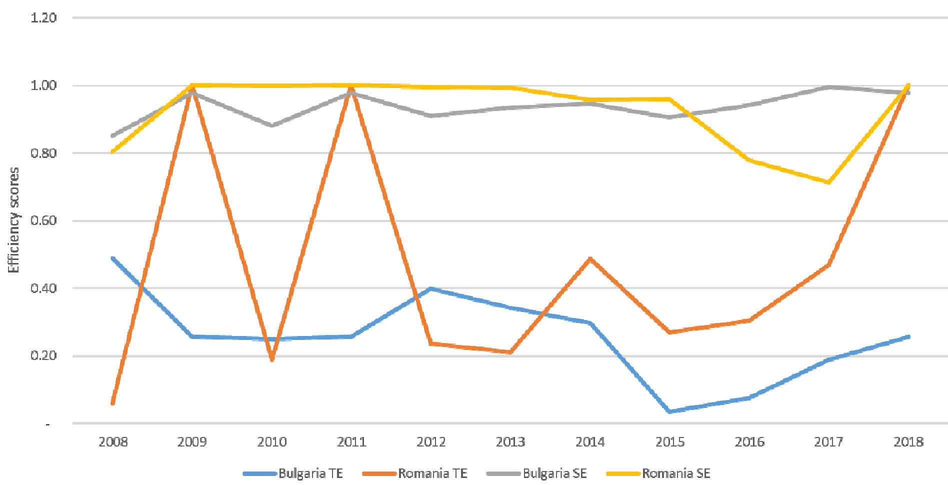

Fig. 3. *Efficiency scores for technical efficiency (TE) and scale efficiency (SE)*

The Figure 3 shows that Romania has had its successes in efficiency. Despite the large variation in points, it has managed over the years to be completely efficient as far as scale efficiency is concerned. This means that investments were made in more significant volumes of machinery and equipment. The technical efficiency has a greater variation and there were successes in only three of the years. A big impression is made by the significant progress in technical efficiency in 2018 compared to 2008. For ten years, optimality in the investment/added value ratio was achieved. The situation in Bulgaria is not the same. Until any improvements in the management of fixed assets were made in Romania, the policy in Bulgaria remained the same for the whole period. Investments were made in a comparatively good scale, but there were no optimality improvements in the investment value added ratio. This is the reason TE fell for the whole period. The values of the Malmquist index in Figure 4 support the results in Figure 3.

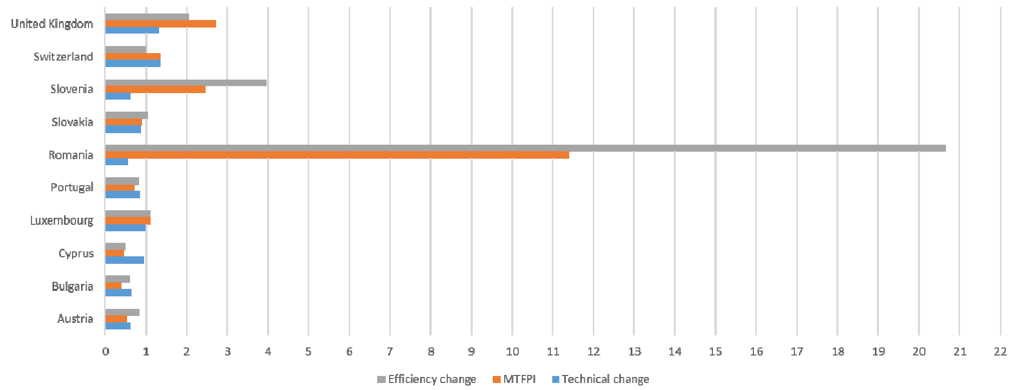

Fig. 4. *Results for Malmquist productivity index*

Figure 4 shows that Romania made a giant leap from 2008 to 2018. It is not surprising because of the very low base of efficiency in 2008. The fact is that Romanian forestry has achieved a great improvement in the scale. There were many more investments in 2018. The fact is that annual investments in machinery and equipment increased significantly as a volume, but not as technology. Switzerland has the most balanced improvement with both – technical improvement and scale improvement.

4. Discussion

The findings in this paper suggest that the countries with efficient investment policy have lower variance of the annual efficiency scores. Sustainability in investment policy in each forestry sector ensures the optimality in transforming the sources into investments. It has been proven that the efficiency of the highly efficient countries is also sustainable, i.e., the variation of efficiency scores for the studied period is minimal. Countries are more BCC efficient, which means that they achieved investments in machinery and equipment with good budget planning. From inputs like labour and net value added, the efficient countries have invested a big share of the value added. Until other research like Kovalcik's [12], which shows that the efficiency of Bulgaria is greater than in Romania, the current research reveals that the investments in machinery and equipment are not sufficient in Bulgaria. The small Malmquist index of the country reveals the low ability for improvement of the fixed assets management in forestry. It is an interesting find of the current research that the efficient countries can also have low values for the Malmquist Index. Three strategies can be distinguished. The first one is maintaining the state of high efficiency, like Austria. The second one is constant improvement, like Switzerland. This country is an absolute leader in efficiency as well as in technological improvement. The results suggest that other countries like Romania and the United Kingdom are improving their efficiency through total efficiency changes, but not through innovations.

5. Conclusions

The current paper aimed to classify and reveal the efficient fixed assets investments in the forestry of different countries inside and outside the EU. Forestry in Austria and Switzerland is the most economically efficient. Economic efficiency in the developed countries included in the study showed that the development of the economic scale at the expense of technological development does not lead to high economic efficiency. Investments in innovation and technology are a leading method of improving economic efficiency. The analyses showed that Bulgaria and Romania should intensify efforts in this direction.

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IMPACTS OF SUPPORT MEASURES ON THE OPERATING ENVIRONMENT OF THE LHV IN FINNISH TIMBER TRANSPORTATION

Teijo PALANDER[1]

Abstract: *This study was set up to find out how Finnish timber transport entrepreneurs perceive their operating environment in terms of using larger and heavier vehicles (LHV and HCV). The main aim was to provide guidance for developing policies that improve profitability of timber transportation. A total of 100 entrepreneurs responded to a questionnaire survey administrated by an online service. Five-point Likert scales were used to collect perceptions, and the Kruskal Wallis and Mann-Whitney U test was used to compare the responses of the entrepreneurs. The results show that driving and rest time regulations as parts of working time legislation were perceived as the most disruptive. Further, the availability, and responsiveness of technical support, and long delays in solving the queries of drivers were critical problems for an efficient use of in-vehicle ICT-applications. In the near future, the current skilled workers will be retiring and there are too few educated ones to replace them. This is expected to increase wages, which may be reflected in a decreased profitability in the timber transport sector. These issues should be focused on by society's support measures for improving the timber transport sector.*

Key words: *LHV, HCV, driver education, information system, regulation monitoring, profitability.*

1. Introduction

Society's support of the road timber transport consists in strategic measures to be implemented by parties outside the transport company, which in turn will affect the operating environment [13-15]. In general, society aims at developing transport logistics and at increasing cost efficiency in transport operations. In this regard, the unit costs of long-distance timber transport have remained almost at the same level since 2010 in Finland [32]. On the other hand, starting from 2022, the costs have started to rise due to the war in Ukraine [28]. The cost efficiency is primarily affected by the regulations of the dimensions and transport masses [2, 5]. For instance, Palander's [20, 21] studies have shown that increasing the maximum size and mass of vehicle combinations in the right working

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environments saves significant amounts of fuel, which is the most significant cost factor of transport companies [12, 33, 34]. Therefore, as a general rule of the Road Traffic Act [11], allowing larger vehicles to operate can be seen as a support measure (Figure 1 and Table 1), and the regulations can also grant temporary transport permits for HCV combinations over 76 t [11, 35, 37]. However, entrepreneurs have not been asked directly how these regulations can be utilized effectively in the new operating environment.

Fig. 1. *Most common axle solutions of timber transport vehicle combinations (60 and 76 t)*

Table 1

The maximum total mass of the vehicle combination and the load when transporting timber

Number of axles	Structure of axles	Mass [t]
4	A	36
5	A	44
6	A	53
7	A	60
8	A	64
8	B	68
9	A	69
9	B	76
10	A	74
>11	A	76

Note: A = the share of two-wheeled axles of the trailer mass is ≤ 65%;
B = the share of two-wheeled axles of the trailer mass is > 65%.

Within the road transport, an important cornerstone of operational activities is digital competence. Drivers and entrepreneurs use forest information systems and vehicle applications, which in this work are classified as a support measure, because their use is possible with the consent of the forest industry. In addition, the timber transport will probably face a challenging future which will need the support functions of education. The transport of timber is known to be the most difficult task of road transport because wood is delivered all year round from challenging environments (Figure 2). The vehicles are to be driven in severe frost, on slippery roads or in an operating environment saturated by water. Drivers also operate on tight schedules, making and tying the loads themselves. All this, and much more, is done in addition to driving a vehicle 40 times heavier than a passenger car. Society's support measures may affect the availability of skilled drivers on the labor market. This is often seen as a future success factor for a transport company, which is influenced by the salary level and attractiveness of the industry on the one hand, and by the level of education organized by society on the other [18, 19, 29]. Therefore, the availability of skilled drivers can be positively influenced by developing cooperation between school and transport practice. It is presumed in this study that this can be achieved by offering work opportunities to students and to those undergoing training internships in large transport companies that use advanced technology both in terms of equipment and data transfer technology.

Fig. 2. *The transport of timber operates all year round in challenging environments*

Regulation monitoring of timber transport generally aims at the same positive effects in the form of support measures, however, in some circumstances they may be perceived as burdensome and they may have opposite effects on the operating environment. Before the weight limit regulation of the vehicle combinations came into force [5], it was common for vehicles to be overloaded, i.e., the total weight of the vehicle combination could be more than 60 t [20, 21]. The overload increased cost efficiency and the profitability of the transport company. Nowadays, in 76 t vehicles, overloads are rare, but possible. For example, the high humidity of timber may cause an excessively heavy load in the wet weather conditions of autumn. The forest industry has set sanctions for exceeding the weight limits, and police authorities also monitor excessively heavy loads. Overloading monitoring is just one example of regulation and control, but generally, this regulation is a positive manifestation of developed society and it is necessary as a common rule of the operating environment. So far, Nordic studies have well considered old operating and working environments [12, 13, 15, 30]. However, it is equally important to broadly open up the regulations' multiple effects by asking transport entrepreneurs' opinions about them in the current operating environment [37].

New information is needed from transport entrepreneurs with the aim of developing both the operating environment of road transport and profitability. In this study, a survey is administered to them. Soirinsuo and Mäkinen [30] pointed out that profitability of timber transport is resource oriented. In this respect, the results describe how the entrepreneurs' responses differ in relation to LHVs (≤ 76 t) and HCVs (> 76 t). The development needs of the regulation and support functions are considered for both groups. The conclusions tap into the actions/measures and policies, which are required for improvements of timber transportation.

2. Material and methods

The research was carried out via a questionnaire survey directed at timber transport entrepreneurs. The survey collected information about the situation in the operating environment of transport companies in 2019. We especially focused on events between 2014 and 2018. The survey was carried out on an online, e-form service, which is a form software used with an internet browser. The respondents accessed the survey via a URL link without any requirement to log in while the survey was open. Entrepreneurs were sent a link to the survey by email on March 6, 2019. The response period for the survey ended on March 24, 2019. Entrepreneurs invited to the survey were sent a reminder about it on March 18, 2019, when there was a week left to respond. In the e-mail containing the link, it was emphasized that the responses were processed in such a way that the respondents were anonymous in the study.

The questionnaire contained two sections: Background information (A) and Operating environment (B). It was designed so as to enable the responses to given questions without any prerequisite in completing the answers to previous questions and it received a total of 103 responses. Sections B had five-point Likert scale statements, e.g., claims to regulation monitoring, from which the respondent could choose the answer that best fit his/her own experience. The polarity of the scale was arranged from negative to positive in such a way that the most negative answer was the one on the left and the most positive answer was the one on the right [27]. In the profitability analysis, the vehicle options, 3+4 (60 t), 3+5 (68 t), 4+4 (68 t), 4+5 (76 t), 5+4 (76 t), 5+5 (84 t), were included into two groups (≤68 t and >68 t). Claims of section B also related to information systems which were targeted at the smoothness of use, and its effect on operations were investigated on a general level. As the last issue of section B, the entrepreneurs' opinions were asked about training and labor issues in the transport sector, without forgetting the entrepreneur's future plans.

Microsoft Excel spreadsheet program and IBM SPSS Statistics 29 statistical program were used for data processing, calculation, and analysis [31]. First, the data were transferred from the e-form software to an Excel file and to an SPSS file. Three wrong lines were removed from the processed data. Consequently, a database containing 100 answer lines was used for data processing. First, the statistic values were solved by SPSS for the description of the data: mean, median, mode, and standard deviation. Then the Kruskal Wallis test was used when comparing the distributions of the two answer groups and the Mann-Whitney U-test was used when comparing the paired responses of the answer groups on the ordinal scale [7, 10, 16]. In the implementation of the tests, the null hypothesis was that the distributions or responses were the same. The significance levels used in the analysis were $p < 0.05$, $p < 0.01$, and $p < 0.001$. If the p-value given by the test was less than the assumed level of confidence, the null hypothesis was rejected [6, 8].

3. Results

3.1. Profitability between 2014 and 2024 in the Two Vehicle Groups (≤68 t, >68 t)

All respondents rated financial profitability for the years 2014-2018. 45% of the respondents felt that profitability has weakened slightly or remarkably in the last five years. In contrast, 27% of the respondents felt that profitability has improved slightly or remarkably. The median response was that profitability has remained unchanged for the past five years. On the other hand, 30.2% of the respondents predicted that profitability would decrease slightly or remarkably during the next five years (2020-2024). However, 42.7% of respondents anticipated that profitability would remain the same, and 28.1% of respondents estimated that profitability would improve slightly or substantially over the next five years.

The responses to the statement on the best financial profitability achieved with a vehicle combination when timber is transported from the forest were divided into two groups, namely those in favor of combinations weighing ≤68 t, and those in favor of combinations weighing >68 t. The former group received a total of 31 responses and the latter group received 53 responses. When comparing the responses given by these two groups to the claim put to them about the development of profitability during the five years between 2014-2018, the responses were very much in the same direction. Both groups felt that, on average, financial profitability has remained unchanged or has decreased slightly (Figure 3). The K-W test performed between the distributions indicated no statistically significant differences between the groups ($p = 0.677$, $t = 2.321$).

