Utilization of fodder stands by game in Western Poland

Wojciech Kozak

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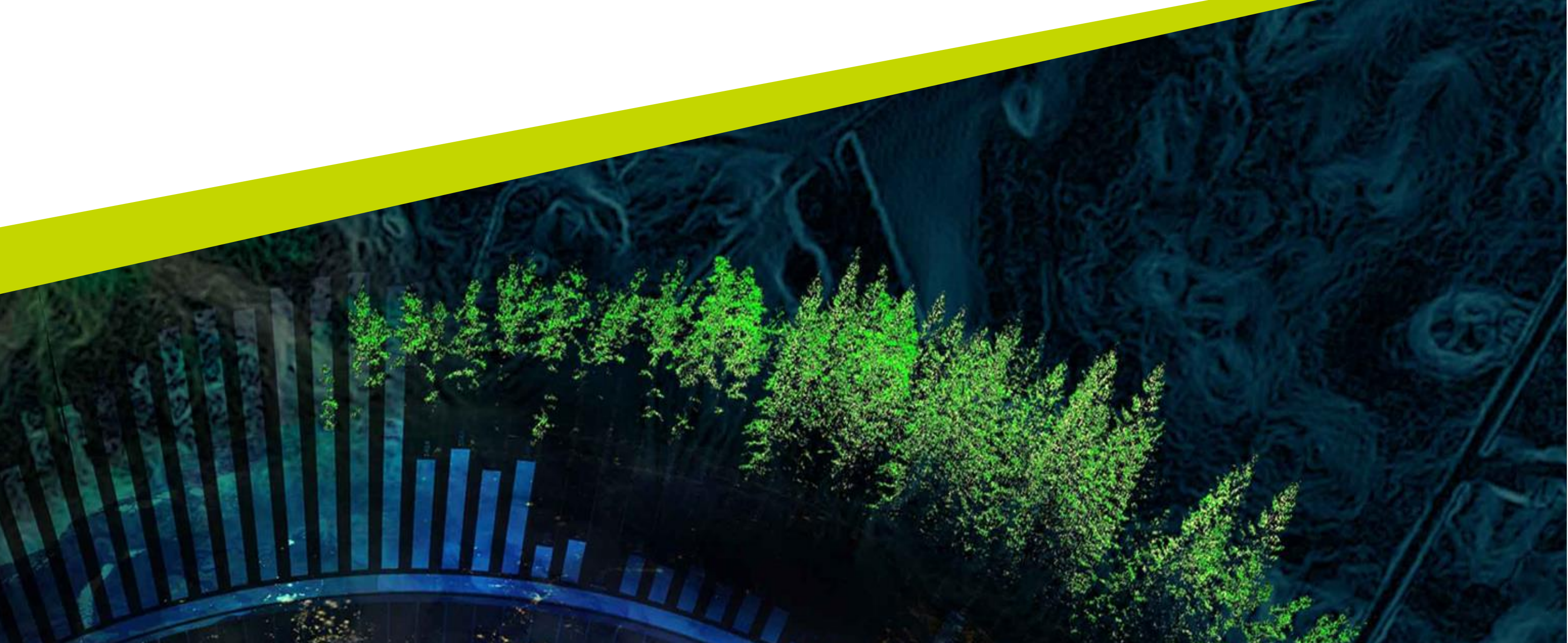

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Supervisor:	**Annika Felton, Faculty of Forest Sciences Southern Swedish Forest Research Centre**
Assistant supervisor:	Marcin Churski, Mammal Research Institute, polish Academy of Sciences
Examiner:	Mikołaj Lula, Faculty of Forest Sciences Southern Swedish Forest Research Centre

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Swedish University of Agricultural Sciences
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Southern Swedish Forest Research Centre

Abstract

Damage caused by cervids is one of the main issues in forest management in Europe nowadays. Reduction of cervid population density to reduce damage to timber production stands is not always enough. Landowners in Europe practice multiple additional methods to reduce the browsing pressure on their production forests, e.g. by establishing fodder stands. Fodder stands provide woody fodder (trees) for the cervids instead of other methods like supplementary feeding where the forage provided normally consists of hay, root vegetables and other crops.

In my study I aimed to analyze utilization of fodder stands by wild ungulates managed in two Forest Districts in Western Poland: Głusko and Drawsko. I collected the data in five fodder stands and five timber production stands nearby (control stands), to determine differences in utilization by the wild ungulates. Data were collected from camera trap inventory during three weeks (12^{th} March to 3^{rd} April). After that I conducted an inventory of browsing intensity in the stands and collected tree shape data including total height and crown width to assess how the trees respond to browsing. All of that data were compared between stands and their management purpose.

Camera trap inventory did not show any reliable evidence of more extend utilization of fodder stand in comparison with control stand. Most of the photos triggered by the ungulates was taken the control stands. However, overall number of photos with the ungulates was relatively low. The browsing intensity inventory showed that fodder stands were browsed twice as intensive (average 42% of trees were browsed) as the control stands (21%). Similar patterns were observed in Głusko and Drawsko Forest District, although the browsing intensity as much higher in Drawsko. Data from tree shape analysis also suggest that trees in response to intense browsing in the fodder stands formed a cage structure to a greater extent than in production stands. Cage structure is estimated as a ratio between crown width to tree total height. A low ratio means trees are more slender and invest more in height growth rather than development of crown, while a high ratio indicates a cage structure typically induced by intensive browsing. Also species preferences of cervids on these plantations were analyzed with use of Jacobs Preference Index. Results shows that broadleaf species such as beech, linden and hornbeam are preferred by the local cervids. I did not find any strong relationships between camera trap observations and browsing intensity, which could be due to relatively short observation period and big areas of observed stands, however it is still interesting method in long term inventory of fodder stand utilization.

This study showed that cervid utilize fodder stands as intended, and there are as such good reasons to practice this type of management . However, this topic still need long term research with wider spectrum of fodder and control stands.

Keywords: Cervids, camera trap, fodder stand, browsing intensity, tree shape, species composition

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1. Introduction

Deer (Cervidae) are members of the ungulate clade, and have been documented to significantly influence forest ecosystems (Leopold 1933). In past decades in US and Europe it is visible that several populations of free ranging cervids have increased in size and distribution (Apollonio 2010; Côté et al. 2004; Ward 2005). Reasons for these increases in abundance differ for different species but may include changes in land use (Mysterud et al. 2002), game management regimes (Milner et al. 2006) and climate, the latter resulting in higher survival of some species due to milder winters and higher forage availability (Mysterud et al. 2001; Presley et al. 2019; Felton et al. 2024). Moreover, high densities of game are favoured by hunters who are interested in keeping high numbers of ungulates for easier and greater hunting scores (Gordon et al. 2004; Mysterud 2010).

