

Article

Insights in Managing Ungulates Population and Forest Sustainability in Romania

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Abstract: Improved forage and living conditions in certain parts of Europe over the past few decades have led to alarming levels of ungulate densities. Consequently, the overabundance of red deer, roe deer, and fallow deer in the Western Plains of Romania has begun to generate issues in the development of young oak stands. In addition to causing damage to the agricultural sector and increasing the risk of vehicle collisions, ungulates are increasing pressure on the forestry sector, mainly through the browsing of young saplings. This study quantifies the levels of ungulate browsing in oak stands using a permanent sample grid of 42 plots in both natural and artificial regeneration areas. A total of 3223 individual saplings were measured, revealing browsing intensities of 49.65% in clearcut systems and 12.8% in continuous forest cover systems. With high ungulate densities identified as the main cause, the Sustainable Population Threshold was calculated using a complex set of indices and compared to the actual numbers of ungulates, both of which were translated into stock unit equivalents. A logistic regression model was developed based on silvicultural and wildlife indices to identify other factors influencing browsing occurrence. The findings indicate that the proportion of forested areas in the hunting ground and the type of silvicultural system are significant factors in the occurrence of browsing. The problem of ungulate overabundance clearly influences forest development, and new solutions should be identified in terms of both forestry and wildlife management.

Keywords: ungulate; browsing; forest management; wildlife management



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1. Introduction

The interactions between wildlife and forest ecosystems are essential for preserving biodiversity and maintaining ecosystem health. They support the sustainable management of natural resources—both game and timber—by enhancing biodiversity through seed dispersal, pollination, and species diversity; regulating ecosystem processes via predation, herbivory, and nutrient recycling; and maintaining habitat structure for forest resilience [1–3]. In some temperate areas in Europe, ungulates have increased in number over the past decades, creating imbalances between conservationists, ecologists, farmers, wildlife managers, and forest managers [4–8].

Noticeable shifts in ungulate populations have coincided with climate change and advances in agricultural practices, which have improved forage conditions. As a result, there have been significant increases in both the populations and the range of these species [9,10].

Throughout Europe, the overabundance of ungulates has resulted in damage to the agricultural sector through reduced yields of several crops, damage to the forestry sector due to browsing, fraying, and trampling, and human safety concerns stemming from vehicle collisions [11,12]. This study specifically focuses on the damage within the forestry sector caused by browsing. Ungulate browsing is represented by the consumption of vegetal material other than bark from young saplings which interfere with the normal development of the plant.

Browsing is a well-researched topic in the literature, with over 155 research papers published in Europe, of which roe deer (*Capreolus capreolus* L.) is the focus of 95 studies and red deer (*Cervus elaphus* L.) is the subject of 93 studies [13]. One trend in the study of browsing focuses on the damage inflicted on coniferous species, particularly the replacement of more palatable species like silver fir (*Abies alba* Mill.) with less palatable ones such as Scots pine (*Pinus silvestris* L.) and Norway spruce (*Picea abies* L.) in Central and Southern Europe [4,14–19]. Another trend is the preference for broadleaved species over coniferous species in mixed plantations, as their palatability is much higher [20,21]. This is the case for oak species [22–24], which are part of mixed regeneration with less valuable species; however, oak typically serves as a future crop tree [25]. Therefore, the loss experienced is not only ecological but also economic. Even if the browsed saplings survive, it has been shown that the future timber depreciates due to the development of multi-stem trunks and the onset of additional diseases that affect timber quality [26].

This is particularly evident in the Western Plains of Romania, where populations of red deer (*Cervus elaphus* L.), fallow deer (*Dama dama* L.), and roe deer (*Capreolus capreolus* L.) have increased in numbers. The study area is characterized by large-scale, intensive agriculture on flat terrains, bordered by forests, similarly to areas found in the Hungarian Great Plain [27]. Ungulates utilize the agricultural fields as both feeding and resting zones [28,29] almost year-around, with the exception of late winter and early spring when the crops are harvested and no abundant food is available. During their refuge period in the forests, the overabundant ungulates exploit all available resources. However, due to intensive browsing, the tree species struggle to develop adequately or survive in order to reach the canopy stage [30].