These groups saw the financial profitability of the next five years (2020-2024) as very similar (Figure 4). However, here distributions of the groups (2014-2018 vs. 2020–2024) were different according to the K-W test ($p = 0.003$, $t = 16.140$). The responses were a little more positive than the results of the previous five years (2014-2018).

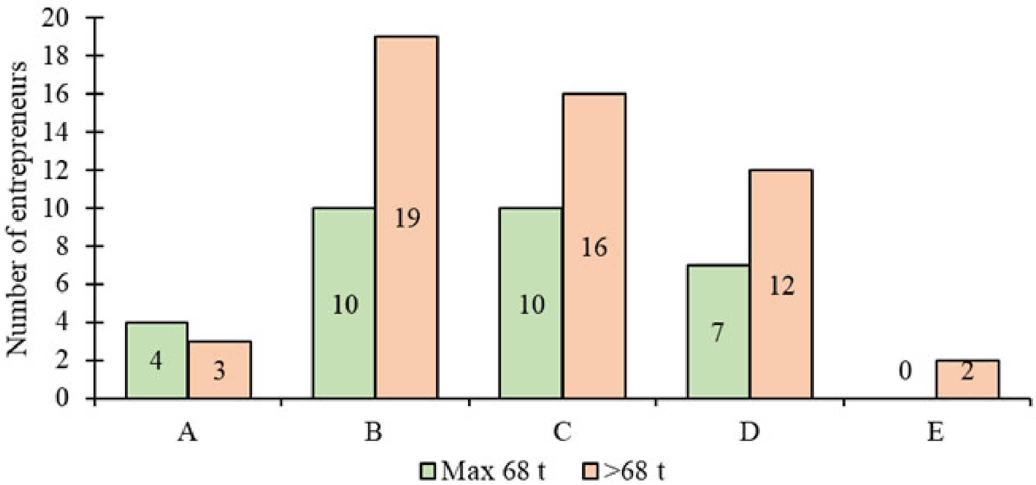

Fig. 3. *Financial profitability of vehicle combination groups (≤ 68 t and > 68 t) in the period between 2014 and 2018. A = Substantially weakened; B = Weakened slightly; C = Remained unchanged; D = Increased slightly; E = Substantially improved*

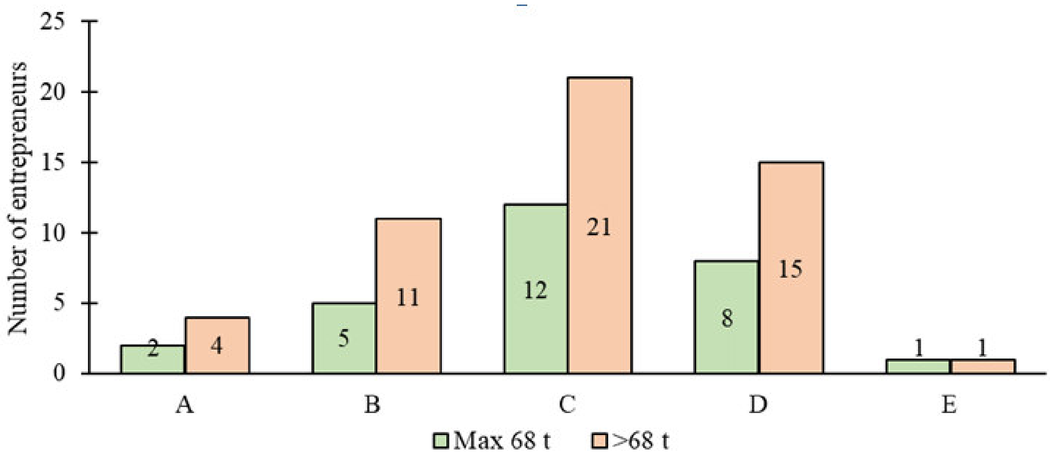

Fig. 4. *Financial profitability of vehicle combination groups (≤ 68 t and > 68 t) for 2020-2024. A = Weakens substantially; B = Weakens slightly; C = Remains unchanged; D = Improves slightly; E = Improves substantially*

3.2. Regulation Monitoring of Operating Environment

51.5% of the respondents completely or slightly agreed that “the transport of timber is regulated too precisely”, while 13.1% slightly or completely disagreed (Table 2). The same way, 42.4% of the respondents completely or slightly agreed with the claim that “the transportation of timber is monitored too closely”, whilst 25.3% of the respondents either slightly or completely disagreed.

68.7% of the respondents slightly or completely agreed with the statement "working hours legislation makes it difficult to transport timber", whilst 18.2% of the respondents slightly or completely disagreed. In the claim "the driving and rest time regulation makes it difficult to transport timber", most of the responses were slightly or completely in agreement (64.6%), while 19.2% slightly or completely disagreed. For the claim "The overloaded vehicle law is interpreted and enforced too closely", the responses were mostly evenly distributed: 38.4% of respondents slightly or completely agreed, while 30.3% slightly or completely disagreed. 55.6% of the respondents slightly or completely agreed with the statement "There are too many occupational safety and other trainings associated with transporting", while 15.1% slightly or completely disagreed.

Table 2

The impact of regulation monitoring on the operational performance of transport

Average number	A	B	C	D	E	F
Average	3.57	3.24	3.82	3.77	3.14	3.62
Median	4	3	4	3	3	4
Mode	3	3	5	5	3	4
Standard deviation	1.061	1.153	1.232	1.276	1.237	1.01

A	The transport of timber is regulated too precisely
B	The transportation of timber is monitored too closely
C	Working hours legislation makes it difficult to transport timber
D	The driving and rest time regulation makes it difficult to transport timber
E	The Overload Act is interpreted and enforced too closely
F	There are too many occupational safety and other trainings associated with transporting

Note: 1 = Completely disagree; 2 = Slightly disagree; 3 = Neutral; 4 = Slightly agree; 5 = Completely agree.

3.3. Forest Information Systems and Vehicle Applications as a Support Function

73.2% of the respondents slightly or completely agreed with the statement "Vehicle applications have made it easier to plan and implement transportation", while 21.6% of the respondents neither agreed nor disagreed (Table 3).

48.5% of the respondents slightly or completely agreed with the statement "Training has been available for vehicle applications", while 25.8% of the respondents slightly or completely disagreed with the statement. 45.4% of the respondents slightly or completely agreed with the statement "With the vehicle application, you can work with several customers", while 22.7% slightly or completely disagreed with the statement. 67.0% of the respondents slightly or completely agreed with the statement "A well-built vehicle application improves the economic profitability of timber transport", while 22.7% neither agreed nor disagreed.

Table 3

Entrepreneurs' experiences with vehicle applications and information systems

Average number	A	B	C	D	E	F	G	H	J
Average	3.94	3.25	3.62	3.28	3.75	3.09	2.72	3.21	2.73
Median	4	3	4	3	4	3	3	3	3
Mode	4	4	4	3	4	3	3	4	3
Standard deviation	0.933	1.118	1.103	1.205	1.011	1.022	1.058	1.169	0.896

A	Vehicle applications have made it easier to plan and implement transportation
B	Training has been available for vehicle applications
C	The use of vehicle applications has brought considerable additional work to the company
D	With the vehicle application, you can work with several customers
E	A well-built vehicle application improves the economic profitability of timber transport
F	The technical support of the vehicle application knows how to solve problems
G	Technical support for the vehicle application is easy to reach
H	Poorly functioning connections make it difficult to use the vehicle application
J	The vehicle application is incomplete or faulty

Note: 1 = Completely disagree; 2 = Slightly disagree; 3 = Neutral; 4 = Slightly agree; 5 = Completely agree.

38.1% of the respondents slightly or completely agreed with the statement "The technical support of the vehicle application knows how to solve problems", while 25.8% slightly or completely disagreed with the statement. 21.6% of the respondents slightly or completely agreed with the statement "Technical support for the vehicle application is easy to reach", while 38.1% slightly or completely disagreed with the statement. 43.8% of the respondents slightly or completely agreed with the statement "Poorly functioning connections make it difficult to use the vehicle application", while 30.2% slightly or completely disagreed with this statement. 13.4% of the respondents slightly or completely agreed with the statement "The vehicle application is incomplete or faulty", while 39.2% of respondents slightly or completely disagreed with this statement.

3.4. Labor Factors and Education

39.2% of the respondents slightly or completely agreed that increasing “The efficiency of operations will ease the labor shortage” in the transport sector, while 27.8% of respondents slightly or completely disagreed (Table 4).

12.2% of the respondents slightly or completely agreed that “Timber transport sector is of interest to young people”, but 73.5% slightly or completely disagreed. 7.1% of the respondents slightly or completely agreed with the claim “The cooperation between companies and educational institutions is close and the skills of new drivers are at a good level”, while 72.4% slightly or completely disagreed. 36.7% of the respondents slightly or completely agreed that “Work orientation is a planned process in your transport company”, while 24.5% slightly or completely disagreed. 57.7% of the respondents slightly or completely agreed with the statement, "Employees are committed to the company and industry", while 21.6% slightly or completely disagreed.

Table 4

Views on the labor and education in the future of timber transport

Average number	A	B	C	D	E	F	G	H	I	J
Average	3.16	2.05	2.03	3.14	3.39	4.24	4.33	2.59	3.08	3.65
Median	3	2	2	3	4	4,5	5	2	3	4
Mode	3	2	2	3	4	5	5	1	3	5
Standard deviation	1.115	1.019	0.936	1.045	1.056	0.981	0.847	1.539	1.10	1.378

A	The efficiency of operations will ease the labor shortage.
B	Timber transport sector is of interest to young people
C	The cooperation between companies and educational institutions is close and the skills of new drivers are at a good level
D	Work orientation is a planned process in your transport company
E	Employees are committed to the company and industry
F	Many of the current experts will retire in the next few years
G	A possible shortage of drivers will increase the wage level and thus transport costs
H	Generational change will be topical in your company in the next few years
I	I am aware of the implementation of generation change
J	We intend to continue as entrepreneurs in another five years

Note: 1 = Completely disagree; 2 = Slightly disagree; 3 = Neutral; 4 = Slightly agree; 5 = Completely agree.

The opinion of the respondents (83.3%) was slightly or completely in agreement with the claim "Many of the current experts will retire in the next few years", while 6.3% slightly or completely disagreed with it. Also, the responses to the claim "A possible shortage of drivers will increase the wage level in the future and thereby transport costs" were slightly or completely in agreement (85.7%), while 2.0% of the respondents disagreed completely with it. 31.6% of the respondents slightly or completely agreed with the statement "Generation change will be relevant in your company during the next few years", while 54.1% slightly or completely disagreed. To the claim "I am aware of the implementation of generation change" the responses given were evenly distributed. 35.8% of respondents slightly or completely agreed with the statement. To the claim "We intend to continue being an entrepreneur in another five years" most of the responses were slightly or completely on the side of agreement (56.1%), while 18.4% of respondents slightly or completely disagreed with the statement.

4. Discussion

Based on the results, conclusions are drawn about improving the utilization of the vehicle combinations in various operating environments because the combined effects of the operating environment and the vehicle combination are important for profitability. New research data can highlight the development needs of various support functions such as regulation monitoring, information systems, workforce, and education in the same context. In the entrepreneurs' responses, one can find guiding success factors for the growth of the transport company for a better common future. According to Soirinsuo and Mäkinen [30], and Soirinsuo [29], it is surprisingly difficult to find a success model which focuses explicitly on small business growth and profitability. However, growth of transport companies is necessary due to decades of too low wood extraction. The Finnish forests have aged, and their growth has decreased, which threatens their carbon binding capacity and the future of forestry [9, 17, 24].

Currently, the most common option in timber transport is the 76 t vehicle combination, which can be used to transport the maximum amount of wood permitted by law [37]. The most commonly used axle solution of the 76 t combination is 4+5. The profitability of 84 t combinations increased in terminal transports, which is understandable from a practical point of view. These results are consistent with previous studies and in theory, the HCVs are more profitable than the LHVs [25]. However, at least the HCV-combinations are so large in terms of their physical dimensions that their use is not possible on Finnish road networks [23], and particularly on private roads [26].

In order to consider profitability more accurately for LHVs, the transport fleet of LHVs was divided into two groups (≤ 68 and > 68 t). When looking at the development of profitability over the last five years (2014-2018), the results show that the profitability of ≤ 68 t combinations has weakened more than the profitability of > 68 t combinations. There was no statistical difference between the distributions of the groups, but relatively more entrepreneurs felt the profitability to be substantially weakened if ≤ 68 t combinations were used. At the same time, everyone who felt that profitability had improved substantially belonged to the group of > 68 t. With these extremes emphasized, it can be concluded that ≤68 t combinations are a determining factor for profitability, because those who use them experienced the past five years (2014-2018) as economically worse than users of > 68 t combinations. When looking at the responses about the development of profitability for the next five years (2020-2024), the responses in these two groups even out. For both groups, the responses moved in a more positive direction compared to the 2014-2018 period. In both respondent groups, a larger proportion of respondents felt that profitability would improve slightly or substantially. This looks a little bit strange because respondents seem to feel the future brighter than the past five years. Actually, the fuel price which increased in the spring of 2022 is not included in the survey' analysis, which may explain this situation.

When examining the operating environment, the focus is on the effects of its suitability for the current vehicle combinations ≤ 76 t, but we have also looked over its suitability for combinations weighing > 76 t. This is new information, because previous studies focused on 60 t vehicle combinations [34]. On the other hand, some recent studies have focused on routing and more specific working environments instead of the operating environment [3]. Nowadays, the majority of vehicles are 76 t LHV combinations (approximate 90%), so the importance of the survey is related to these combinations. In addition, the results found for > 76 t HCV combinations are also useful and accurate, because all the vehicles in use were operated by the study respondents.

Regulation has guided the transition of heavy traffic to LHV vehicle combinations. Therefore, entrepreneurs, as well as contractors, have been compelled to acquire equipment and vehicle combinations. However, at the same time, the operating environment has remained unchanged [1, 36]. The law stipulates that the transport fleet must be in a condition for safe operation and the driver must be fit and competent to transport his vehicle combination [4, 5, 37]. Should it also be written in the law that the operating environment should be in a condition worthy of these top professionals and first-class vehicle combinations? Regulation and its monitoring are positive manifestations of a developed society. In some industries, regulation monitoring of the operating environment significantly affects daily operations, including operational work, of which the road transport of timber is a good example. Therefore, this study discusses the effects of regulation monitoring for the development of the operating environment. Another support function in this category looked at labor and training factors, which were also seen as the most important factors for the company's short-term success in the current labor shortage. The discussion therefore includes a small amount of future analysis in addition to the operational analysis that examines the present.