On the other hand the impact of deer on vegetation may be leading to conflict with humans (Côté et al. 2004). Damage made in production forest is an important issue in United States (Conover 1997) and many European countries (Hardalau et al. 2024; Reimoser & Putman 2011). Moreover, overabundance of deer can negatively affect habitats with high conservation values for example by reducing herb or tree diversity (Ammer 1996; Augustine 1998; Putman 2004), and can also result in high numbers of traffic accidents (Steiner et al. 2021). All of these examples are leading to concerns about ecological and economic consequences (Fuller and Gill 2001; Côté et al. 2004; Gordon et al. 2004). In Poland, the estimated cost for State Forest Company protecting their forests from cervids was 287,3 million PLN (~67,3 million EUR) in 2024 (Statistical Yearbook of Forestry). The state owns the majority of the forest in Poland (82% of forest cover) and all wild animals, including game species, are meant to be state owned. The costs for damage made by ungulates are calculated in the financial plan of State Forest Company, and private owners have rights to get financial compensation accordingly. As recent studies show the global trend of increasing browsing damage, these costs are expected to increase as well (Gerhardt et al. 2013; Schuck and Requardt, 2008).

To compensate for high browsing pressure managers may have to apply adaptive management involving a wider spectrum than only management by hunting. Reduction of the population density by hunting may not be enough, as browsing intensity is not only dependent on deer density (Kuijper 2011; Putman et al. 2011). Research suggest that other factors like quality of the habitat and availability of forage for ungulates (Reimoser & Gossow 1996; Spake et al. 2020). Another important factor is predation, which is creating a different landscape of fear for the cervids compared to the fear created by hunting activities (Kuijper 2011). European forest-dwelling herbivorous ungulates causing most damage, namely red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*), fallow deer (*Dama dama*), moose (*Alces alces*) and European bison (*Bison bonasus*), have a high percentage of woody plant species in their diet (Hofmann 1989). Most critical moment is winter and early spring when a lack of herbs and grasses leads to a high consumption of woody fodder, particularly in regions with deep snow (Bergqvist 2018; Homolka 1990).

Managers facing a problem of game damage started to develop methods to mitigate them in other ways than reduction of population densities. First example of ways that land owners can mitigate damage besides using hunting, is to establish fodder fields with crop plants cultivated for game (Månsson et al. 2014; Smith et al. 2007). Alternatively, a simple and frequently used method in Europe is supplementary feeding with hay, beetroot and similar forage (Putman & Staines 2004). However, supplementary feeding is forbidden or regulated in some European countries due to the sometimes negative repercussions of this management approach, for example spread of diseases (Sorensen et al. 2014). Fodder fields with crop plants and supplementary feeding with hay are both common approaches today in Poland, but they are not sufficient to meet the food demand of the deer. In addition to considering forage quantity, managers also need to be aware of the quality of the forage. The composition of the rumen microbiome goes through seasonal adjustments, as it responds to changes in the ungulates' diet which gradually includes increasing proportions of woody forage during the autumn and winter. (Felton et al. 2017). For that reason, crops provided by supplementary feeding may not be appropriate for these animals during the winter.

To meet the nutritional needs of cervids during the autumn and winter seasons, some land managers in Poland have established fodder stands. These sites are similar to classical fodder fields. However, instead of cultivating agriculture crop plants, fodder is provided in a form of planted or sown woody plant species, with the aim to disperse browsing damage in the landscape so the level of damage is reduced in timber production stands (Fruziński, 1990). In such fodder stands, the tree species used normally include broadleaf species, starting with those commonly used in forest management, such as linden (*Tilia spp*.), hornbeam (*Carpinus betulus*), and beech (*Fagus sylvatica*), and extending to less common species like crab apple (Malus sylvestris). This approach to forage resource management more closely resembles the natural food resources available to cervids in the environment (Błaszczyk, 2011). As a result, cervids are provided with an alternative food source that better matches their digestive requirements and, in practical terms, can help reduce browsing damage.

Management by fodder stands is not only practiced in Poland. Landowners in other European countries are also familiar with that method. In Slovakia they are establishing similar fodder stands to protect their production stands (Libosvár, & Hanzal, 2010). In Denmark there are experimental sites with use of broadleaf species in order to protect surrounding Sitka spruce (*Picea sitchensis*) plantations (Madsen et al., 2022).

1.1 Background on fodder stands

Fodder stands are managed with the purpose to provide alternative forage for wild ungulates and thereby reduce browsing damage on timber production trees. This method has been practiced in Poland by land managers' hunting clubs, State Forest Company or the Polish Hunting Association. However, during the last decades that method started to be less and less used by managers of hunting grounds. In my research to find potential fodder stands to conduct my research in, I contacted 18 hunting ground managers who own 27 hunting grounds of total area of 217 046,21 ha. (appendix 1). During my conversations with them I asked several questions about the fodder stands as a management tool. Out of 18 managers 6 continue to use fodder stands and 5 abandoned them and 7 never used it. Among those who abandoned or never used the fodder stands the most common reasons for that were the work effort and costs of establishment and maintenance. That is the reason why fodder stands are practiced more common in hunting ground owned by SFC which has easier access to workforce and sufficient budget for that type of investment. Hunting clubs are mostly based on voluntary activities of local hunters. Another reason in favor of state owned hunting districts is the fact that the area within the clubs' hunting grounds is often also owned by the state. Most of the hunting clubs are renting or owning relatively small areas of agriculture land or meadows. In my study I also was trying to find some information about similar practices in European countries.

The premise of fodder stand is to provide high amount of attractive fodder for the ungulates and in that way attract them. Because of that the trees in these sites should be kept within the browsing reach by the managers so that the ungulates are able to consume twigs (Renaud et al., 2003). If the browsing pressure is high, the trees are kept low anyway, without needing intervention by the managers. Due to chronic herbivory, some of the plant species adapt to these condition by changing their individual architecture to the cage structure (Churski et al. 2022, 2024; Cacciatori et al., 2025). In that type of growth, trees are creating numerous woody structural stems instead of one. Thanks to investment in growth of structures like that, plants are reducing access to crucial parts such as top shoots or main stem and browsing is dispersed to less important parts of the trees in terms of survival. That phenomena is very useful in establishment of fodder stands because each tree then provides much more potential fodder for the ungulates. Cage structure in central Europe condition is mostly common up to 2 meters height which is range of browsing for red deer (Churski et al. 2024). Moreover, fodder stands that are kept relatively low (within browsing height of deer) resemble natural openings in the forest canopy. Browsing height is defined as the height span within which a deer can reach the top of the tree with their mouth (Shipley, 2007). As shown by Kuijper et al., (2009) all central European native ungulates, except wild boar, are more likely to utilize such open or semi-open sites in forest environment in order to get food. In addition, the open or semi-open condition of fodder stands are creating opportunities for the development of attractive species of grasses and herbs (Modry et al., 2004). This is similar to the growth conditions occurring on the forest production plantations, which fodder stands are meant to protect (Piechowski, 1994). Additionally, due to good light conditions trees are growing in higher pace (Modry et al., 2004) and they are developing bushier and denser crowns compared to trees growing in shaded habitats (Edenius, 1993, Churski et al. 2022).