The aim of wildlife managers is to maintain the population at a level which the ecosystem can support, while preventing the loss of genetic diversity, enhancing the long-term survival, and reducing the damage caused to the other sectors [31]. In most of the cases, the economical compensation has to be covered by wildlife managers [32]; however, in some situations, the legislation does not provide enough flexibility to manage the population effectively, as the behavior of the ungulate species has significantly changed, resulting in an increased natural annual growth [6,33]. Similarly, forest managers have to assure that the forest will develop properly and to use preventive measures against ungulate browsing, such as fencing or the use of repellents [34]. Some silvicultural practices are also influencing the levels of damage, as the silvicultural system uses different regeneration techniques with highly varied sapling densities [35].

This study provides the first assessment of ungulate browsing in young oak stands in Romania and evaluates ungulate occupancy in forests with high ungulate densities. Analyzing browsing from both forestry and wildlife management perspectives, it aims to clarify the primary impact of high ungulate density—exacerbated by intensive agriculture—and to identify secondary factors based on local silvicultural practices. A comparison between actual and optimal ungulate populations, using Sustainable Population Threshold (SPT), offers a clear visualization of density discrepancies. The findings will equip wildlife and forestry managers with crucial insights to mitigate browsing damage.

2. Materials and Methods

2.1. Study Area

The study area was conducted in northwestern Romania, in the Western Plains, within forests managed by the Forest Administration Tinca. The location of this study is at 46° 46' N latitude and 21° 55' E longitude. This study encompasses five hunting grounds (HG): HG 25 Boboștea, HG 26 Păușa, HG 30 Peri, HG 31 Goroniște, and HG 35 Oșand (Figure 1), all under the jurisdiction of the Forest Guard Bihor. These hunting grounds cover a productive area of 43,282 ha, of which 13,562 ha are represented by forested areas, representing 31.33% of the total area of the hunting grounds.

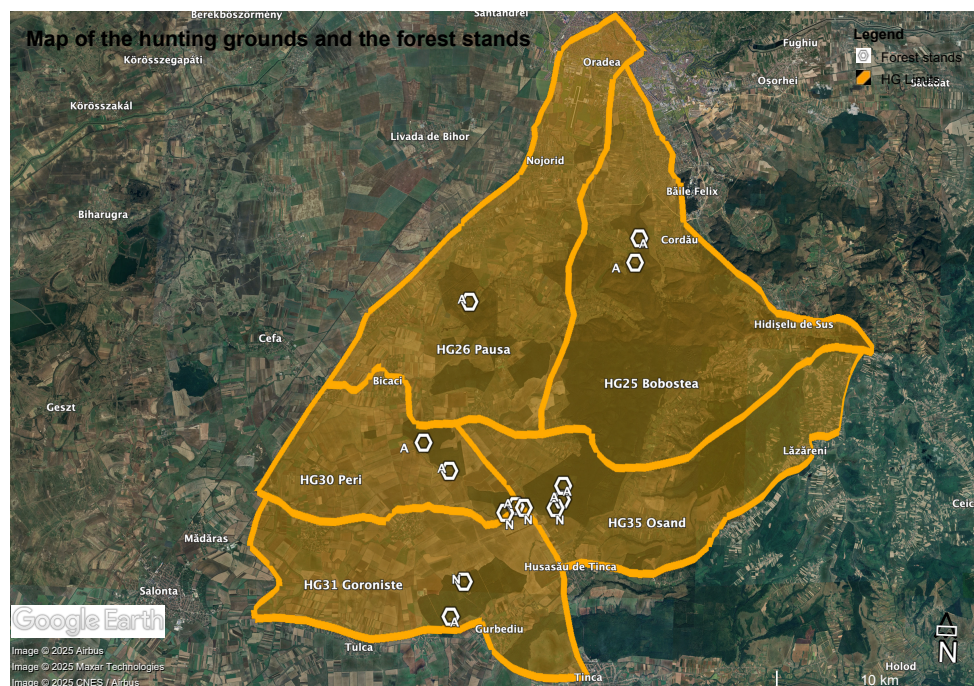


Figure 1. Map of the hunting grounds and forest stand included in this study.