Based on the results, it is notable that entrepreneurs feel that the regulation of operations is excessive (Table 2). More than half of the respondents feel that the transport of timber is regulated too precisely. The working time legislation and the driving and rest time regulation were especially perceived as factors that make transportation inefficient. In general, the trend for poorer profitability at high working time utilization has also been reported by Lindström and Fjeld [12]. Their results show that profitability decreased with increasing annual operating hours per truck. A significant proportion of respondents feel that there is too much supervision. These responses can be interpreted as the fact that the laws and regulations are perceived as too strict, but the activities of the supervising authority are nevertheless accepted as based on laws and regulations. This would reflect well the honest character quality of the respondents.

A vehicle combination transporting standard piece goods operates on a long route. In this case, the driver would need a very long continuous driving performance, which needs to be broken up into statutory rest breaks. In timber transport, such a situation, where a single driving performance would take several hours, is rare. As in Sweden, the high proportion of wood from non-industrial private forest owners and distribution of saw and pulp mills requires the coordination of a number of assortments from scattered harvesting sites to multiple mills [12]. During the working day, the drivers visit several storage locations and get out of the cab to load the vehicles or to visit the measuring station of the receiving production plant. In this case, the drivers will have natural breaks in their numbing driving work; in addition to this, they will get some exercise, which will get the blood circulating comfortably. It seems that in Nordic countries it is not correct to compare timber transport with other heavy traffic transports. Further, the regulations could be rationalized in such a way that drivers do not have to knowingly break the regulations. Therefore, road transport of timber should be considered as its own transport sector in the driving and rest time regulations.

When looking at the impact of support measures on the execution of timber transports, it was reported in the survey that the vehicle applications of forest information systems are perceived to have facilitated the planning and implementation of transports, but at the same time they are perceived as incomplete tools (Table 3). The training and system support available for the applications divide opinions strongly, although the responses are slightly on the positive side. The impact of poorly functioning communication connections during the use of vehicle applications also divided opinions. Although vehicle applications are perceived to have made operations more efficient, their use is also perceived to have brought significant additional work. Despite negative experiences, entrepreneurs are aware that a well-built vehicle application could improve the financial profitability of transportation.

The vehicle application of the forest information system has brought real-time wood inventory monitoring, which benefits both the wood procurement organization and the transport entrepreneur in outsourcing of operations [22]. Despite the difficult and nerve-wracking problems in daily work, it is a fact that real-time inventory management and reliable storage location-specific balance information improve operations at different stages of the wood procurement chain, and transportation is one of the biggest beneficiaries. However, a clear problem is the issues related to the accessibility and responsiveness of the technical support of the applications, as well as the long delay in fixing non-critical problems. In many places, the world is not ready, and the same also applies to forest information systems and their vehicle applications. Software companies are currently struggling with a labor shortage to a significant extent because there is a global shortage of coders. Because of this, human resources have to be used for critical repair and maintenance work, and lower priority developments and improvements are delayed or not done. This is annoying for users of information systems which get constantly small errors in the user interface.

Finally, some suggestions about the labor situation and training in the road transport can be seen in Table 4. It was noticed that the entrepreneurs have a very unanimous view on many labor issues. A strong majority was of the opinion that young people are not interested in the timber transport sector and that the cooperation of educational institutions with companies is not sufficient; in addition, the skill level of new drivers is not sufficient. It seems that labor will be the success factor in the current growth of the timber transport companies as it has been for 60 t vehicle combinations [29, 30]. Further, the current experts committed to the sector will soon retire and there are not enough new and well-trained professionals entering the sector. This is believed to increase wage costs in the future, which will be reflected in increased transport costs. To generalize, based on the entrepreneurs' responses, the labor situation may be the most important success factor for the transport company in LHVs for the near future.

5. Conclusions

Regulations set limits regarding the operating environment for the road transport of timber and profitability has guided entrepreneurs to use the LHV as 76 t with a 4+5 axle construction. This has happened, but entrepreneurs were concerned about the following factors of the operating environment: driving and rest time regulations, forest information systems, and labor situation. They should be improved by support measures of customers and society. The entrepreneurs suggested the following policies for support functions: *i)* road transport of timber should be considered as own transport sector on the regulations*, ii)* transport entrepreneurs' valuable experience and development ideas should be used for the development of systems, and *iii)* the forest industry, entrepreneurs, educational institutions and organizations should cooperate more visibly in education matters and invest in the forest industry's image in order to attract young people to apply for the driver's profession. If society wants to move to LHVs or HCVs on a larger scale than the current one, this requires long-term cooperation between the government, administration and companies operating in the forest sector. Abroad, Finnish experiences about LHVs and HCVs provide alternative information to the forest industry on how to develop the efficiency of timber harvesting.

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THE CHANGES IN CHEMICAL COMPOSITION OF NARROW-LEAVED ASH WOOD IN REGARD TO THE CONDITIONS OF THE ACETIC ACID PRETREATMENT

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Abstract: *Different pretreatments (physical, chemical, biological) have different effects on various properties of wood. The effects of chemical treatments depend on the type of reagent and treatment conditions. This work evaluates the influence of the concentration of acetic acid solution and the treatment temperature on the chemical composition of Narrow-leaved Ash wood particles (0.5-1 mm). The particles were treated in autoclaves for 60 minutes and at temperatures of 100 and 120°C. The applied concentrations of acetic acid solution were (0.03, 0.06, and 0.09 g/g ODW). The treatments slightly increased the content of both cellulose (1-9%) and hemicelluloses (8-30%). The concentration of acetic acid showed no significant effect on these compounds at the treatment temperature of 100°C. However, at 120°C the content of cellulose decreased with the increase in acetic acid concentration, probably caused by its degradation. The changes in lignin content after the treatment at 100°C was not significant (0.7-2.3%), but it was about 3-8% lower after the treatment at 120°C. The lignin content was not affected by the acetic acid concentration. The treatments had the most pronounced effects on the extraneous components, significantly lowering their content. Hence, the contents of extractives dissolved in toluol/ethanol mix and in water, they decreased by 12-54% and 73-88% respectively, while the mineral matter decreased by 62-81%. The content of extraneous materials was higher for the particles treated at 120°C, which was probably caused by the increase in lignin degradation at higher temperature, but it decreased with the increase in acetic acid concentration. FTIR spectra confirmed that the treatments had no significant effects on the content of the main constituents of wood.*

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1. Introduction

The need to preserve the environment and mitigate climate change caused by excessive processing and consumption of fossil raw materials requires the use of carbon-neutral, renewable raw materials for the production of chemicals and energy. Wood lignocellulosic biomass represents a potential raw material for the production of liquid and gaseous biofuels and chemicals that are important for meeting global demands [14]. Specifically, various organic substances that build wood tissue, such as cellulose, hemicelluloses, lignin and extractives can be converted into a wide range of commercial chemicals through biorefining processes [10]. As a result, the demand for wood is growing, which imposes the need for a more rational use of wood.

As an important step in the biorefining and complete utilization of wood, various physical, chemical, physicochemical, or biological pretreatments can be introduced into wood processing technologies [31]. The interconnection of wood polysaccharides (cellulose and hemicelluloses), as well as their connection by ester and ether bonds with lignin in a stable composite structure make the lignocellulosic complex resistant to degradation processes [34, 35]. The main goal of any pretreatment is to change the initial wood structure, which facilitates further processing, such as hydrolytic decomposition [13, 25] or wood pulp production [18, 33]. The type of treatment applied, as well as the processing conditions, lead to different effects such as: partial removal of lignin and hemicelluloses, reduction of crystallinity [25] and degree of cellulose polymerization [28], removal of acetyl groups from hemicelluloses [16, 25], and the like. In this way, the physical and chemical properties of the wood cell wall are modified, which results in a material more suitable for further decomposition [21, 30].

Pretreatment of lignocellulosic raw materials in an acidic environment is often applied to increase the efficiency of hydrolytic degradation of cellulose during the production of bioethanol [31]. The most common wood reactions that take place in an acidic environment are the hydrolysis of glycosidic bonds of cellulose and hemicelluloses [8, 22]. Glycosidic bonds in amorphous parts of cellulose and hemicelluloses are susceptible to acid hydrolysis, while the rate of hydrolysis of crystalline areas of cellulose is several orders of magnitude lower [12]. The final effects of chemical pretreatments in an acidic environment depend on the type of reagent (acid) and the conditions of the process [32]. Wood pretreatment processes can utilize either concentrated acids (30-70%) at low temperatures (<100°C) or diluted acids (0.1-0%) at high temperatures (80-250°C) and with the reaction time in the range of 10-2000 min [5, 10, 15, 20]. The degree and the rate of polysaccharide decomposition depend on the type and concentration of applied reagents, temperature and pressure, as well as on the duration of the process [8]. In addition, the degree of reaction depends on wood properties, such as chemical composition, porosity, permeability, and dimensions of the samples.

One of the main effects of wood pretreatments at low pH values, such as steam explosion [9, 29], hot water treatments [3, 4, 11, 36], and dilute acid treatments [17, 19, 25] is the removal of a significant amount of hemicelluloses from the wood tissue. Hemicelluloses decomposition products in the form of monomers and oligomers, together with other wood decomposition products, are dissolved in the liquid fraction from the treatment, which is often called extract or hydrolyzate. Hydrolyzates from the acid hydrolysis process are rich in monosaccharides (xylose, arabinose, mannose, etc.), which are products of hydrolytic decomposition of the carbohydrate components of wood, and also contain acetic acid, phenolic and other aromatic components, extractive substances, as well as aromatic monomers as products of lignin decomposition [10, 32]. Under mild treatment conditions, glucose concentrations in the hydrolyzate are low, but the amount of cellulose degradation products in the hydrolyzate increases with the increasing severity of the reaction conditions [32]. Wood decomposition products from hydrolyzate can be used for the production of biofuel (bioethanol), but also for obtaining other commercial products [2, 36], which optimizes the use of wood.

Chi et al. [7] consider acetic acid pretreatment as one of the most promising technologies for wood biorefining. Acetic acid shows good properties as an organic solvent [1]. During the pretreatment with acetic acid, there is a partial decomposition of hemicelluloses, lignin of low molecular weight and the lignin-carbohydrate-complex (LCC), which disrupts the ultrastructure of wood [7]. The advantages of hydrolysis in acetic acid environment are a short reaction time, mild operating temperatures, and a lower concentration of catalyst [1].

In this paper, the influence of acetic acid treatment parameters on the chemical composition of Narrow-leaved Ash wood is examined.

2. Material and Methods

2.1. Material

Wood samples: A 72 year old Narrow-leaved Ash tree (*Fraxinus angustifolia* Vahl. ssp. *Pannonica* Soo & Simon) was sampled in Morovic, Sremska Mitrovica, Serbia. The debarked log was prepared according to the Standard TAPPI method T 257 cm-12. The chips were further reduced in a hammer mill and the obtained wood particles were sieved through the standard test sieves. The fraction of wood particles of the 0.5 - 1 mm in size was adopted for this research. The moisture content of the samples was determined gravimetrically, according to the TAPPI method T 264 cm-97.

Reagents: Acetic acid (CH_3COOH) glacial, 99.5% (Zorka Pharma - Hemija d.o.o., Serbia).

2.2. Acetic Acid Pretreatments

The air-dried particles of Narrow-leaved Ash (0.5 - 1 mm) were classified into six groups, with the weight of each group being approximately 130 g. The wood particles were treated with water solution of acetic acid dosage of 0.03, 0.06, and 0.09 g/g oven dried wood (ODW) in a solid to liquid ratio 1:5 (g/g). The particles were treated in the autoclaves rotating in the ethylene glycol bath (Stalsvet, Sweden). The treatment lasted 60 min and two different temperatures were applied: 100 and 120°C. After the treatment, the particle samples were rinsed in distilled water until reaching the neutral pH, then air dried.

Table 1
Pretreatment conditions and marking samples

Acetic acid addition [g/g]*	Treatment temperature [°C]	
	100	120
0.03	KT1	KT4
0.06	KT2	KT5
0.09	KT3	KT6

Note: *g acetic acid/g oven-dried wood.

2.3. Analysis of Chemical Composition

The chemical composition of the treated and non-treated samples of Narrow-leaved Ash was analyzed. The cellulose content of the samples was determined by the nitric acid-ethanol method [6]. The lignin content in the ethanol-toluene extracted samples of Narrow-leaved Ash was determined by the Klason method (T 222 om-11), together with the spectrophotometric determination of acid-soluble lignin according to the TAPPI method T UM 250. The total lignin content was determined as a sum of the Klason and acid-soluble lignin. The mixture of toluene and ethanol in the ratio of 2:1 ($C_6H_5CH_3/C_2H_5OH$ = 2/1, v/v) was used to determine the content of extractives dissolved in organic solvents, according to the standard ASTM-D1107. The content of extractives dissolved in hot water was determined according to the standard TAPPI method T 207 cm-99. The content of mineral material (as ash) was determined according to ASTM D1102. The content of hemicelluloses was calculated as the addition to the sum of other components up to 100.

2.4. FTIR Analysis

Functional groups of Narrow-leaved Ash samples were analyzed with the application of Fourier transform infrared spectroscopy (FTIR). The samples were gound in powder, mixed with potassium bromide (KBr), and then pressed in order to prepare the KBr pellet samples for scanning. PerkinElmer Spectrum two FTIR spectrometer (PerkinElmer, Inc., Waltham, Massachusetts, USA) in transmission mode was used to record the FTIR spectra of the samples. The spectra were recorded in the range from 4000 to 400 cm^{-1} with the resolution of 4 cm^{-1}.

2.5. Statistical Analysis

The comparison of chemical compositions between the treated and non-treated Narrow-leaved Ash samples, as well as between the different groups of treated samples, was evaluated using the single factor ANOVA at the confidence level of 95%.

3. Results
3.1. The Chemical Content

Figure 1 shows the content of chemical constituents of the nontreated (Control) Narrow-leaved Ash sample and the samples treated with three different acetic acid solutions (0.03, 0.06, and 0.09 g/g ODW) at temperatures of 100 and 120°C. As a result of the pretreatment, the contents of cellulose (Figure 1a) and hemicelluloses (Figure 1c) increased, while the lignin content decreased. The contents of wood extractives and ash (Figure 1d, e, and f) decreased for all treated samples.

3.2. Statistical Analysis

Table 2 shows the statistical analysis of the changes in the chemical composition of the Narrow-leaved Ash wood caused by acetic acid pretreatment.