Despite that fodder stands are used at least in some parts of Europe, we still know quite little about this management technique, and most of the knowledge is coming from popular science magazines, books or knowledge of local managers. There is not many research projects about this type of management. How effective it is? Which tree species are well suited in fodder stands?

1.2 Objectives of the thesis

The overall aim of this thesis was to investigate the utilization and management of fodder stands by wild cervids in Poland.

My specific objectives were to:

1. Find out if the utilization by free-ranging cervids of the fodder stands is higher in comparison with how the animals use similar environments in commercial timber production stands.
2. Investigation of the cage structure of the trees planted on productive stands in comparison with fodder stands as utilization indicator.
3. Provide guidelines for forest managers. How should people manage this type of forest, and which benefits do this management method brings to production forestry and what species are suitable for that type of management?

My hypothesis is that fodder stands are utilized to a greater extent by wild cervids than stands used for timber production.

2. Study area

My research was conducted in two hunting grounds owned by Forest Districts of State Forest Company: Głusko Forest District hunting ground no. 1 and Drawsko Forest District hunting ground no. 183 (Figure 1). Both hunting grounds are associated with the Regional Directorate of Polish Hunting Association in Gorzów Wielkopolski. Both of the sites are placed in the nemoral zone. Dominated species in the main tree layer are Scots pine (*Pinus silvestris*), beech and sessile oak (*Quercus petraea*).

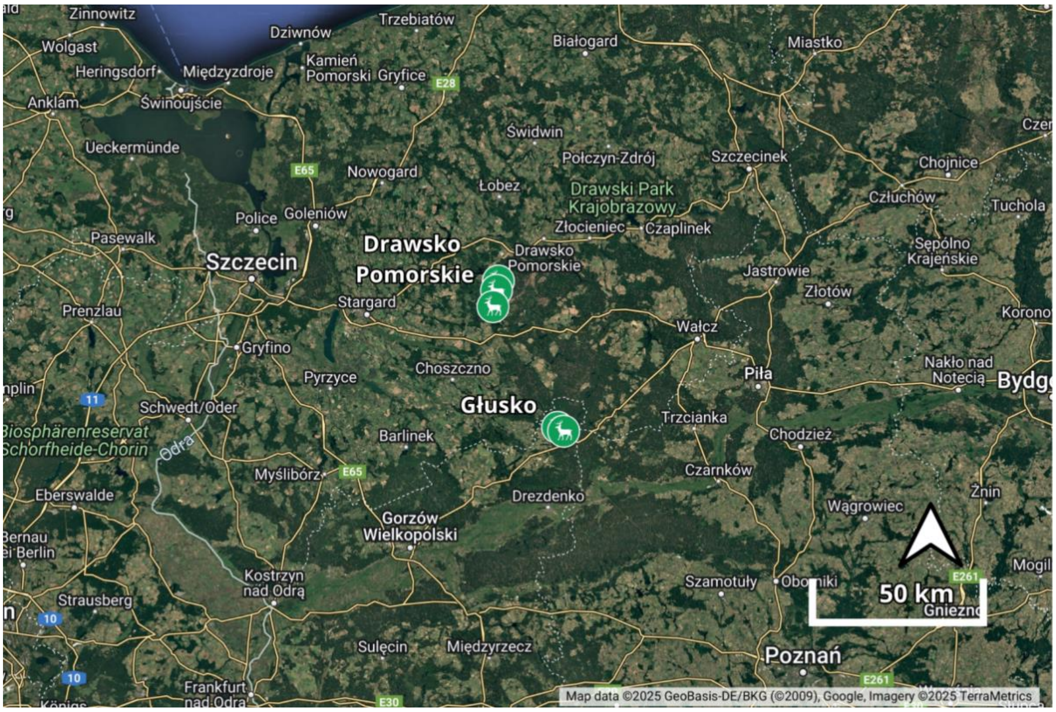

Figure 1. Location of the fodder stands in Western Poland

The local population of ungulates is mostly dominated by red deer (*Cervus elaphus*), and roe deer (*Capreolus capreolus*). Moreover, that region has permanent population of European bison (*Bison bonasus*) introduced in 2006 with high success (Tracz et al. 2008). Nowadays the population size of bison was estimated to size of 465 individuals divided into 11 herds. In each of Forest Districts is one herd 89 individuals in Drawsko and 27 individuals in Głusko according to data from the Western Pomeranian Nature Society. Fallow deer (*Dama dama*) on the other hand is present only in Drawsko in relatively small numbers (Forest Data Bank, 2025). Both places are each year visited by migrating moose (*Alces alces*). Estimated densities of red deer, roe deer and fallow deer in terms of number of animals per 1000ha forest cover differ between the two study areas (Table 1). All of the data about local population density are assumed yearly for date of 10th March before breeding of females (Forest Data Bank, 2025). The estimates about populations are collected by local hunters in cooperation with state forest with use of “tyraliera” counting method (Kamieniarz et al. 2023). In that region are present also two big carnivores grey wolf (*Canis lupus*) and European lynx (*Lynx lynx*).

Table 1. Total number and density per 1000 ha of forest cover of permanently occurring cervids in Głusko and Drawsko hunting grounds (Forest Data Bank, 2025)

Place	Scale	Red deer	Roe deer	Fallow deer
Głusko	Total	335	282	-
	per 1000ha of forest cover	20,18	13,99	-
Drawsko	Total	1080	1060	56
	per 1000ha of forest cover	49,88	48,96	2,58

Within each of these two hunting grounds I created 5 experimental plots inside 5 different fodder stands (Table 2). Each fodder stand was paired with a regeneration of commercially important tree species which were unfenced and where the young trees were not covered with repellents against ungulates. Distances between pairs of stands varied from 100 to 400 meters. These were considered “control” stands. The size of stands ranged between 0,4-1,38 ha in Głusko Forest District and 20,44-25,32 ha in Drawsko Forest District. Plots were placed in the control stands in a similar manner as in the fodder stands.

2.1 Study design and data collection

Design of my experimental plots was inspired by research made by Kuijper (2009) and Churski (2022). I used two different data collection methods. The first approach involved estimating visitation rates by wild ungulates in the fodder stands and control stands by camera traps. The second approach involved inventory of tree shape and browsing intensity by field surveys in all stands.

Camera trap inventory was conducted during a three week period. Deployment of the traps was made between 12-13th of March 2025 and I collected the photographs 2-3rd of April. This period was chosen because of the relative lack of forage in the agriculture landscapes and therefore a high demand for woody fodder by the cervis. One camera trap was deployed at each of the fodder stands and control stands. Each trap was placed on a tree located in the middle of the stand at the height of 1 meter. Each camera faced north. The detection range of the camera trap is around 24 meters depending on local conditions. Camera traps were deployed in places where full or most of that range was possible to use. For the inventory I used camera traps Browning BTS-8E-HPS. Each of the camera had the same setup. Camera was triggered by movement and took a series of 3 photos per trigger (hereafter referred to as 'series'). A minimum delay of 5 minutes was set before the next series of 3 pictures could have been recorded.