The forests included in this study are primarily dominated by oak species: Turkey oak (*Quercus cerris* L.), Pedunculate oak (*Quercus robur* L.), Hungarian oak (*Quercus frainetto* Ten.), Sessile oak (*Quercus petraea* L.), and Northern red oak (*Quercus rubra* L.). Other tree species of forestry interest that can be found in the study area include European ash (*Fraxinus excelsior* L.), hornbeam (*Carpinus betulus* L.), black locust (*Robinia pseudoacacia* L.), and wild cherry (*Prunus avium* L.). The area is characterized by mostly flat terrain with altitudes below 200 m.a.s.l. The primary regeneration method implemented in the management plan is natural regeneration, as most silvicultural systems are continuous (shelterwood cutting). In forest-type substitutions, ecological reconstruction, and clearcuts, artificial regeneration is employed.

A total of 13 forest stands with abundant regeneration were selected, consisting of stands in the removal cut stage of shelterwood silvicultural systems or artificially regenerated stands within the first three years after planting. The selected forest stands covered a total area of 78.57 ha, of which nine stands were artificially regenerated (15.71 ha) and four stands were naturally regenerated (62.86 ha). All the studied stands were characterized by the inadequate exclusion of ungulates, including inappropriate fencing or partial use of slash, which did not keep the wildlife away. The area is characterized by a high density of the following ungulates: roe deer (*Capreolus capreolus* L.), fallow deer (*Dama dama* L.), and red deer (*Cervus elaphus* L.). The presence of large carnivores in the study area is limited, with infrequent sightings of gray wolves (*Canis lupus* L.) reported. The forested area is

bordered by agricultural fields (54.3%) and meadows (23.9%), which provide wildlife with essential resting and feeding zones during the vegetation season. However, in winter and early spring, most wildlife (except for a portion of the roe deer population) migrates into the forest as the agricultural fields are harvested and meadows are heavily occupied by livestock.

2.2. Sampling Design and Data Collection

For this study, a sample grid consisting of 42 plots, each covering an area of 100 m², was established in the late winter of 2023. For artificial regeneration, a rectangular plot measuring 10 m on each side was utilized of five rows of saplings, in line with the adopted planting scheme of 2 × 1 m for all stands. In contrast, for natural regeneration, where sapling distribution was randomized, a circular plot with a radius of 5.64 m was employed. This method facilitates measurements and obtains minimal errors, ensuring that the collected data can be effectively compared [36].

The data collection protocol was adopted based on similar approaches [37,38] conducted in Central Europe. The main parameters used during the measurements were represented by the presence of browsing on the sapling, whether it was on the terminal or lateral bud or shoots, the type of species, the root collar diameter (mm), the height of the saplings (cm), and the sapling vigor (3 classes). Only saplings of forestry interest species were recorded, while shrubs were not considered. The maximum height measurement for the saplings was 1.3 m. In addition to the data recorded from the terrain, stand characteristics data were gathered from forest and wildlife management plans.

Secondly, using a concept developed in 1989 [39], and in accordance with the methodology from Order 393/2002 [40], the Sustainable Population Threshold (SPT) was calculated for the study area. The SPT is defined as the maximum density of individuals per 1000 hectares for a given species, considering economic, ecological, and social acceptance based on the best and worst conditions identified throughout the natural habitats in Romania. The calculation is based on a four-category scoring system: biotic, abiotic, management, and anthropogenic factors. These indicators consider climate factors, orographic factors, silvicultural practices, predation, agricultural impact, and includes the particularities of the ecoregions. Based on these factors, the optimal number of each specimen for an area of 1000 hectares was determined. Additionally, the stock unit equivalents for game species were calculated based on the largest ungulate in this study, the red deer.

2.3. Statistical Analysis

The database and parts of the visualization and descriptive statistics were created using Microsoft Excel 16.91. All statistical analyses were performed using R, incorporating the following packages: MASS [41], ggplot2 [42], and jtools [43]. Box plots were developed to better visualize sapling density in both artificial and natural regeneration cases, as well as browsing occurrence.