Table 3 shows the statistical analysis of the effects of pretreatment parameters (acetic acid addition and temperature) on the chemical composition of the Narrow-leaved Ash wood.

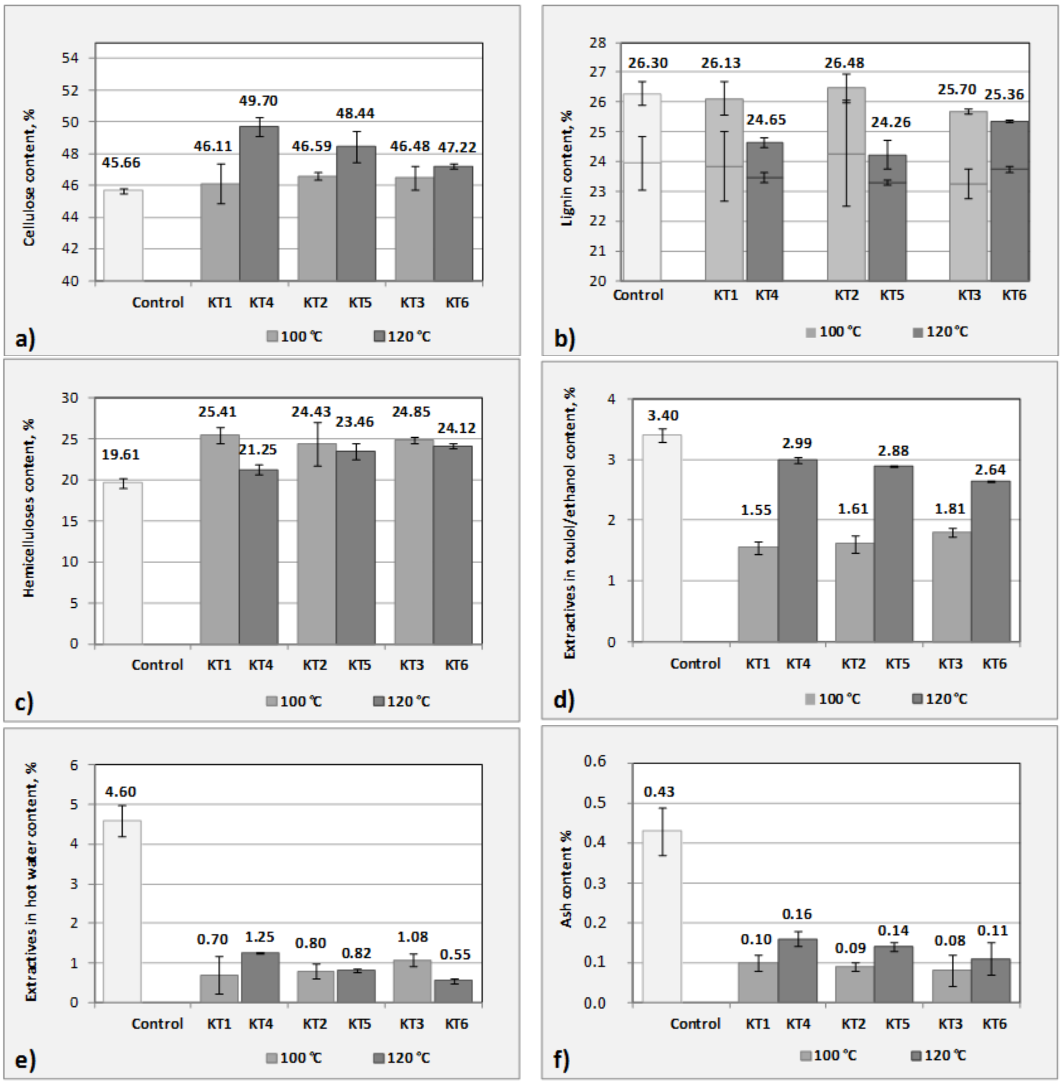

Fig. 1. T*he contents of structural and extraneous components of wood: cellulose (a), lignin (as a sum of Klason and acid-soluble lignin) (b), hemicelluloses (c), extractives in toulol/ethanol (d), extractives in hot water (e), and ash (f)*

Table 2

The results of the statistical comparison of the effects of acetic acid pretreatment on the chemical composition of the Narrow-leaved Ash wood using the analysis of variances method (ANOVA)

Samples	100°C		*Samples*	120°C	
	P-value	*F/Fcrit*		*P-value*	*F/Fcrit*
Cellulose content					
Control/KT1	0.5725	0.0551	Control/KT4	0.0003	16.8509*
Control/KT2	0.0043	4.4237*	Control/KT5	0.0093	2.8758*
Control/KT3	0.1318	0.4632	Control/KT6	0.0003	18.1529*
Lignin content					
Control/KT1	0.8683	0.0041	Control/KT4	0.0593	0.8854
Control/KT2	0.9047	0.0021	Control/KT5	0.0300	1.4102*
Control/KT3	0.4118	0.1087	Control/KT6	0.2039	0.2985
Klason lignin content					
Control/KT1	0.9138	0.0017	Control/KT4	0.4297	0.0999
Control/KT2	0.7869	0.0108	Control/KT5	0.2921	0.1906
Control/KT3	0.3200	0.1669	Control/KT6	0.7119	0.0204
Acid-soluble lignin content					
Control/KT1	0.8638	0.0043	Control/KT4	0.0321	1.4232
Control/KT2	0.7047	0.0215	Control/KT5	0.0185	2.1580
Control/KT3	0.7629	0.0135	Control/KT6	0.0951	0.5732
Hemicelluloses content					
Control/KT1	0.0010	9.7567*	Control/KT4	0.0281	1.4717*
Control/KT2	0.0373	1.2230*	Control/KT5	0.0045	4.3096*
Control/KT3	0.0003	17.9382*	Control/KT6	0.0004	16.2548*
Ash content					
Control/KT1	0.0007	11.6673*	Control/KT4	0.0033	5.0919*
Control/KT2	0.0006	12.0722*	Control/KT5	0.0076	4.0951*
Control/KT3	0.0010	9.4267*	Control/KT6	0.0076	4.0826*
Content of extractive materials in the mixture of toluene and ethylene					
Control/KT1	0.00003	56.5673*	Control/KT4	0.0199	2.0412*
Control/KT2	0.00007	36.9155*	Control/KT5	0.0097	3.4494*
Control/KT3	0.00003	53.7413*	Control/KT6	0.0031	7.5631*
Content of extractive materials in hot water					
Control/KT1	0.0001	33.7188*	Control/KT4	0.0014	12.8561*
Control/KT2	0.0001	28.8500*	Control/KT5	0.0001	31.6395*
Control/KT3	0.0001	27.3596*	Control/KT6	0.0008	18.7543*

*Note: *denotes a statistically significant difference at the confidence level of 95%.*

Table 3

The results of the statistical comparison of the effects of acetic acid addition and pretreatment temperature on the chemical composition of the Narrow-leaved Ash wood using the analysis of variances method (ANOVA)

Influence of the acetic acid addition						Influence of the pretreatment temperature		
100°C			120°C					
Samples	*P-value*	*F/Fcrit*	Samples	*P*	*F/Fcrit*	Samples	*P-value*	*F/Fcrit*
Cellulose content								
KT1/KT2	0.5449	0.0637	KT4/KT5	0.1379	0.4442	KT1/KT4	0.0062	3.1203*
KT2/KT3	0.8046	0.0091	KT5/KT6	0.1079	0.5528	KT2/KT5	0.0368	1.2326*
KT1/KT3	0.6725	0.0305	KT4/KT6	0.0023	6.1871*	KT3/KT6	0.1625	0.3792
Lignin content								
KT1/KT2	0.8244	0.0073	KT4/KT5	0.0626	0.8502	KT1/KT4	0.1277	0.4767
KT2/KT3	0.5819	0.0464	KT5/KT6	0.0003	16.9699*	KT2/KT5	0.1614	0.3818
KT1/KT3	0.6152	0.0384	KT4/KT6	0.0102	2.7140*	KT3/KT6	0.2519	0.2322
Klason lignin content								
KT1/KT2	0.7428	0.0161	KT4/KT5	0.1686	0.3654	KT1/KT4	0.6168	0.0381
KT2/KT3	0.3928	0.1188	KT5/KT6	0.0074	3.2661*	KT2/KT5	0.3945	0.1178
KT1/KT3	0.4725	0.0814	KT4/KT6	0.0855	0.6696	KT3/KT6	0.1912	0.3203
Acid soluble lignin content								
KT1/KT2	0.8715	0.0039	KT4/KT5	0.1761	0.2283	KT1/KT4	0.0832	0.6470
KT2/KT3	0.4726	0.0814	KT5/KT6	0.0091	5.8467*	KT2/KT5	0.0395	1.2085
KT1/KT3	0.6742	0.0266	KT4/KT6	0.0574	0.8601	KT3/KT6	0.0018	10.9498*
Hemicelluloses content								
KT1/KT2	0.5805	0.0468	KT4/KT5	0.0269	1.5148*	KT1/KT4	0.0030	5.3527
KT2/KT3	0.7889	0.0106	KT5/KT6	0.3145	0.1714	KT2/KT5	0.5867	0.0452
KT1/KT3	0.4345	0.0977	KT4/KT6	0.0014	8.0469	KT3/KT6	0.0766	0.7303
Ash content								
KT1/KT2	0.7666	0.0131	KT4/KT5	0.7273	0.0145	KT1/KT4	0.4535	0.0892
KT2/KT3	0.5849	0.0457	KT5/KT6	0.3903	0.0639	KT2/KT5	0.0277	1.5951*
KT1/KT3	0.5009	0.0709	KT4/KT6	0.7178	0.0156	KT3/KT6	0.5273	0.0502
Content of extractive materials in the mixture of toluene and ethylene								
KT1/KT2	0.5597	0.0524	KT4/KT5	0.0914	0.5114	KT1/KT4	0.0004	33.3499*
KT2/KT3	0.0984	0.5975	KT5/KT6	0.0026	20.4110*	KT2/KT5	0.0012	14.2791*
KT1/KT3	0.0209	1.7706*	KT4/KT6	0.0093	5.7058*	KT3/KT6	0.0005	25.1540*
Content of extractive materials in hot water								
KT1/KT2	0.5335	0.0601	KT4/KT5	0.0287	1.5502*	KT1/KT4	0.0146	2.5669*
KT2/KT3	0.1193	0.5066	KT5/KT6	0.0511	0.9827	KT2/KT5	0.6674	0.0278
KT1/KT3	0.0326	1.3372*	KT4/KT6	0.0026	20.6690*	KT3/KT6	0.0172	2.2780*

*Note: *denotes a statistically significant difference at the confidence level of 95%.*

Figure 2 shows the FTIR spectra of the control sample of Narrow-leaved Ash wood and the samples treated with different acetic acid solutions (0.03, 0.06, and 0.09 g/g ODW) at temperatures of 100°C (KT1, KT2, and KT3) and 120°C (KT4, KT5, and KT6).

Table 4 presents the characteristic FTIR band assignments of Narrow-leaved Ash and its major components: cellulose, hemicelluloses, and lignin, as can be noticed in Figure 2.

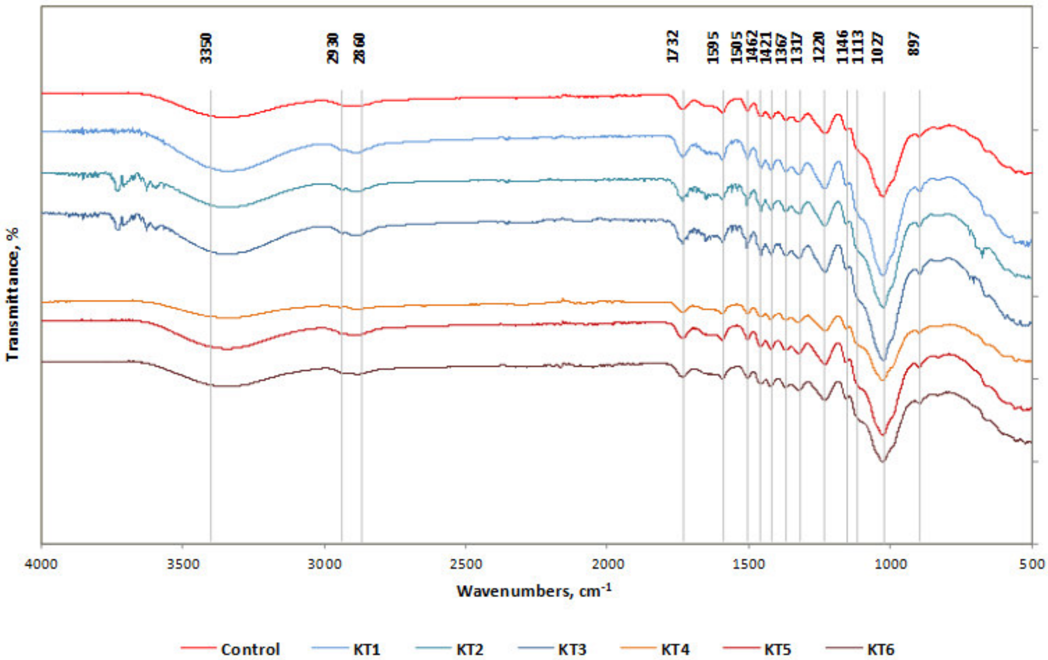

Fig. 2. *FTIR spectra of the nontreated (Control) sample and treated samples of Narrow-leaved Ash wood*

4. Discussion

4.1. The Effects of the Treatments

According to the graphs in Figure 1, it can be noticed that the applied pretreatments affected the chemical composition of the Narrow-leaved Ash wood, which led to changes in the relative proportions of the chemical components in the treated samples. The pretreatments had the highest effects on the extractives and ash content (Figure 1d, e, and f). This was expected since these wood components can be easily dissolved with the application of appropriate solvents [8]. The content of these organic and inorganic non-constitutive substances decreased significantly in all treated samples in comparison to the control sample of Narrow-leaved Ash, regardless of the treatment conditions (Table 2). The content of extractives soluble in the toluene/ethanol mixture and in hot water was reduced by 12-54% and 73-88%, respectively. The content of mineral substances in the treated samples decreased by 62-81% compared to the control sample.