The inventory of the trees was conducted at the end of the phototrap period. I collected tree shape data inside circular plots with an area of 50m^2 (radius 4,99m). In relatively dense regenerations (<10 000 trees per hectare) the plot size was reduced to 10m^2 (radius 1.78m), due to time limitation. Plots were placed randomly next to the camera trap location. In the plots I recorded data on the trees' total height (cm), height of crown (cm; measured from first vital branch), crown width (+/- 5cm) and tree base (mm). I also noted the species of each tree. Moreover, the number of trees per plot was counted to estimate spacing at each of the stand.

In each of the ten stands I checked randomly chosen 100 trees for any signs of fresh ungulate damage. Moreover, on every 10th tree I measured branching intensity and percent of browsed top shoots. Branching density was measured as a ratio, namely sum of length of two randomly chosen secondary branches divided by the number of twigs. Percent of browsed shoots was measured by choosing randomly 10 top shoots (tops of the main branches) in each tree and count the number of browsed vs. unbrowsed shoots. What was used for evaluating browsing pressure per tree.

3. Data analysis

After the tree inventory in the field I reviewed all the photos manually on my computer using Windows Media Player, and compiled the data using excel spreadsheet. I collected the following information from the recorded pictures: animal species, number of individuals, date and time. I was looking for photos where animals were present. In my study I focused mostly on the cervids, but in my data I included also wild boar. As one visitation event I counted every series where at least one photo had register ungulates and series were not made after minimum delay period. Furthermore I counted visitation rate (number of visitations divided per number of observations days) for all of the stands and for every stand per observation period. This dataset was then used as supplementary information to support the main results obtained from the fodder and control stand inventories conducted in the field.

Tree inventory data analysis was conducted using R (version 4.3.1) (R Core team 2023) and packages: dplyr, ggplot2, corrplot.

The first step of tree inventory data analysis was to identify the tree species composition in each of the stands, and for that purpose I used data collected from circular plots established at each of the stands.

Browsing inventory data was analyzed from two points of view. First I compared utilization of fodder stands versus control stands on stand and single tree level. On the stand level I tested using ANOVA if there were any differences between browsing intensity in fodder and control stands. In the tests I checked percentage of browsed trees and the percentage of browsed top shoots. Moreover I checked if the browsing intensity (% of browsed trees) in the stands was related to the relative browsing pressure per tree (% of shoots with signs of recent browsing) within the stand. Based on the results, I decided to assess the strength of the relationship between the two variables by calculating Pearson's correlation coefficient. Given the significant correlation, I then proceeded with a linear regression analysis. Cervids preferences on the single tree level I tested differences in browsing frequency among tree species with regarding of their availability in the stands. For that purpose I used Jacob's Index of selection (Jacobs, 1974). $D = \frac{\mathrm{r-p}}{\mathrm{r+p-2rp}}$

Equation of Jacob's Index (Jacobs, 1974) where:

- D = Jacob' index
- P = share of food type (tree species) in the environment

- R = share of food type in diet (browsed trees) from all browsed trees

Furthermore I analyzed data collected for branching density to test for differences between fodder and control by ANOVA test.

The data I collected proved challenging to analyze due to differences in species composition, particularly between the fodder stands in Głusko and Drawsko Forest Districts. Another significant issue was the often uneven age structure and considerable age differences between the stands (Table 2). Consequently, I focused on identifying differences between sites using variables less dependent on age, rather than relying only on simple metrics such as tree height or crown width. Instead I used the ratio mean crown width to total tree height (R1), which better describes the overall tree shape. This ratio more accurately reflects the structural adaptations of severely browsed trees. To find statistically significant differences between fodder and control stand I conducted ANOVA test comparing R1.

From my inventory I obtained comparable data from five of my study stands two from productive stands and three from fodder stands. These stands were all dominated by beech which were of the same age (~12 years). This data is valuable in showing differences in tree shape and height in population of beech in the same age in the stands with different management objectives. I conducted an ANOVA test to confirm results for R1 obtained for all of the species if they ar observed also within the same species in the same age.

4. Results

4.1 Photo inventory data

During the inventory period, the camera traps recorded a total of 1,862 series. However, only 40 of all obtained series were triggered by animals (Table 2). Based on these observations, 26 individual visitation events were identified. The average animal visitation rate across all sites was 1.23 visits per day, corresponding to 0.14 visits per day per stand.

Overall most of the visitations were found in the control stands (22). In the fodder stands 4 visitations were recorded. The highest number of visitations (11) was recorded at the 3rd and 5th control stands located in the Drawsko Forest District. On the fodder stands, visitations were registered at the 2nd (1 visitation), 4th (2 visitations), and 5th (1 visitation) stands. During the observation period in the Głusko Forest District, only one visitation was observed, whereas in the Drawsko Forest District, a total of 25 visitations were recorded.

The species with the highest number of recorded visitations was the red deer, with 15 observations, followed by the wild boar (*Sus scrofa*) with 5 observations, roe deer with 4 observations, and 2 unidentified individuals classified as “others” .

Table 2. Number of series registered at each site in total and triggered by the ungulates

Site		Series	Triggered by the ungulates
1	Stand	253	0
	Control	39	0
2	Stand	131	1
	Control	0	0
3	Stand	9	0
	Control	96	14
4	Stand	4	3
	Control	33	21
5	Stand	7	1
	Control	1330	0

4.2 Tree species composition

Tree species composition of fodder stands varied between hunting grounds in Głusko Forest District where managers had planted mostly combination of species like hornbeam, beech, linden ,sessile oak, willow (*Salix spp*.) and crab apple (Table 3). Spontaneous regeneration of birch and pine was also visible on the both fodder stands in that District. In Drawsko Pomorskie fodder stands were mostly beech dominated with mixture of hornbeam, linden and oak (Figure 2), under a canopy of remaining alive pine trees after pest outbreaks. Control stands were mostly dominated by broadleaves and they were less heterogeneous compared with fodder stands. One of the control stands was pine monoculture (Figure 3).

Table 3. Description of fodder and control stands chosen in the research. Data collected from the field. "other" broadleaves include all species with a proportion lower than 5% of share

Stand	Forest District	Age	Species composition	Spacing	Control stand	Potential habitat
1	Głusko	~12	Apple hornbeam pine oak linden other broadleaves	7200	Beech 12y.o.	Coniferous-broadleaves
2	Głusko	~20	Apple linden pine other broadleaves	3000	Beech hornbeam 2-10 y.o.	Broadleaves
3	Drawsko	~12	Beech hornbeam linden oak other broadleaves	4700	Beech, spruce, birch, oak, hornbeam 5-8 y.o.	Coniferous-broadleaves
4	Drawsko	~12	Beech other broadleaves	2900	Beech 2 y.o.	Coniferous-broadleaves
5	Drawsko	~12	Beech hornbeam linden birch	6400	Pine 8y.o.	Coniferous-broadleaves