A regression model was utilized to examine the spatial patterns and environmental factors affecting browsing incidence. Before fitting any models, the dataset was carefully checked for outliers and collinearity among the predictor variables (Table 1). To ensure comparability, all continuous variables were standardized and harmonized. The density of the ungulates was not included in the model, as the premise of the model is to identify the secondary variables that influence the browsing occurrence. The presence of browsing was treated as the dependent variable, encoded with 1 for its presence and 0 for its absence.

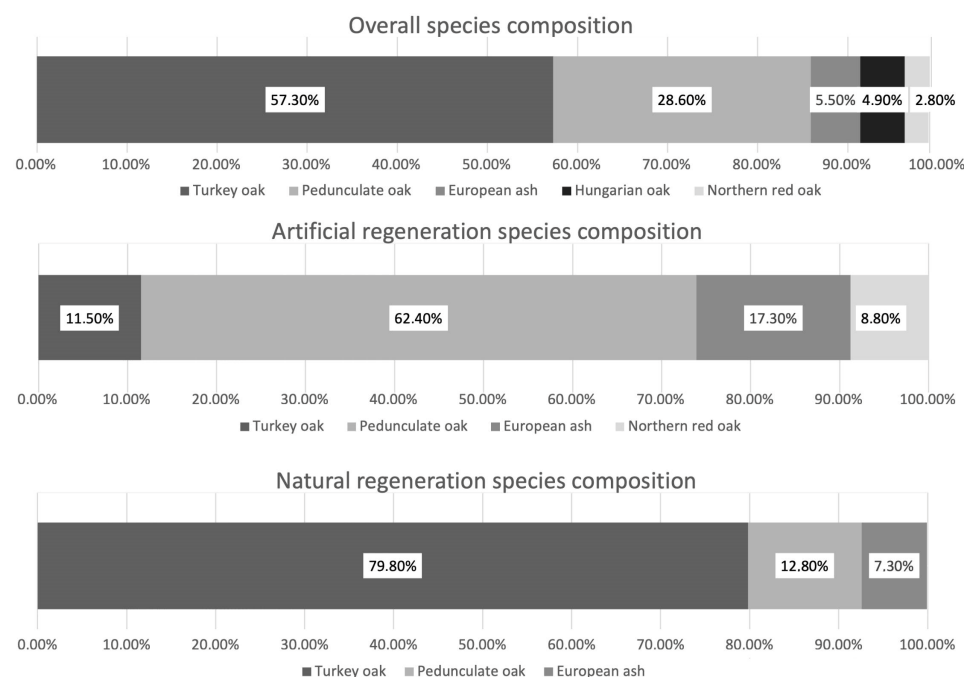
Table 1. Variables used to model the browsing occurrence, with encoding, type of variable, and parametric.

Variable	Code	Type	Min.	Max.	Mean
Dependent Variable					
Browsing occurrence	BO	Categorical (2 levels): 0 or 1			
Independent Variables					
Sapling Characteristics					
Species	SP	Categorical (8 levels)			
Sapling vigor	VI	Categorical (3 levels)			
Root collar diameter	RD	Continuous	16	346	83.89
Height	HE	Continuous	10	130	53.70
Environmental Characteristics					
Soil	SO	Categorical (10 levels)			
Forest share	DW	Continuous	0.12	0.41	0.33
Forest treatment	RT	Categorical (2 levels): Natural or Artificial			

3. Results

3.1. Regeneration and Browsing Characteristics

In total, 3223 individual saplings were recorded from both natural and artificial regeneration. Regeneration was observed in all 42 sapling plots. In the artificial regeneration plots, 1041 saplings were recorded, of which 62.4% were Pedunculate oak, 17.3% were European ash, 11.5% were Turkey oak, and 8.8% were red oak. In the natural regeneration plots, 2182 saplings were recorded, with 79.8% being Turkey oak, 12.8% Pedunculate oak, and 7.3% European ash. Overall, the species composition of saplings for both types of regeneration was as follows: 57.3% Turkey oak, 28.6% Pedunculate oak, 5.5% European ash, 4.9% Hungarian oak, and 2.8% Northern red oak (Figure 2).