Table 4

FTIR band assignments of Narow leaved Ash and its major components: cellulose, hemicelluloses and lignin

Absorption band [cm^{-1}]	Assignment	Components	Reference
3350	O-H Stretching vibrations	Cellulose, hemicellulose, lignin	[27, 37]
2930-2860	C-H stretching	Cellulose, hemicellulose, lignin	[27, 37]
1732	C=O Stretching vibrations	Hemicellulose, Lignin	[37]
1592	C=C Stretching vibrations of aromatic structure, C=O stretching	Lignin, Hemicellulose	[24, 27, 37]
1505	Aromatic skeletal vibration	Lignin	[27, 37]
1456	C-H Asymmetric bending deformation (methyl and methylene)	Lignin	[24, 27, 37]
1421	C-H in-plane deformation with aromatic ring stretching	Lignin	[27]
1367	C-H bending, C-H stretching in CH_3	Cellulose, Hemicellulose, Lignin	[26, 37]
1317	C-O of syringyl ring	Lignin	[27]
1220	C-O of guaiacyl ring	Lignin	[27]
1146	Asymmetric stretch of C-O and C-C	Cellulose, Hemicellulose	[24, 37]
1113	Guaiacyl C-H and syringyl C-H	Lignin	[27]
1027	C-O stretching, aromatic C-H in plane deformation	Cellulose, Lignin	[37]
897	C-O-C stretching (β-Glucosidic linkage)	Cellulose, Hemicellulose	[24, 26, 37]

The acetic acid pretreatments showed lesser effects on the content of the wood constitutive components. The cellulose content in all treated samples increased by 1-9% compared to the control sample (Figure 1a). The increase in cellulose content was more pronounced and statistically significant in the samples treated at 120°C (Table 2).

The pretreatments showed the least effects on the total lignin content. The pretreatments at 100°C resulted in only 0.7-2.3% change in lignin content, while the pretreatments at 120°C reduced lignin content bz about 3-8%. However, these changes were not statistically significant (Table 2). On the other hand, Marks and Viell [23] state that acetic acid is an effective agent for removing lignin, especially at high concentrations. Some of the ether linkages between the lignin phenylpropane units reacts even under mild conditions and undergo hydrolysis with hot water or dilute acetic acid [12]. Goldstein [12] states that even under the influence of acetic acid released during the steaming of wood, lignin can be transformed into soluble fragments. In addition, Chi et al. [7] found that during pretreatment with acetic acid, there is a partial degradation of low molecular weight lignin and its dissolution into the liquor. Accordingly, it can be assumed that lignin degradation occurred to some extent during the applied pretreatments, but its relative ratio did not change significantly in comparison to the control samples, due to the removal of a significant amount of extractives.

The applied pretreatments had significant effects on the content of hemicelluloses, regardless of the concentration of the acetic acid solution and the temperature (Table 2). The content of these polysaccharides increased in all treated samples by 8-30% (Figure 1). However, it is considered that the hydrolysis of glycosidic bonds in cellulose and hemicelluloses is the most common reaction of wood in an acidic environment [8], which is particularly a characteristic for glycosidic bonds in hemicelluloses and amorphous areas of cellulose. Acetic acid released during the wood steaming process can completely hydrolyze hemicelluloses to their constituent monosaccharides [12]. Chi et al. [7] also reported partial degradation and dissolution of hemicelluloses during acetic acid pretreatment. In this context, the increase in the content of cellulose and hemicelluloses in the treated samples of Narrow-leaved Ash can be explained by a significant decrease in the content of other wood components.

4.2. The Influence of Acetic Acid Addition and Pretreatment Temperature

Table 3 shows the results of the statistical analysis of the effects of pretreatment parameters (acetic acid addition and temperature) on the content of chemical components of Narrow-leaved Ash wood. The increase of the acetic acid addition in the treatment solution did not produce significant changes in the cellulose content during the treatments at 100°C. However, a higher pretreatment temperature of 120°C led to a significant increase in the cellulose content in samples treated with solutions with the acetic acid addition of 0.03 and 0.06 g/g ODW (Table 3). However, with the increase in acetic acid addition in the treatment solution, the cellulose content in the samples treated at 120°C decreased (Figure 1a), which led to a significant difference in the cellulose content between samples KT4 and KT6 (Table 3). This indicates that the increase of acetic acid concentration in the treatment solution and at higher temperatures (120°C) promotes the hydrolysis of glycosidic bonds in the amorphous regions of cellulose.

The increase of acetic acid concentration in the treatment solution also showed no significant effect on the content of hemicelluloses components of wood (Table 3) at a temperature of 100°C. However, samples treated at a temperature of 120°C have a lower content of these compounds compared to the corresponding samples treated at 100°C. This indicates that the increase in temperature affected the increase in the degradation of these compounds, but this difference is significant only between samples KT1 and KT4 (addition of acetic acid 0.03 g /g ODW). Although the heat accelerates chemical reactions, it can also initiate them. It is considered that the thermal decomposition of hemicelluloses already starts at 120°C [12], which may also have an effect on the reduction of the content of these wood components with the increase in pretreatment temperature. At the same time, at the pretreatment temperature of 120°C, the concentration of the acetic acid solution showed more pronounced effects on the content of hemicelluloses in the tested samples. As a result, there are significant differences in hemicelluloses content between samples KT4 and KT5, as well as between samples KT4 and KT6 (Table 3).

The content of Klason and acid-soluble lignin, as well as the total lignin content in the samples treated at 100°C does not differ significantly compared to the control sample of Narrow-leaved Ash. Although the sample treated with the addition of acetic acid of 0.09 g/g ODW showed a decrease in lignin content compared to the control, this change is not statistically significant (Table 3). According to these results, it can be assumed that the concentration of acetic acid had no effect on the lignin content in the samples treated at 100°C. Increasing the pretreatment temperature to 120°C results in a decrease in the lignin content. However, only samples KT3 and KT6 differ significantly in the content of acid-soluble lignin (Table 3). Sample KT6 treated with a solution with the addition of acetic acid of 0.09 g/g ODW recorded a significant increase in total lignin content compared to the other two samples treated at 120°C (KT4 and KT5).

As mentioned, the content of the secondary wood components (extractives and ash) was significantly reduced in all treated samples compared to the untreated Narrow-leaved Ash wood. Neither the concentration of the solution nor the temperature of the treatment had a significant effect on the content of inorganic substances, expressed as the content of ash (Table 3). At the pretreatment temperature of 100°C, the content of extractives soluble in organic solvents (toluene/ethanol) increased with the increase of acetic acid concentration in the solution. There is a significant difference in the content of these substances between samples KT1 and KT3. The reason for this could be a more intense decomposition of the structural wood compounds with an increase in the concentration of acetic acid in the treatment solution. At a higher pretreatment temperature of 120°C, the extractive content (toluene/ethanol) was significantly increased compared to the corresponding samples treated at 100°C (Table 3). However, at a treatment temperature of 120°C, the increase of the acetic acid concentration in the solution decreased the content of these substances, which resulted in significant differences in their content between samples KT4 and KT6, as well as between KT5 and KT6 (Table 3).

The increase of the pretreatment temperature from 100 to 120°C similarly affected the water-soluble extractive substances, resulting in significant differences in the content of these substances between samples KT1 and KT4, as well as between KT3 and KT6, treated with acetic acid solutions of the same concentration. In addition, the increase of the acetic acid concentration in the treatment solution affected the content of extractives soluble in hot water, resulting in significant differences in the content of these substances between samples KT1 and KT3 (100°C), KT4 and KT5, as well as between KT4 and KT6 (120°C), as shown in Table 3.

The increase in the content of the secondary substances and cellulose with an increase in the pretreatment temperature is probably due to an increased decomposition of lignin and hemicelluloses at higher treatment temperature.

4.3. Analysis of FTIR Spectroscopy

Figure 2 shows the FTIR spectra of the treated Narrow-leaved Ash wood samples. The absorption bands of the characteristic functional groups of wood are shown in Table 4. The FTIR spectra of the treated samples contain all of the absorption bands that were observed in the control sample. Accordingly, it can be concluded that the same functional groups are present in both the control and the tested samples. However, the intensity of the absorption bands of the different samples is not the same. This indicates changes in the number of functional groups, which corresponds with changes in the content of the wood constituents of Narrow-leaved Ash due to the applied treatments.

5. Conclusions

The applied pretreatments affected the chemical composition of the Narrow-leaved Ash wood, which was reflected in the relative ratio of the chemical constituents of the treated wood samples in comparison to the control sample, but also to each other.

The applied pretreatments have resulted in a slight increase in the content of cellulose (1-9%) and hemicelluloses (8-30%). After the treatment at 100 °C, the lignin content did not change significantly (0.7-2.3%), while in the samples treated at 120 °C it decreased by about 3.5-7.8%, which was not a statistically significant difference.

The content of secondary components was significantly reduced after the treatment. The content of extractives soluble in the toluene/ethanol mixture and in hot water was reduced by 12-54% and 73-88%, respectively and the content of mineral substances by 62-81%.

At the pretreatment temperature of 100°C, the concentration of the acetic acid solution generally had no significant effect on the content of wood constituents in the treated samples. However, with an increase in the pretreatment temperature to 120°C, the influence of the acetic acid solution concentration on the content of almost all wood constituents in the treated samples also increased. This was reflected in significant differences in the content of cellulose, lignin, hemicelluloses, and extractives between samples treated with solutions with different concentrations of acetic acid. The decrease in cellulose content with the increase in the addition of acetic acid in the treatment solution indicates that at higher temperatures (120°C) the increase in acid concentration promotes the hydrolysis of glycosidic bonds in the amorphous areas of cellulose.

The increase in the pretreatment temperature at the same concentration of acetic acid solution had a significant effect on the increase in the content of cellulose and extractive substances, and to a lesser extent it was reflected in the decrease in the content of hemicelluloses and lignin. The increase in the content of secondary substances and cellulose with an increase in the pretreatment temperature is probably due to the simultaneous increase in the decomposition of lignin and hemicelluloses.

FTIR spectra established the presence of the same functional groups in the treated and control samples. Differences in the intensity of the absorption bands of different samples indicate changes in the number of functional groups, which are in accordance with the changes in the content of wood constituents of Narrow-leaved Ash due to the applied pretreatments.

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RED DEER (*CERVUS ELAPHUS L.*) TROPHIES FROM ROMANIA

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Abstract: *Trophies, as a result of hunting activity express a series of elements that need to be analyzed, quantified and ranked. Trophies are classified according to objective criteria, with the International Council for Game and Wildlife Conservation developing an evaluation formula whose elements consist of measurements and assessments [12]. Based on the material presented, hunting exhibitions can generate objective deductions regarding the progress or regression of species, both zonally, regionally and nationally, becoming a vector in the establishment of game protection and extraction activities [20]. To carry out the study and select the data, the catalogs of all the national and international exhibitions in which Romania participated were consulted. This resulted in a number of 184 data sets, the provenance of red deer (Cervus elaphus L.) trophies covering 25 counties from the period 1919-2003.*

Key words: *Cervus elaphus, hunting trophies, hunting exhibitions, Romania.*

1. Introduction
1.1. General Information

The red deer (*Cervus elaphus* L.) is the big game species firstly ranked in terms of hunting and faunal interest, as well as economic importance [17]. The trophy, composed of antlers, represents weapons, ornaments, and a sign of vigor. Size, weight, number of trays, shape, and symmetry are indices of deer quality, both as a population and as an individual [19, 20]. Trophies are classified according to objective criteria, with the International Hunting Council developing an evaluation formula whose elements are made up of measurements and assessments [13].

1.2. The Importance of Evaluation Methodology

Trophies, as a result of hunting activities, express a series of elements that need to be analyzed, quantified and ranked. The initially subjective visual assessment has evolved over time

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towards the identification of parameters that can be measured based on a methodology as objective as possible. The data obtained in this way will be transposed through a calculation formula into points. Thus, through measurement, the morphometric elements of the trophy acquire a mathematically defined value and their specific characteristics can be formulated and analyzed. At the same time, the quality of trophies expressed in this way reflects the possibility of objective deductions over time, regarding the vigor of populations, seasonal conditions, and species management activities [23].

1.3. C.I.C. – International Council for Game and Wildlife Conservation – Trophy Evaluation System

The evolution of hunting events through the organization of thematic exhibitions at an international level has generated the need for an initiative to develop evaluation formulas based on the clearest criteria. The development of these well-defined criteria and instructions into a calculation method gradually replaced the subjectivity of visual judgments. In 1925, the first evaluation formula thus formulated and based on a calculation method for the red deer (*Cervus elaphus*) belongs to the zoologist and journalist Herbert Nadler, director of the Budapest Zoological and Botanical Garden [15]. The development of this evaluation formula was appropriated as one of the priority objectives of the establishment of the International Hunting Council (C.I.C.), through the elaboration of trophy evaluation methodologies in Berlin, February 5, 1930. The development and progressive adjustment of the methodology was carried out in Warsaw 1934, Prague and Berlin 1937, Madrid 1952, Düsseldorf 1954, Copenhagen 1955. An improved international system was funded in Budapest 1971, unified with a series of adjustments and suggestions in 1977 [15]. The current form of the trophy evaluation system expressed in the form of a manual of the Trophy Evaluation Commission (TEB), following the 61st general assembly in Milan, April 2014, was published in November 2014. The current evaluation methodology of hunting trophies can be found in the most recent format in the "CIC Handbook for the Evaluation and Measurement of Hunting Trophies - 2019" [7]. The C.I.C. trophy evaluation methodology is the most widespread and approached basic formula at European level, being recognized in more than 50 countries worldwide.

1.4. The Importance of Hunting Trophy Exhibitions

The manifestations of hunting culture, such as hunting exhibitions that focus on presenting hunting game trophies, can be classified based on their origin and scope as local, regional, national, and international [22]. Thus, based on the material presented, hunting exhibitions can generate objective deductions regarding the progress or regression of species, both zonally, regionally, and nationally, becoming a vector in the establishment of game protection and extraction activities [20].