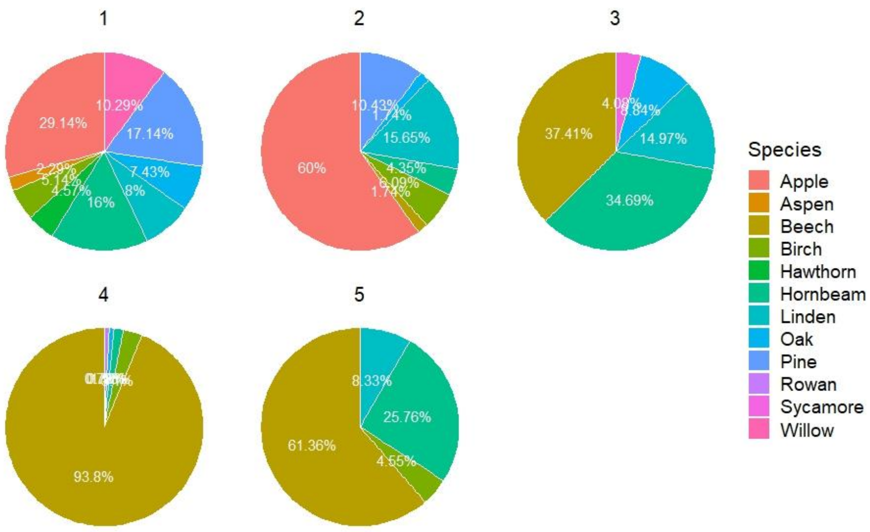

Figure 2. Species composition on the fodder stands

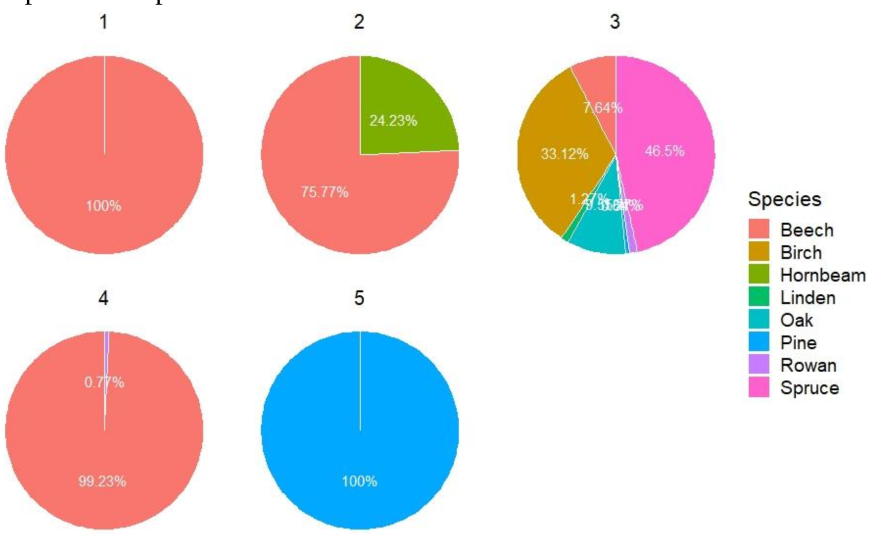

Figure 3. Species composition on the control stands

4.3 Browsing intensity inventory

The inventory of browsing intensity revealed that the percentage of browsed trees differed between stands and their designated purposes. Overall, I found that fodder stands had been browsed about twice as intensively as the control stands, in terms of % browsed trees. For the all fodder stands together percent of browsed trees was 42% and for the control it was 21%. In the Głusko Forest District, the average percentage of browsed trees in fodder stands was 10%, whereas in the control plantations it was 4.0%. In contrast, in the Drawsko Forest District, the average browsing percentage in fodder stands was 64%, and in the control plantations 32% (Figure 4).

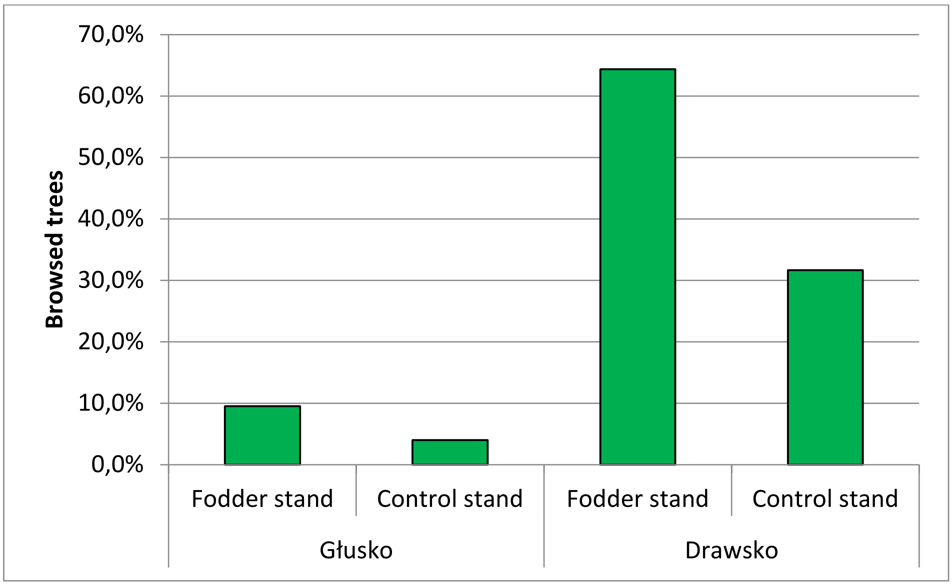

Figure 4. Comparison of browsed trees between fodder control stands among two localization in Głusko and Drawsko Forest District measured during browsing inventory

Browsing intensity together with site spacing is providing interesting information about how many trees are browsed per hectare in each stand . Table 4 presents average browsing per hectare for fodder and control stands and separately for both forest districts. For the fodder stands average number of browsed trees per hectare was 2080 and for the control plantations 1204. High differences were observed between Głusko and Drawsko Forest Districts, in Głusko only 495 trees per hectare were browsed on the fodder stands and in the Drawsko it was 3136 tree per hectare. Similar situation for the control stands in Głusko it was 176 and for Drawsko 1889 trees per hectare.

Table 4 Comparison of number of browsed trees per hectare between fodder and control stands together and divided to Głusko and Drawsko Forest Districts

	Fodder stands	Control stand
Drawsko	3136	1889
Głusko	495	176
Mean	2080	1204

Similar patterns were observed in the inventory of browsed top shoots. Majority of browsed top shoots were observed on the fodder stands compared to control stands was less than 10% of shoots was browsed. Again, a lower percent of browsed shoots was recorded in the Głusko Forest District compared to the Drawsko Forest District. In Głusko, no browsed top shoots were observed in the control plantations, while in the fodder stands the percentage reached 6.5%. In contrast, in Drawsko, 13 % of trees in control plantations showed evidence of top shoots browsing, and in fodder stands, this value increased to 29% (Table 5).