**Figure 2.** Species composition in the study area based on the 3223 saplings recorded.

In the case of clearcut forest treatment with artificial regeneration, the maximum density was 5500 saplings per hectare, while the minimum was 4200 saplings per hectare

(Figure 3). The densities for artificial regeneration primarily fluctuated between 4825 and 5150 saplings per hectare, with an average of 4980 saplings per hectare. In contrast, for continuous forest cover treatment with natural regeneration, the maximum density reached 17,100 saplings per hectare, while the minimum density was 8400 saplings per hectare. The densities for natural regeneration mainly fluctuated between 9600 and 15,650 saplings per hectare, with an average of 12,830 saplings per hectare.

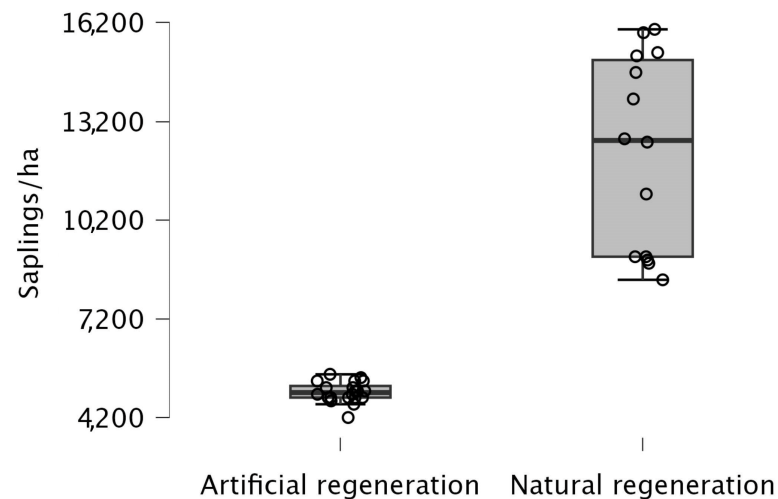


Figure 3. Sapling density per ha for artificial and natural regeneration in 2023 based on 3223 saplings recorded.

The occurrence of browsing in the study area varies according to the type of forest treatment (Figure 4). In the case of clearcut fellings with artificial regeneration, browsing occurrence ranged from 42 to 55%, with an average of 49.65%. In contrast, for continuous cover forestry with natural regeneration, the occurrence ranged from 8 to 17%, with an average of 12.8%.

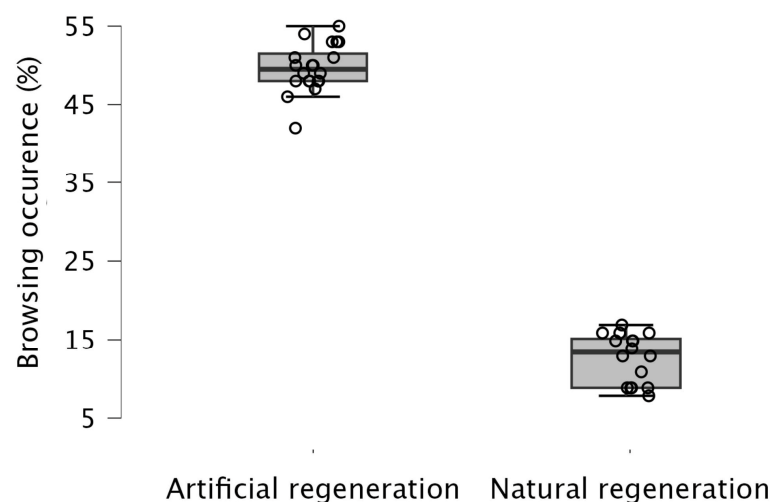


Figure 4. Browsing occurrence in artificial and natural regeneration in 2023 based on 3223 saplings recorded.

3.2. Occurrence of Ungulate Browsing

Out of the seven independent variables used in the regression model, only two were found to be significant: forest area share ($p < 0.01$) and forest treatment ($p < 0.01$). It was determined that a lower percentage of forest in the hunting ground increases the probability of browsing occurrence, as a greater proportion of agriculture results in considerably

better feeding conditions. Regarding the silvicultural system, it was observed that clearcut fellings, which utilize an artificial regeneration scheme with a predetermined sapling density per hectare, have a considerably higher probability of browsing occurrence compared to continuous cover forestry, which employs natural regeneration at a significantly higher density.