1.5. Romania in the Context of National and International Hunting Exhibitions

The evolution of trophy exhibition hunting events was historically marked by the first international hunting exhibition in Vienna May 7 – October 16, 1910 - Erste Internationale Jagdausstellung Wien 1910. Ever since this first large-scale event with over 2.7 million visitors and 22,000 exhibits [21], Romania's territory today continues to maintain its position and results at the top of the world rankings for the main species of hunting interest. Although it did not officially participate in this exhibition, record trophies of chamois (*Rupicapra rupicapra*) with provenance from the territory of Transylvania and Austria-Hungary were present [9-11]. Following the appearance of the Nadler evaluation formula in 1925 and the establishment of the C.I.C., Romania was among the 11 countries participating in the international exhibition in Leipzig May - September 1930, annex of the international fur fair - IPA - Internationale Pelzfach-Ausstellung, Internationale Jagd-Ausstellung. At this exhibition, Romania obtained the international records for roe deer (*Capreolus capreolus*), wild boar (*Sus scrofa*) and red deer (*Cervus elaphus*), with the "Kosch" trophy from the Călimani Mountains - 219.32 Nadler points, also representing the first official manifestation of the country internationally (Comșia 1961) obtaining 36 medals (7 gold, 15 silver, and 14 bronze). The national hunting exhibition in Bucharest 9 May - 9 June 1935 represents the first initiative of its kind in Romania where the Nadler formulas and the Carpathian formula were used for red deer (*Cervus elaphus*) tropies. The international hunting exhibition in Berlin - Internationale Jagdausstellung Berlin 2 – 21 November 1937 surpassed all previous events by the number and quality of exhibited trophies, 25,000 (the Romanian pavilion comprising 760 pieces), but also by the number of participanting countries, 29. The event also promoted elements of hunting culture, art and tradition. At this exhibition, Romania obtained the title of world record for the chamois trophy (*Rupicapra rupicapra*) and bear skin (*Ursus arctos*), but also the world vice record for the roe deer (*Capreolus capreolus*) and red deer (*Cervus elaphus)* with the "Kosch" trophy from Călimani Mountains that scored 230.1 points. Romania excelled in the number of medals obtained, namely 354 (112 gold, 122 silver, 120 bronze), a performance that thus reflects the value and quality of Romanian game [18]. For the red deer species (*Cervus elaphus*), the method used by the evaluation committee was the improved version of the Nadler formula [8] in Prague in May 1937. Remarkable results were also obtained through Romania's participation in the subsequent events: the international exhibition Florence - Mostra Mercato Internazionale della Caccia - Firenze 1964, International exhibition Novi Sad – Sajam Lova I Ribolova Novi Sad 1967,Vadászati Világkistállí Budapest 1971 with 24, Mostra Internazionale della Caccia e della Pesca exhibitions, respectively the Concorso Internazionale di Trofeistica section - Turin 1972 and 1973, Celostátní Myslivecká Výstava - České Budějovice 1976, Chassexpo Méditerranée - Marseille 1977 [18]. The first and only international hunting exhibition organized in Romania is represented by the International Hunting Exhibition - Bucharest, 5 - 14 October 1978, followed by two national hunting exhibitions - Bucharest (and Bulgaria) 1997 and 2003. 21st century marks the fragmentation of trophy exhibitions at national level. The recent exception and pinnacle of international events in the field is represented by the World Exhibition - One with Nature – World of Hunting and Nature Exhibition Budapest 2021. As an anniversary cultural event (1971-2021), the exhibition focused on the importance of sustainable utilisation of nature, nature conservation by hunting and game management as well as hunting tradition and methods; bowhunting, falconry, muzzleloader, and dog and horse hunting. A trophy show was presented for the Carpathian Basin as well as other exotic game species. Numerous countries were invited to participate, including Romania, and over 1 million visitors were in attendance [14].

Currently, trophy exhibitions in Romania are carried out on a rather regional initiative, some events already embodying a form of tradition throught the creation of multiple successive editions: Expo-Venatoria - Timișoara, Expo-Moldavia - Bacău, H-Hunting Prize - Sibiu.

2. Material and Methods

2.1. Material

This paper analyzes the particularities of the measurable parameters of red deer (*Cervus elaphus*) trophies, from the upper class of medalable trophies, both historical and recent, whitin the C.I.C. evaluation method. The study aims to analyze and highlight the ratio between measurable parameters, total score, areas and the evolution of their performances over time [1-6, 16].

2.2. Data Selection

To carry out the study and select the data, the catalogs of all the national and international exhibitions in which Romania participated were consulted. From the total of these exhibitions, only a part recorded in the event catalog every measurable/appreciable parameter of the trophies. At the same time, in order to calibrate the data regarding the relevance of the ratio between the performances of the measurable parameters of the trophy and the age classes, the data of the trophies of over 210 C.I.C. points were selected (gold medal trophies). The provenance of the trophies includes 25 counties from the period 1919-2003. This resulted in a number of 184 data sets according to the following exhibits:

- 36 trophies from the Bucharest 1997 national exhibition;
- 29 trophies from the Bucharest 2003 national exhibition;
- 28 trophies from the international exhibition Novi Sad 1967;
- 34 trophies from the international exhibition Budapest 1971;
- 25 trophies from the international exhibition České Budějovice 1976;
- 8 trophies from the Nitra 1980 international exhibition;
- 13 trophies from the international exhibition Plovdiv 1981;
- 11 trophies from the international exhibition Brno 1985.

2.3. The Selected Components for Analysis Expressed Parametrically, within the C.I.C. Evaluation Formula for the Common/Red Deer Trophy (*Cervus Elaphus L.*)

From the C.I.C. evaluation methodology for the red deer trophy, the following measurable parameters with acronyms were selected for the study (Table 1):

- the length of the main beams - LMB;
- the length of the brow tine - BRT;
- the length of the tray tine - TRMT;

- the circumference of the coronets - CC;
- the lower circumferences of the beam - C1;
- the upper circumferences of the beam - C2;
- the total number of tines - NT;
- the weight of the trophy - WG;
- the inside spread of the trophy - INS;
- the total score of the trophies - TS.

Explicitation of the parameters Table 1

No.	Acronyms of the measureable parameters	Explanation and unit of the measureable parameters selected for analysis
1	LMB	The average of the left-right main beam length expressed in cm
2	BRT	The average left-right brow tine length expressed in cm
3	TRMT	The average left-right tray tine length expressed in cm
4	CC	The average left-right circumference of the coronets expressed in cm
5	C1	The average left-right smallest circumference identified between the bay tine (if this tine is missing then the brow tine) and the tray tine expressed in cm
6	C2	The average left-right smallest circumference identified between the tray tine and the crown expressed in cm
7	NT	The sum of the total number of tines
8	WG	The net weight of the trophy expressed in kg
9	INS	The inside largest spread of the trophy expressed in cm
10	TS	Total score of the trophy expressed in C.I.C. points*

* the final score derived from the sum of the values obtained for each parameter by category, from which, where appropriate, the amount of penalties deducted:

- bronze medal (170-189.99 C.I.C. points);
- silver medal (190 - 209.99 C.I.C. points);
- gold medal (> 210 C.I.C. points).

2.4. Method

The statistical analysis applied to the data set refers to elements related to the architecture of the trophy and targets its descriptive analytical relations, correlative analysis and multivariate analysis related components.

From the first category, the descriptive statistical analysis refers to the following statistical indices: the arithmetic mean, the standard deviation, the standard error of the means, and the coefficient of variation.

The relationship between the measured elements of the trophy expressed by correlation analysis, simple correlation analysis, and multiple correlation analysis, respectively.

The multivariate analysis treats the PCA module for the 10 analyzed variables.

3. Results

Using the descriptive technique, the data was processed obtaining the main statistical indicators, namely the mean (M), the standard deviation (SD), the standard mean error (Std. err. of mean), and the coefficient of variation (CV%), respectively (Table 2).

By comparing the coefficients of variation, the following aspects can be outlined.

For all of the analyzed variables, it can be observed that the coefficient of variation values are below the 30% value, proving a normal distribution and homogeneity of the sample. Thus, the elements TS, C1, C2, LMB, TRMT with values below 10%, BRT, NT with values below 15% and WG, INS with values above 20% are noted.

Descriptive statistics of variables Tablel 2

Variables	ValidN	Mean	Minimum	Maximum	Standard deviation	Coefficient of variation	Standard error
LMB	28	114,55	103,75	124,50	5,664	4,945	1,0704
BRT	28	39,28	27,15	48,48	4,738	12,062	0,8955
TRMT	28	40,37	33,00	49,00	3,910	9,686	0,7390
CC	28	26,69	23,85	30,30	1,546	5,793	0,2922
C1	28	16,46	15,00	17,88	0,616	3,741	0,1163
C2	28	16,04	13,90	17,85	0,813	5,068	0,1536
NT	28	16,09	12,14	20,00	1,790	11,124	0,3383
WG	28	8,82	0,08	11,70	2,613	29,618	0,4938
INS	25	83,11	2,31	103,00	19,499	23,461	3,8999
TS	28	219,83	210,57	237,33	5,409	2,460	1,0222

Matrix correlation of variables Table 3

Variable	LMB	BRT	TRMT	CC	C1	C2	NT	WG	INS	TS
LMB		0,153	-0,171	-0,266	-0,511^{0}	-0,130	-0,312	-0,155	0,332	-0,055
BRT			0,080	-0,029	0,128	0,066	0,037	-0,040	0,035	0,368
TRMT				0,259	-0,202	-0,497^{0}	0,301	0,053	-0,194	0,417*
CC					0,033	-0,156	-0,066	0,290	-0,064	0,523*
C1						0,558*	0,058	0,032	-0,335	0,373
C2							-0,125	-0,057	-0,203	0,163
NT								0,123	0,232	-0,136
WG									0,422*	-0,023
INS										-0,395
TS										

*significant positive correlation for α = 0,05%;

^{0} significant negative correlation for α = 0,05%.

The simple linear correlation analysis applied to the 10 variables reveals six significant statistical links (Table 3).

It can be outlined that the LMB variable achieves a significant negative simple correlation with the C1 variable, and TRMT with C2. These negative correlations suggest a trophy architecture relationship driven by antler growth capacity. Variable C1 correlates positively and significantly with variable C2 as well as WG with INS, suggesting the effect of proportionality in terms of weight distribution on the two beams. Interesting correlations are made by the TRMT and CC variables with the TS variable, which can be interpreted as a functional relationship between the measurable elements and the trophy score (Figures 1-6).