Table 5 Average percent of browsed trees and top shoots between locations

	Browsed trees		Browsed top shoots	
Location	Fodder stand	Control	Fodder stand	Control
Głusko	9,50%	4,00%	6,50%	0,00%
Drawsko	64,33%	31,67%	28,67%	13,33%
Mean	42,40%	20,60%	19,80%	8,00%

To examine the relationship between the percentage of browsed trees and the percentage of browsed top shoots, Pearson's correlation coefficient was calculated. The analysis revealed a strong positive correlation (r = 0.94), indicating a statistically significant association between tree browsing and top shoots browsing. The linear regression analysis showed a strong relationship between these two variables (p-value <0,001, R^2=0,8912) This suggests that as the percentage of browsed trees increases, the number of browsed top shoots also tends to increase (Figure 5).

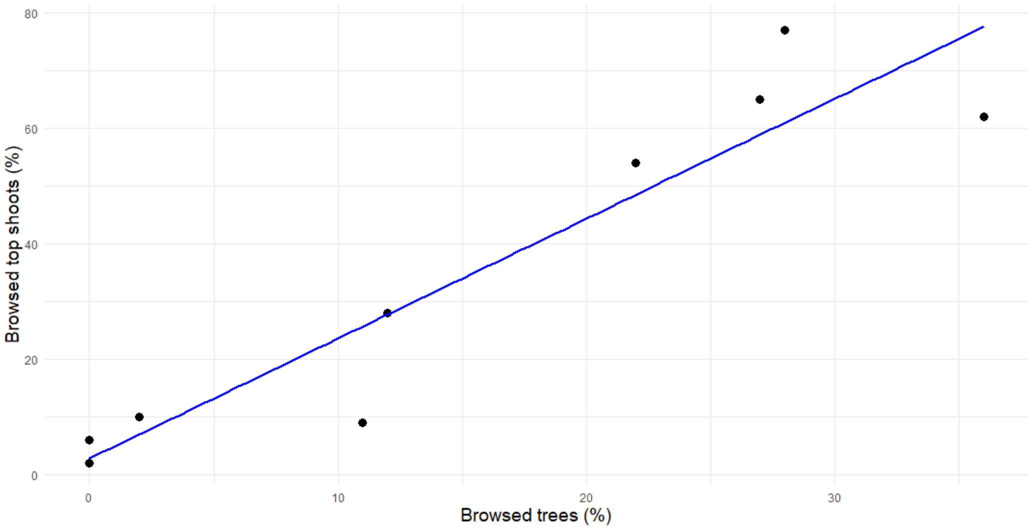

Figure 5. Linear regression between percent of browsed top shoots and trees at all of the locations surveyed during browsing inventory

Furthermore, I evaluated ungulate browsing preferences in relation to species composition. Based on a field survey of 1,000 trees, broadleaf species such as beech, hornbeam and linden appeared to be preferentially browsed by ungulates (Figure 6). Sycamore (*Acer pseudoplatanus*), willow, rowan (*Sorbus acuparia*) and birch also had high Jakob's Indices (preferred) were relatively rare in the stands low share in total number of surveyed trees (p) in the table 6. In contrast, coniferous species such as pine and spruce were browsed less frequently than can be predicted by their availability (Figure 6), particularly in the vicinity of broadleaf-dominated stands. Surprisingly also oak and apple were not preferred by the cervids.

Table 6. Species surveyed during browsing inventory and their Jacob's Index

Species	Share in total number of surveyed trees (p)	Share in total number of browsed trees (r)	Jacob's Index
Beech	0,482	0,648	0,328
Pine	0,127	0,013	-0,838
Hornbeam	0,109	0,140	0,141
Apple	0,094	0,006	-0,884
Spruce	0,052	0,022	-0,414
Linden	0,048	0,076	0,241
Birch	0,044	0,048	0,041
Oak	0,027	0,022	-0,099
Willow	0,010	0,016	0,230
Sycamore	0,003	0,006	0,360
Rowan	0,002	0,003	0,228
Aspen	0,001	0,000	-1,000
Hawthorn	0,001	0,000	-1,000

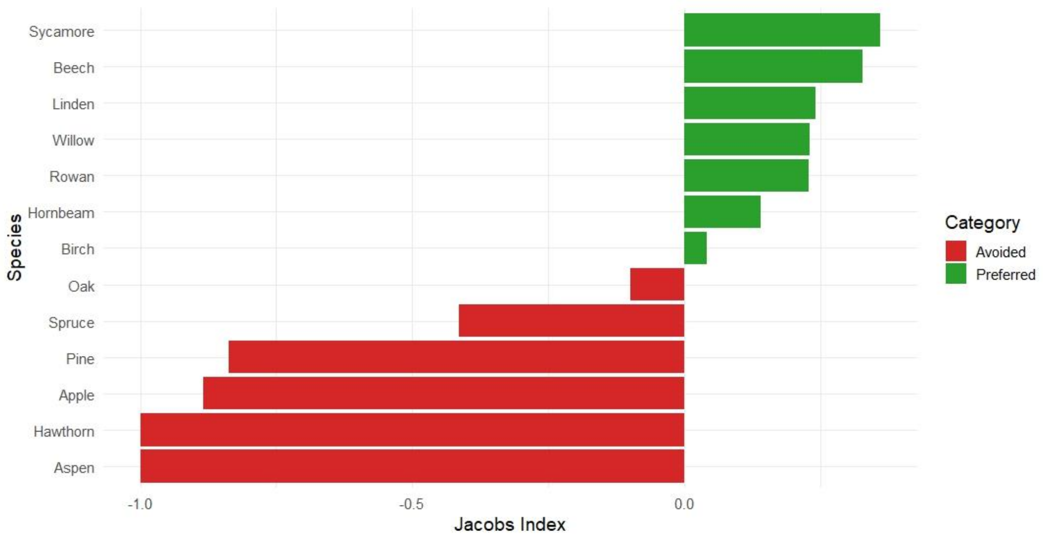

Figure 6. Comparison of Jacob's Index (D) for all of the species surveyed in browsing inventory at all of the stands with categorization to preferred (D>0) and avoided (D<0)

Another measure conducted in the field was the branching density inventory. The results, compared between fodder stands and control plantations for all the tree species combined showed respectively 9,83 and 9,43 cm of branch per growing twig. After performing an ANOVA test, no significant differences in branching rates of individual trees were found (p-value = 0.701).

4.4 Tree shape

R1 was used to assess the potential impact of long term browsing by ungulates. Trees in fodder stands showed a higher crown width-to-height ratio compared to those in control plantations (Figure 7). An ANOVA test revealed that R1 differs significantly between the sites (p-value = 0.005893, F(1, 392) = 7.66).