3.3. Ecosystem Supportability

All of the indicators and values resulting from the calculations of the optimum and actual numbers are presented in Table 2. Based on the four categories of factors, it was determined that the ecosystem can support the following numbers in the study area: 195 red deer, 95 fallow deer, and 820 roe deer. The ungulate population numbers in the study area were as follows: 755 red deer, 380 fallow deer, and 1422 roe deer. According to the stock unit equivalent theory, where the base unit in this study is considered to be the red deer with a value of 1, the fallow deer is equivalent to 0.56 of a red deer, while the roe deer is equivalent to 0.2 of a red deer.

Table 2. Sustainable Population Threshold (SPT) and real number of ungulates in the study area.

Indicator	Red Deer	Fallow Deer	Roe Deer	Total
Deer number/total area	755	380	1422	-
SPT number/total area	195	95	820	-
Stock unit equivalent	1	0,56	0,2	-
SPT equivalent/1000 ha	15.12	3.94	6.34	25.39
Real deer unit equivalent/1000 ha	55.67	15.74	20.97	92.38
Deer unit equivalent/1000 ha	40.55	11.81	14.63	66.99

After converting the stock unit equivalents and calculating the density of ungulates per 1000 hectares, it was found that the total loading of deer equivalents in the study area was 25.39 stock unit equivalents, while the actual number of ungulates was 93.38 stock unit equivalents, exceeding the supportability by approximately 3.67 times. The highest excess of stock unit equivalents was found in the case of red deer, with 40.55 units above the limit, followed by 14.63 units for roe deer and 11.81 units for fallow deer (Table 2).

4. Discussion

This study presents the first assessment of the impact of ungulate browsing in oak-dominated forests in Romania, as previous studies have primarily focused on coniferous species such as the Norway spruce and Scots pine [44–46]. It includes the first quantification of the overabundance of red deer, fallow deer, and roe deer, based on scientific calculations of the Sustainable Population Threshold, which simultaneously considers economic, social, and ecosystem sustainability. The findings of this study are particularly significant from a wildlife management perspective, as they quantify the SPT and actual densities of ungulates, providing evidence for the need for new hunting regulations that can be applied in similar scenarios.

Ungulates typically exhibit a preference for certain tree species and browse them in a particular order [47–49]. However, in this study, the tree species did not influence the selection process, as ungulate density was so high during the refuge period that a shortage of forage occurred, leading to non-selective consumption. The same lack of selectivity under high densities was also identified in a study conducted in Italy [16]. The vigor of the sapling influences the browsing selection process [50,51], but in this study, this factor appears to be insignificant, further demonstrating that overabundance leads to non-selective consumption. The only factors found to be significant in this study, with ungulate

densities 3.7 times higher than the SPT, are forest cover and the silvicultural system. The five hunting grounds that overlapped with the study area had varying proportions of forests and agricultural fields. When the share of forest area in the total hunting ground was below 20%, browsing probability was found to be significantly higher. This can be attributed to a reduced refuge area during critical periods of the year, as many more animals moved into the forests after crop harvesting. Silvicultural treatment plays a vital role in ungulate browsing phenomena, with the probability of browsing occurrence being significantly higher in clearcut systems that employ artificial regeneration with low planting density [4,16,35,52]. In clearcut fellings, not only is the planting scheme considerably lower, but also a light gap is created, facilitating the appearance of grasses and shrubs [53]. In the shelterwood system, natural regeneration is prioritized, and the gaps created through the removal cuts are significantly smaller than those produced by the clearcut system. The removal cuts are executed after prior establishment cuts, which are performed following fruiting years to promote the establishment of a continuous cover of saplings [54]. Also, the planting scheme is not established by foresters and depends on the fructification and germination capacity, which in some cases, such as the European beech can reach up to a million seedlings/ha in the seedling phase [55]. While in the clearcut fellings, the planting schemes are adopted based on the future crop trees technique and to facilitate the silviculture works in the tending phases. In natural regeneration cases, the density is regulated through natural competition and through tending operations [56,57]. In a similar study situation in Austria, it was found that the browsing predisposition is lower in shelterwood systems and higher in clearcut systems [35]. The same study admits that in Austria, Liechtenstein, and Switzerland, a more “close-to-nature” silvicultural can reduce the risk of browsing damage by decreasing habitat attraction for ungulates and favoring abundant regeneration [58]. It needs to be noted that a continuous silvicultural system with natural regeneration is not exempt from the browsing phenomena, but due to a much higher sapling density, the impact is not as visible and economically harmful as in the case of artificial regeneration. In this study, the browsing occurred in the clearcut fellings at an average of 49.65% browsed saplings in an average density of 4980 saplings/ha, while in the shelterwood system at an average of 12.8% browsed saplings in an average density of 12.830 saplings/ha. Even if the proportion of browsed species is quite different in the two cases, the number of browsed saplings is higher in both cases, with an average of 2472 saplings/ha browsed in artificial regeneration and 1642 saplings/ha browsed in the natural regeneration.