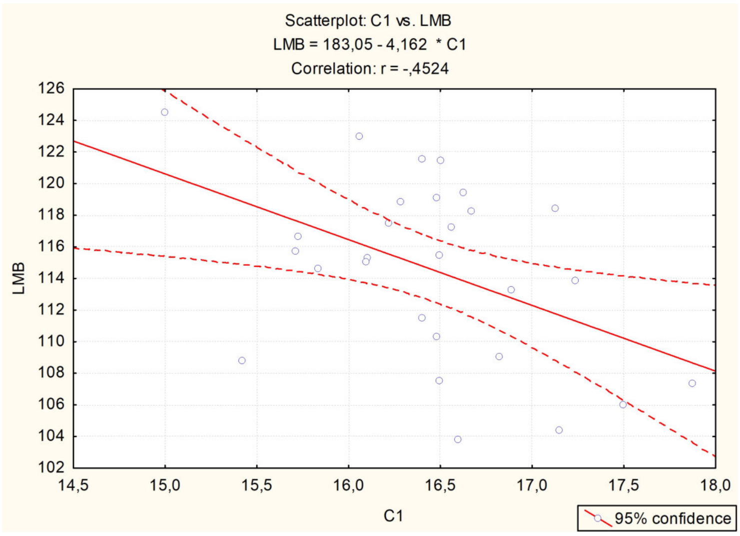

Fig. 1. *Scatterplot between LMB and C1*

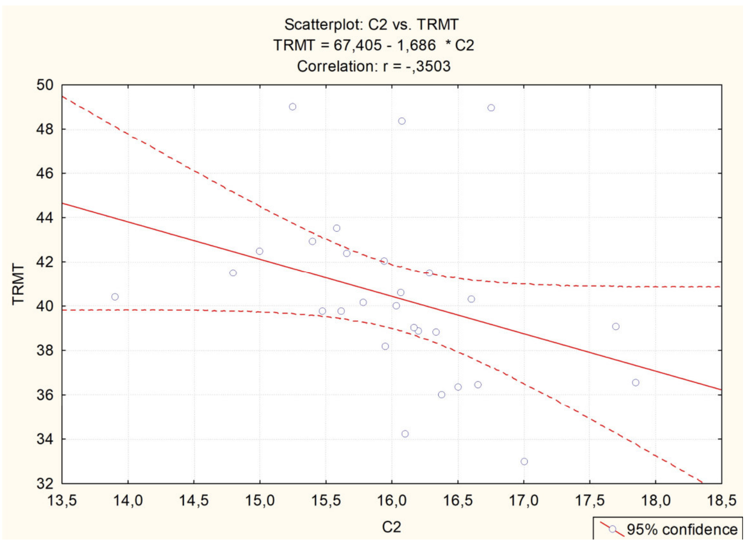

Fig. 2. *Scatterplot between TRMT and C2*

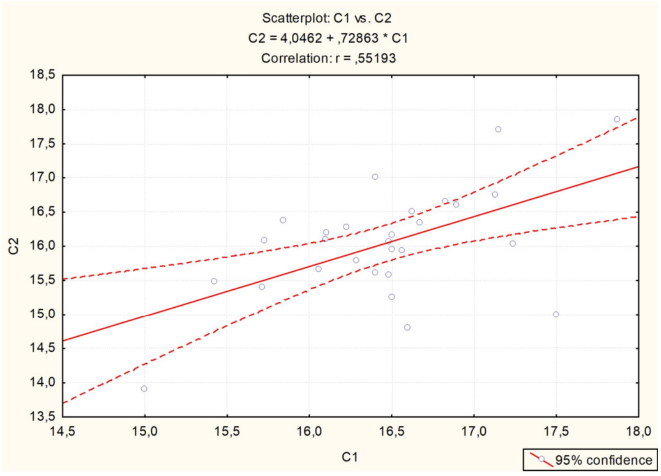

Fig. 3. *Scatterplot between C2 and C1*

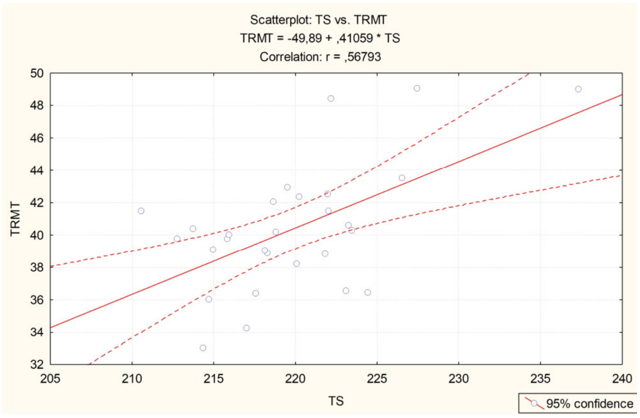

Fig. 4. *Scatterplot between TRMT and TS*

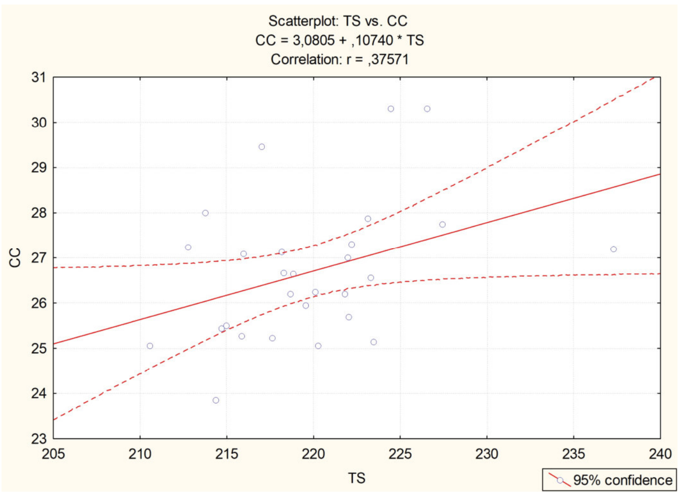

Fig. 5. *Scatterplot between CC and TS*

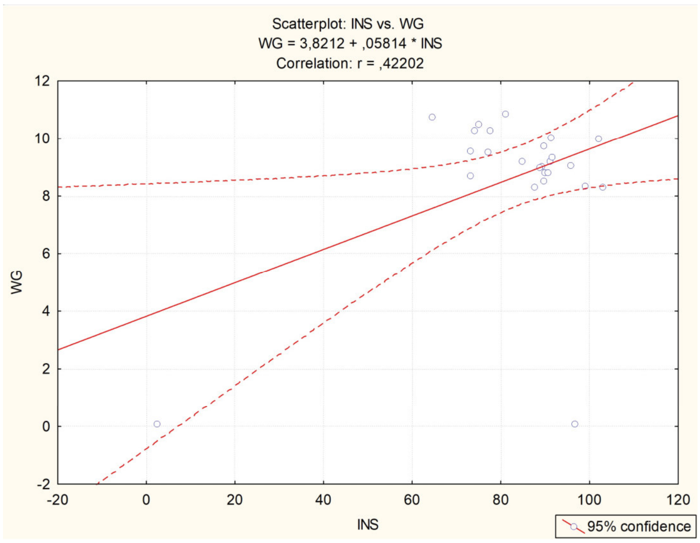

Fig. 6. *Scatterplot between WG and INS*

A detailed analysis regarding the link between the measured variables and the obtained total score was carried out by means of the multiple correlation forward stepwise method (Figure 7).

Analyzing the data in Figure 7, the form of the multiple regression equation can be edited as Equation (1):

$$TS = 30.808 + 0.534CC + 0.525TRMT + 0.496LMB + 0.478C1 \quad (1)$$

Multiple Regression Results (Step 7)

Dependent: TS Multiple R = ,92130445 F = 13,63361
R^2= ,84880189 df = 7,17
No. of cases: 25 adjusted R^2= ,78654385 p = ,000007
Standard error of estimate: 2,014117333
Intercept: 30,808848173 Std. Error: 26,89434 t(17) = 1,1456 p = ,2679

CC beta=,534 BRT beta=,197 INS beta=-,22
C1 beta=,478 LMB beta=,496 TRMT beta=,525
C2 beta=,246

(significant betas are highlighted)

Fig. 7. *Elements of multiple regression analysis*

The multivariate analysis applied to the experiment refers to the PCA (Principal Components Analysis) module (Table 4).

In this context, the main variables were selected: LMB, BRT, TRMT, C1, C2, additional variables and the target group represented by TS.

Factor-variable correlation based on correlation of active variables Table 4

Value number	Eigen value	Total variance	Cumulative Eigen value	Cumulative [%]
1	1,968100	32,80167	1,968100	32,8017
2	1,573464	26,22441	3,541565	59,0261
3	1,066072	17,76786	4,607636	76,7939
4	0,727993	12,13322	5,335630	88,9272
5	0,385665	6,42774	5,721294	95,3549
6	0,278706	4,64509	6,000000	100,0000

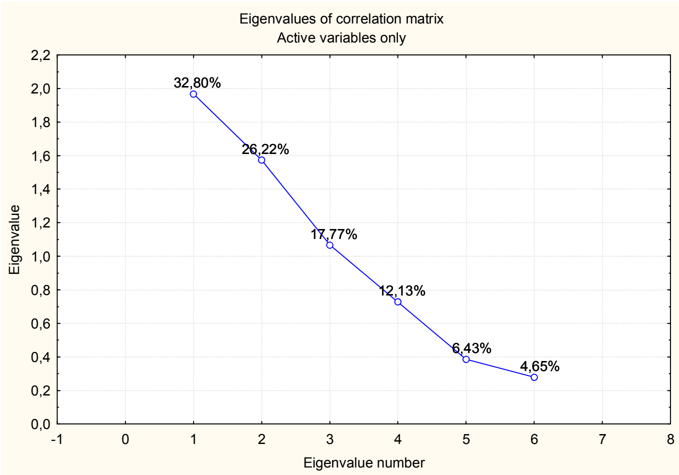

Fig. 8. *Number of factor of successive eigeinvalues*

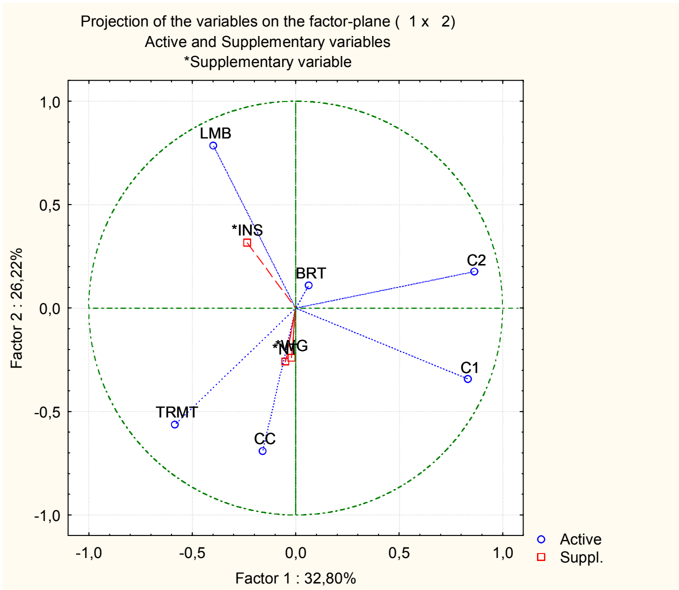

Fig. 9. *Plot of factor coordinates of variables*

4. Conclusions

The trophy elements analyzed show low variations (below 30%), thus proving the homogeneity of the sample.

The simple correlation analysis highlighted significant simple correlations (negative and positive) between the measured elements of the trophy. A multiple regression equation was generated in which the main elements that compete significantly in the evaluation formula are included.

The PCA analysis emphasized the main factors and their degree of participation in establishing the evaluation formula.

Based on the material presented, hunting exhibitions can generate valuable data sets. Therefore, objective deductions regarding the progress or regression in time of the trophies (species) at regional and national level, becoming a vector in the establishment of game management plans.

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THE USE OF GEOGRAPHICAL INFORMATION SYSTEMS FOR ISSUES REGARDING LAND RECEDING OF FORESTED AREAS

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Maria M. VASILESCU[1]**

Abstract: *Although such a long time has passed since property laws that attempted to repair at least part of the injustices of the communist era came into effect, there are still numerous situations in which these laws cannot manifest their effects. There are a great deal of causes that have led to this unfortunate situation, with the largest possibly being the impossibility of harmonizing the technical side with the judicial one. For this paper, a study area in the county of Brasov was chosen, which is comprised of forest parcels that need to be receded to their past owners. This area covers a few hundred hectares, and parcel plans need to be developed for it, which are then sent in to OCPI Brasov for approval (this being the only manner by which these parcels can be recorded in cadastral records). The opportunities which GIS offers in terms of incorporating field data into forestry projects, for carrying out comparisons or validation of forestry parcel plans and for flagging issues were highlighted. A number of critical issues were identified and an attempt was made at solving them using VBA code sequences in the ArcGIS software package.*

Key words: *parcel plan, forest management plan, GIS, precision.*

1. Introduction

There are still unsolved issues with regard to land receding of forest areas to their rightful owners. Although it started many years ago, this problem still encounters significant barriers towards a solution, and it therefore a real challenge for professionals involved in it.

Numerous studies and researchers have proven that Geographical Information Systems are a very useful alternative for solving issues in the forestry sector, with studies proving that: these systems are highly successful in the sustainable administration of forests [4], in establishing the production class of tree stands [7], in the functional zoning of forests [5], in calculations of timber

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volume [6, 8], in determining the accessibility of tree stands [3], in the general management of forests [1] or in the decision-making process for a proper administration of forests [2].

A highly useful alternative is creating a web application [9] that would contain all data available at a national level, thereby helping users track the progress of this activity and achieve somewhat of a standardization of procedures.

This study was carried out for a forested area of about 400 hectares, consisting of forest parcels that were receded during different phases in the application of property laws. These are forest surfaces mixed within agricultural land which are part of the cadastral sector no. 11 of the Poiana Mărului locality and are overlaid with past forest parcels no. 67 through 141.

2. Material and Methods

For the present study, the following materials were used: one *Trimble ProXT* and one *Trimble ProXH.*

GPS receiver, topo-cadastral plans containing silviculture boundaries, forest descriptions of the studied area, and the orthophoto plan of the locality in question. In terms of research carried out, the following methods were used: direct measurements for the determination of point coordinates defining the boundary of the analysed forest bodies and located inside them (corresponding to each title deed), office studies by which the documents in the possession of land owners were analysed, paperwork from the archive of Brasov City Hall and OCPI Brasov, GIS methods for the geo-referencing of cadastral plans, vectorization of necessary data and conception of the VBA code sequences attempting to solve the identified issues.

3. Results

A team consisting of a land surveyor, a representative from City Hall and the landowners went in the field and carried out the necessary measurements for each title deed. As mentioned, one *Trimble ProXT* and one *Trimble ProXH* GPS receivers were used to determine the coordinates of over 2000 points. Points located inside the forest canopy were determined by the *Stop&Go* method with post-processing, using data provided by the TopGeocart permanent station. Meanwhile, points located on the canopy edge were determined using the RTK method with offsetting done additionally. Afterwards, field data was correlated with data from the E-terra platform covering the area of interest. Following this step, a series of issues were discovered which warranted a distinct approach for solving. A GIS project was created, in which the field-measured boundaries were introduced, along with boundaries from silvicultural databases and the E-terra platform (Figure 1). In this GIS project fixing these problems was attempted on a case-by-case basis. The issues in question are as follows:

a. Where landowners had deeds for neighboring agricultural lands registered in the integrated system of cadaster and land register which had overlaps with the forested land, the type of overlap was analysed; for this, a stakeout of certain unobstructed points was carried out in order to verify the correct boundaries in the field. In this manner we established that most overlays were virtual, and would therefore be solved by repositioning (Figure 2); there are however cases of real overlays (Figure 3), which stem from the fact that owners updated their land registry data for the parcels of agricultural land; their motivation was that they had negative area differences and that the land was ‘forever in their use’;

b. In the case where multiple owners had a claim for the same forest surface, the following were considered: the placement of the agricultural land of the two owners and overlays with the old land registry drawings (Figure 4);

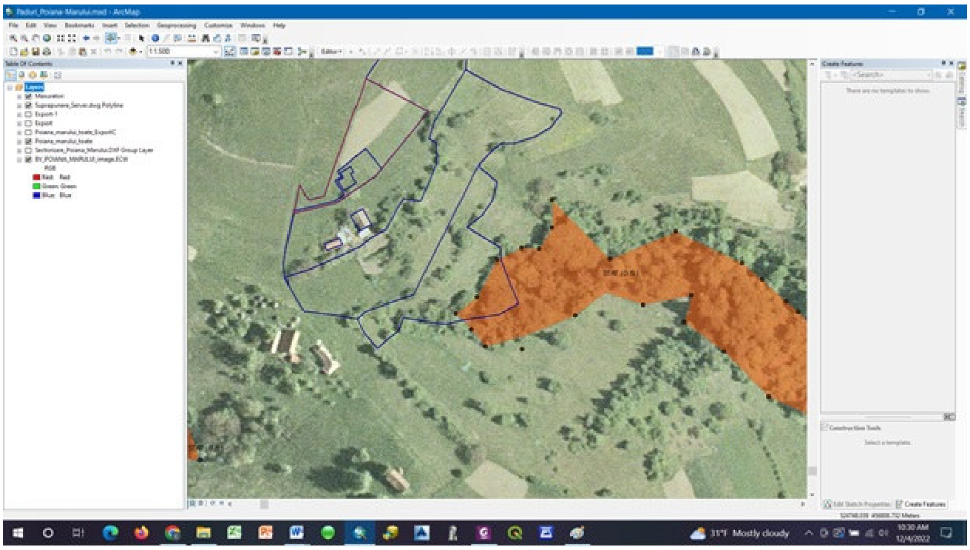

Fig. 1. *Overlay of field survey data with silvicultural parcels and data from the cadastral office’s server*

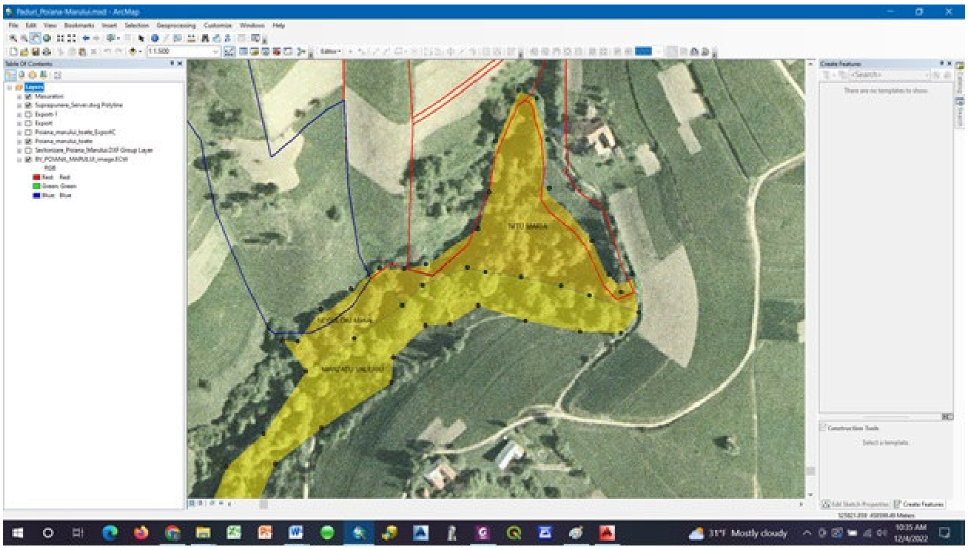

Fig. 2. *Solving of issues through repositioning*

c. Issues of differences in area between field surveys and land deeds were very common (Figure 5);
d. For a forest area with unknown owners, the neighboring area was studied and potential landowners claiming the same forest area were identified, with the intention of carrying out a land area compensation between them.