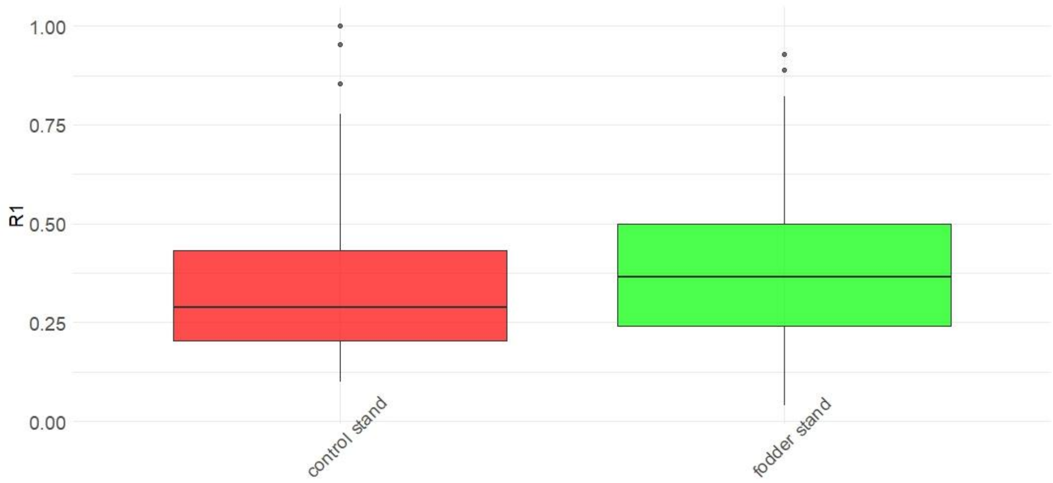

Figure 7. Comparison of mean crown width to total tree height ratio (R1) of various species found in fodder stands and control stands. Tree Sample size in fodder stand (198) and in control stand (196)

Crown width to height ratio of the beech trees in the same age growing on the surveyed stands was also tested. As shown in Figure 8, trees in the fodder stands showed a much higher R1 compared to those in the control plantations. An ANOVA test revealed a significant difference in the R1 between beech populations in the fodder stands and those in the control plantations (p-value < 2e-16).

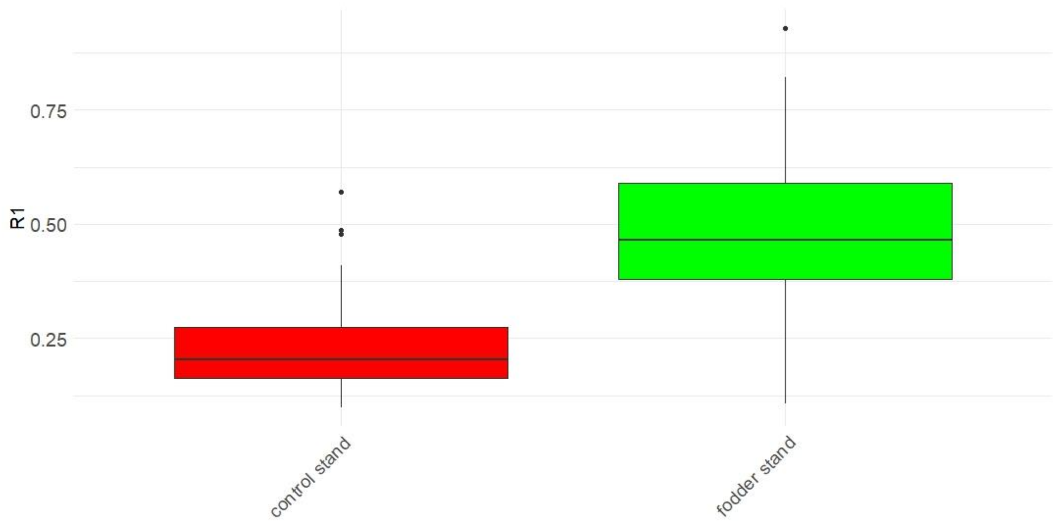

Figure 8. Comparison of mean crown width to total tree height ratio (R1) between beech trees found in the fodder stand and control stands Tree Sample size in fodder stand (56) and in control stand (72)

To explain the high variation in the crown width to total height ratio, Figure 9 illustrates the differences in height structure among these beech populations. As shown, only a few individuals from the fodder stands managed to escape the browsing trap and continue growing in height. In contrast, most of the trees in the control plantations present higher height growth and escape the browsing trap.

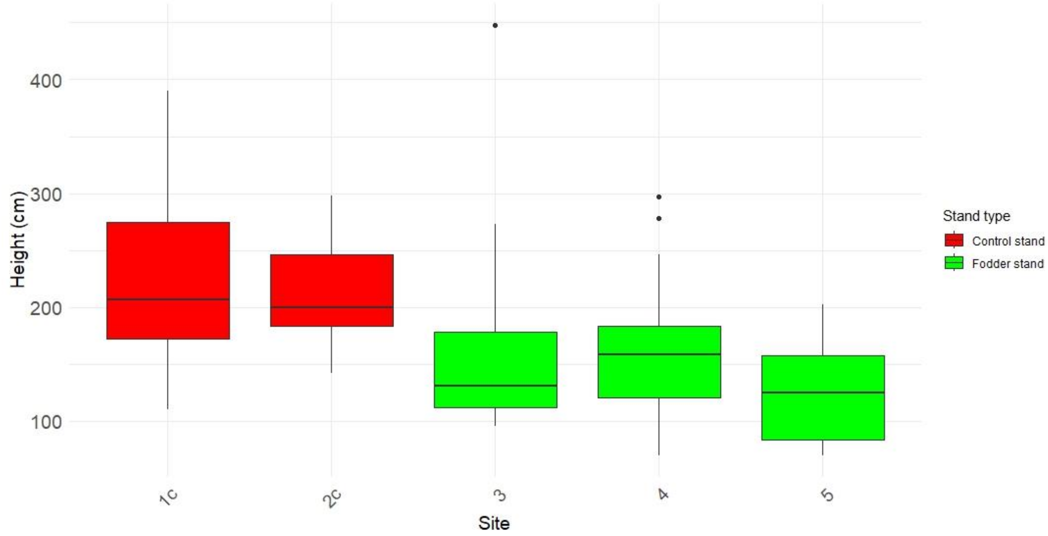

Figure 9. Height differentiation between beech populations from the control stands (1c, 2c) and fodder stands (3,4,5)

5. Discussion

5.1 Utilization of the fodder stands

Fodder stands are not common practice in forest management, but based on developments in forest management they could potentially become a promising tool for managers interested in integrating forest and game management. This is reinforced by the results of this research were a key finding supporting the hypothesis that fodder stands are more utilized than production plantations are coming from browsing intensity inventory. Higher browsing intensity in fodder stands compared to control stands (plantations) suggests that fodder stands are used more intensively by wild ungulates compared to production plantations. This results are also visible in number of browsed trees per hectare within surveyed stands.

Similar patterns supporting the hypothesis were observed in the tree shape analysis, specifically in the crown width to total height ratio. The results indicate that trees in the fodder stands tend to be shorter and broader, in contrast to the taller and more slender trees found on the control stands (Figure 7).These findings should be interpreted with caution, as the uneven age structure and differences in species composition between the stands (Table 3) may have influenced the results. However, it is worth noting that control stands were largely composed of coniferous species, which actually showed some of the highest crown width-to-height ratios among all species surveyed. This suggests that species composition alone does not fully explain the observed differences in tree architecture. A particularly compelling result comes from the comparison of European beech trees in fodder and control plots. Beech trees growing in fodder stands exhibited significantly higher crown width-to-height ratios than beech trees of similar age growing in control stands (Figure 8). This pattern may reflect a long-term response to browsing pressure. As described by Churski (2024), trees subjected to chronic browsing often develop a "cage-like" growth form. In this type of growth, trees produce numerous woody structural stems rather than a single main stem. By investing in the growth of such structures, plants reduce access to critical parts, such as the top shoots or main stem, so that browsing is spread across less vital parts of the tree, which are less important for survival. This phenomena is useful in fodder stands because each tree then provides much more potential fodder for the ungulates.