To mitigate damage caused by ungulate browsing in the long term, forest managers should adapt their management process to adapt to the situations caused by the climate change and the impressive growth of ungulate number [59], adopting a silvicultural system with higher regeneration density and with mixed composition [60]. Measures such as fencing [61–63], tree guards [64], repellents [65], and natural obstacles [66,67] are solutions to prevent damage from browsing, fraying, and trampling; however, they are costly and require continuous maintenance, which can place a burden on forest managers [68].

The biggest emphasis should be put on the management of the wildlife species to control the number of ungulates. The current legislation [69] in Romania heavily regulates hunting processes, with quotas determined by annual evaluations of game species. In the study area, ungulate populations have reached alarming levels, suggesting that the existing legislation may not be appropriate for this situation. At densities 3.7 times higher than the SPT, the densities of ungulates should be considered to be an overabundance. Similarly, in Lithuania, the hunting law [70] establishes a maximum limit of 28.75 red deer equivalents per 1000 ha of deciduous and mixed stands of deciduous trees with coniferous species. However, the legislation allows for the culling of red deer, fallow deer, and roe

deer without a designated hunting season or quota. In Italy, a similar equivalent system was used in the elaboration of the Ungulate Density Index (UDI), where the UDI was employed to quantify the magnitude of ungulate abundance [16]. In commercial forests in Scotland, the tolerable threshold of red deer was considered to be 4 deer per 100 ha [71]. In Germany, the tolerable densities for roe deer depending on habitat quality have been suggested at between 4 and 12 roe deer per 100 ha [72]. Relying on the current quota system from Romania's hunting law [69] may be considered outdated in this case, indicating that special regulations granting greater flexibility to wildlife managers might be needed, and higher quotas should be adopted. Similar cases were identified in Germany [73], where non-selective culling has been adopted to control game numbers. An additional hunting season should also be implemented for red deer, allowing the harvesting of two-year-old specimens that are not participating in reproduction by professional hunters. In high-density populations, particularly among cervid species, individuals experience a reduction in body weight [74,75]. To effectively control the damage caused by ungulates to forest ecosystems, a comprehensive set of hunting regulations and practices should be implemented in critical areas of overabundance. These measures should aim to reduce the populations of both males and females to optimal levels while preserving genetic diversity and maintaining the overall health of the game.

In terms of combined wildlife and forest management, this study can be viewed as an interdisciplinary effort that addresses both sectors simultaneously. Future research on ungulate browsing should not only present actual ungulate densities but also calculate an SPT. Since the term "overabundance" can sometimes be ambiguous, it is essential to establish a clear threshold between actual and optimal numbers to determine if an area is experiencing ungulate overabundance. Future studies should focus on viable solutions to reduce damage levels in areas with high ungulate densities while also identifying effective methods for controlling ungulate populations.

5. Conclusions

This study provides a valuable first assessment of ungulate browsing on oak stands in the plain region of Western Romania, a region lacking a normal density of large carnivores to control ungulate numbers through natural selection. The overabundance of ungulates is identified as the primary factor contributing to the damage, while this study also highlights secondary factors influencing the occurrence of browsing.

The results underscore the importance of a collaborative approach between wildlife and forest management to understand the extent of the damage caused by ungulates. These findings can inform foresters, hunters, and conservationists, serving as scientific evidence for reforms in hunting legislation. Furthermore, this study demonstrates that humans and wildlife can coexist, and it is essential to adopt appropriate measures to prevent conflicts between them.

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