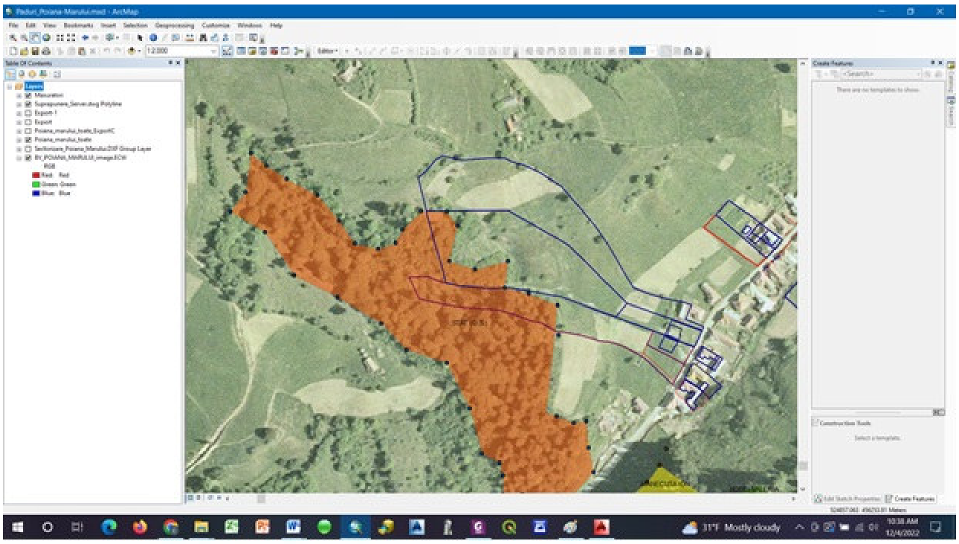

Fig. 3. *Issues of real overlay*

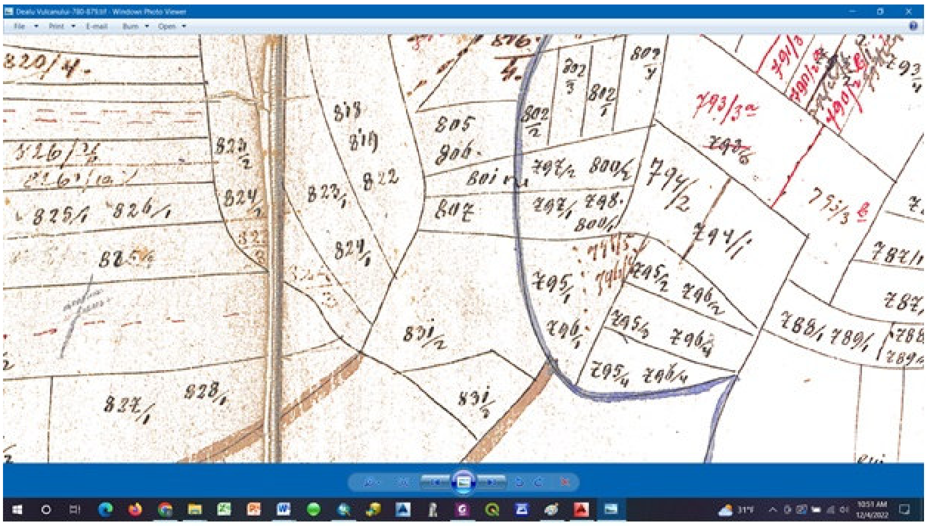

Fig. 4. *Analysis of old cadastral registry drawing*

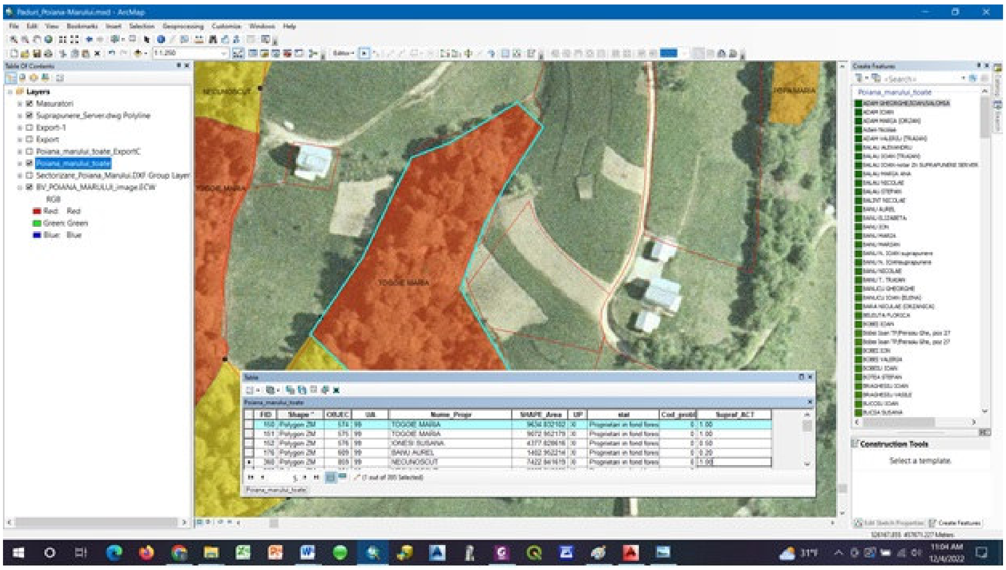

Fig. 5. *Area differences*

4. Discussion

Each of the cases described above was analyzed separately with the intention of finding a favorable solution. For the analysis of overlays, a VBA code sequence was written in order to flag all areas of overlay (Figure 6). The creation of this sequence involved loading into the project all data downloaded from the e-Terra platform of ANCPI, together with all field-collected data. These two layers were used in the creation of the sequence, with the aid of the intersection and reunion functions. After cases with issues were identified, quantitative estimations of the types of recorded overlaps could be made. The creation of this sequence is beneficial not only to this project, but to any other GIS project. By running this sequence, all overlays were identified, regardless of their nature. By further application of the Buffer and Clip functions on this newly created layer, a total area of 6.38 ha of overlays was established. Next, each overlay was analysed individually. In the case of virtual overlays, the manner of solving was discussed previously. A total area of 4.03 ha of virtual overlays was identified consisting of 33 land parcels, the solving of which involved field surveys carried out by a team of two land surveyors and the positioning of 275 points. The translations and rotations of parcels were carried out using a minimum of 8 points. Afterwards, repositioning documentations were compiled, which on average took about 3 hours per documentation. With regards to real overlays, each case was analysed separately, but solutions converged towards the same conclusion: in order to solve this issue, the landowners' agreement was required in order to shrink the agricultural land area and fix the issues with forest areas according to current legislation. Eight properties are in this situation. Repositioning documentations, along with surface rectifications, were necessary for 5 of them. Landowners who gave notary statements also had property deeds for the portions of forest in their property, therefore these issues were ones of double property records. A single situation remains unsolved (Figure 7), as the landowner did not understand the facts of the matter.

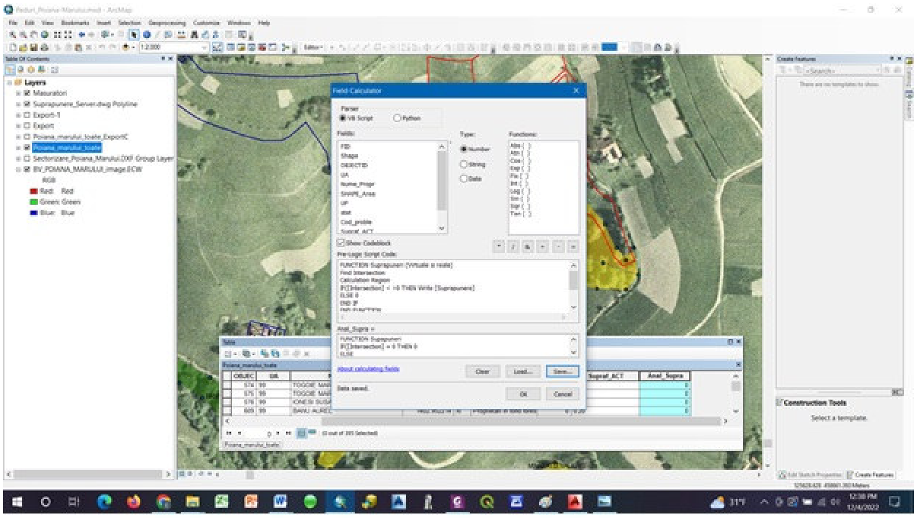

Fig. 6. *VBA sequence for overlay identification*

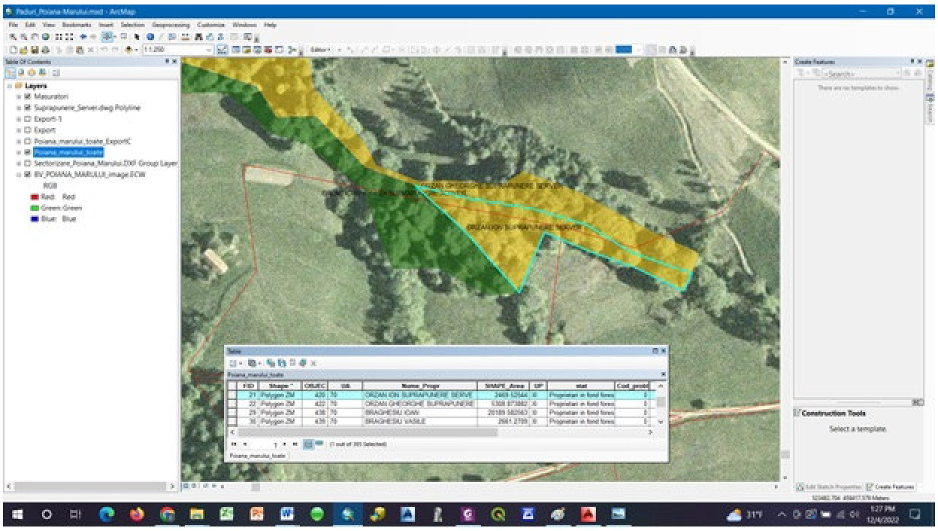

Fig. 7. *An unsolved case of real overlay*

In this case an annulment of the property deed was solicited. It must be mentioned that these kinds of issues require much longer time investments, so for these 8 situations a time budget comparable with the one for the 33 cases of virtual overlaps was needed. In the case of forest areas claimed by multiple owners, a single case was identified (Figure 8). The agricultural land areas owned by these two citizens that claimed this area of 0.35 ha were surveyed. This survey established that one of the two owners uses an extra 0.4 ha of land unaccounted for. Although the old land register drawing was also used which clearly indicates the shape of the boundary between the two, still one of the owners did not accept the fact that this area of forest did not belong to him and he would seek justice in the appropriate courts.

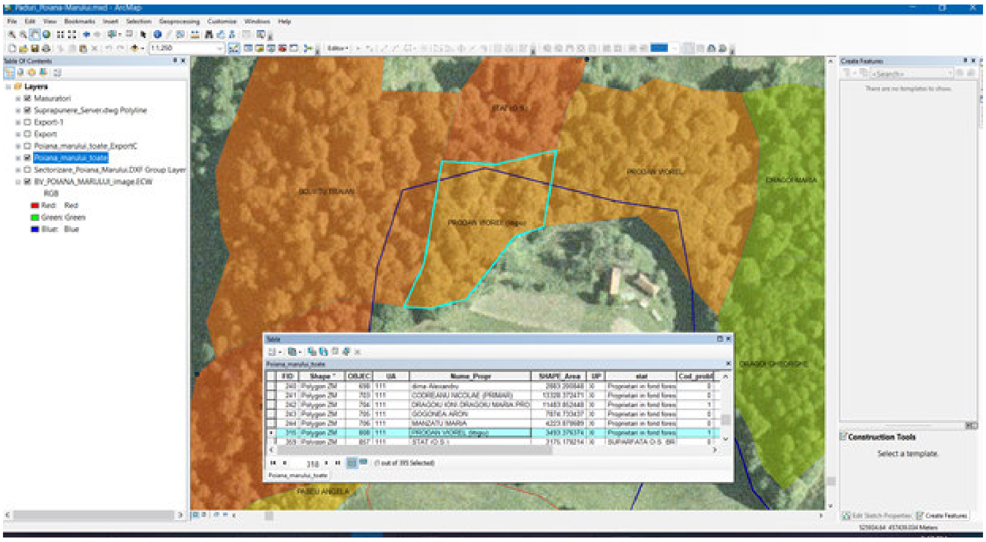

Fig. 8. *Area of forest claimed by two owners*

The last notable issue identified in this study was the fact that, at the time of the field surveys, the owners of a certain portion of forested land were unknown. Fifteen such situations were identified. By studying documents from the City Hall, part of these parcels were identified with the explanation being that land deeds were issued for persons that later deceased and their heirs do not live in the area, with a total of 7 land parcels being in this situation. However, a series of land parcels remain unclaimed. It has been decided that in the parcel plans to be created, these areas would be registered as land reserve for the local committee.

5. Conclusions

Solving issues related to the receding of forest land is very cumbersome, with various technical, social and judicial obstacles. It has been proven that a very elegant approach with numerous advantages is using a Geographical Information System that can put graphical data together with technical and judicial attribute data. A forest area of about 400 hectares was analysed, located in Poiana Marului locality of Brasov county and 71 parcel plans similar to the old forestry parcels were submitted to OCPI Brasov. Only two forest parcels were omitted due to current legal issues. Fifty-seven land parcels which had issues requiring distinct solutions were identified. These totalled a body of work three times larger than the one for the establishment of parcel plans. Of these 57 cases, only a single one could not be solved and will need to involve a court of judgement. It has been proven that GIS is not just a very easy to use and appropriate tool for digital creation of parcel plans, but also that its power resides especially in the pertinent analysis that can be carried out, including with the aid of VBA code sequences which can flag delicate issues and help in solving them. This is the case of the overlays that were identified through such a VBA sequence. Later, with the aid of Buffer and Clip functions, the areas affected by these overlays were precisely determined. By individual analysis of these cases, specific and appropriate solutions were identified. Therefore, each of these cases (with a single exception) has a favorable solution.

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