Another interesting finding was the differing levels of utilization of fodder and control stands between two Forest Districts: Drawsko and Głusko. These two districts clearly represent distinct approaches to forest stand management in terms of stand size and species composition. Nevertheless, some similarities were observed. The percentage of browsed trees and browsed top shoots was approximately twice as high in fodder stands compared to control stands at both locations (Table 4). These differences could potentially be attributed to varying densities of ungulates in the two areas (Table 1). However, as demonstrated by Kuijper (2011), ungulate density alone may not be the primary factor. According to suggestions from a local forester, which I confirmed by analyzing maps of the surrounding forests, the production stands surrounding the fodder stands in the Głusko Forest District contain a higher proportion of broadleaf species compared to Drawsko. This higher availability of preferred food resources in the commercial forests surrounding the fodder stands in Głusko may partially satisfy the feeding needs of cervids, potentially reducing their pressure on the fodder stands.

Results from the camera trap survey showed that more ungulates visited the control plantations than the fodder stands contradicting the trends observed in the tree shape and browsing intensity data. However, the number of photos captured was relatively low, falling short of expectations. The short duration of the observation period likely contributed to the limited dataset. Additionally, unusual weather conditions may have influenced animal behavior. March was exceptionally warm, leading to an earlier than usual onset of vegetation growth in open fields, which likely made alternative food sources more accessible. For these reasons, I consider the camera trap results to be inconclusive and insufficiently robust to either support or refute the main hypothesis. Further observations over a longer period would be necessary to draw reliable conclusions from this method.

Overall, the key findings from browsing intensity measurements and tree shape analysis support my hypothesis that fodder stands are utilized by cervids to a greater extent than nearby commercial production stands. However, this topic remains under-researched and requires further investigation to confirm these results with greater certainty.

5.2 Management guidelines

This research suggests that ungulates show a clear preference for fodder originating from broadleaf species over coniferous trees such as Scots pine and Norway spruce (Figure 6), two of the most economically important species in commercial forest management. Species that appear well-suited for inclusion in fodder stands include linden and hornbeam. These are typically second-layer species with limited commercial value, making them ideal candidates for redirecting browsing pressure away from more valuable species such as beech and oak (Ohse et al. 2017). In fact, linden, hornbeam, and beech were among the most frequently browsed species in this study. On nutrient-poor sites typically dominated by conifers, birch also proved to be an unexpectedly attractive food source for ungulates (Figure 6). An especially surprising result was that apple trees were not browsed at all, contradicting widely held beliefs in Polish hunting literature, which often describe fruit trees as highly attractive to cervids (Janiszewski, 2025). One group of species that may warrant further research is willow cultivars, which have a high nutrient content (Felton et al., 2020; Felton et al., 2021) and are known for their high biomass productivity. These species have been successfully used in livestock systems and could potentially serve a similar role in wild ungulate management.

Nevertheless, the species composition of a fodder stand is a crucial factor in establishing an effective area that successfully attracts and feeds cervids. An interesting exception emerged in the browsing intensity results specifically, the fourth control stand. Despite being classified as a control site, it was located only about 100 meters from a fodder stand and had a very similar species composition. The fodder stand was composed of approximately 93% beech (Figure 2), while the adjacent control stand was a 100% beech plantation (Figure 3). Not surprisingly, browsing levels in both stands were comparable.

This raises an important question for forest managers: Should the species composition of fodder stands replicate the dominant broadleaf species already used in commercial regeneration efforts, or should fodder stands be composed of alternative, more attractive species not typically planted in production forests, in order to shift browsing pressure away from valuable regeneration areas? However, problem of cervids diet selection is very complex problem depending on high number of different factors of the habitat and cervids themselves (Hanley, 1997) and it demands further research.

5.3 Limitations and future research

During the preparation for this research, I was unable to find any studies focusing specifically on fodder stands. In fact, there appears to be a lack of reliable scientific literature on this subject altogether. Some existing studies have addressed the use of fodder fields offering agricultural crops (e.g. Månsson et al., 2014; Smith et al., 2007) or supplementary feeding strategies (Putman & Staines, 2004), but none directly examined the role fodder stands as a forest management tool. Of course, this study has its limitations and would benefit from several improvements. These include: repeating the inventory over multiple years to assess long-term trends, increasing the number of fodder stands included in the analysis, and extending the duration of camera trap monitoring. The inclusion of additional methods, such as pellet count surveys, could also strengthen the dataset and help validate the observed patterns. Additionally, extending the duration of camera trap inventory to whole winter and early spring period could increase the sample size. Also number of camera traps could be increased to cover the study area depending on the size of the studied stands.

Another interesting improvement worth discussing is the establishment of different types of control stands. They could be set up in commercial stands without any fodder stands nearby, in order to examine how such management reduces game damage compared to productive stands located next to fodder areas. It would also be interesting to investigate differences between stands managed with different approaches. However, these sites should be well separated not located within the same forest complex or forest district. Factors such as landscape structure, population density, or predator pressure could also affect red deer presence and influence the results of the survey (Mysterud et al., 2011). Moreover, this is the first research I am aware of that specifically examines the utilization of fodder stands, and I believe that research conducted on a smaller scale provides a better starting point for a deeper understanding of this topic.

Despite these limitations, I believe this study provides a solid foundation for understanding how cervids utilize fodder stands. The results offer practical insights into how this method could help reduce browsing pressure in commercial forests. Further research, ideally on a larger scale and over a longer time period is needed to confirm these findings and provide more robust data for forest stakeholders. To convince landowners and managers to adopt this approach, future studies should focus on species selection tailored to local conditions and long-term effectiveness in mitigating browsing damage.

6. Conclusions

- Browsing intensity was significantly higher in fodder stands:
  On average, 42.4% of trees were browsed in fodder stands, compared to 20.6% in control stands.

- Browsing of top shoots was also more frequent in fodder stands:
  19.8% of top shoots were browsed in fodder stands versus 8.0% in control stands.

- There was a strong positive linear relationship between the percentage of browsed trees and the percentage of browsed top shoots across all surveyed plots.

- Broadleaf species were generally more preferred by cervids than conifers, with some exceptions such as oak and apple, which were browsed less frequently than expected.

- Sycamore, beech, linden, willow, rowan and hornbeam were preferred species, as indicated by positive Jacobs' Index values. Of these, beech, linden and hornbeam played the largest role in providing forage, due to their high density in the stands.

- Browsing intensity and pressure were notably lower in the Głusko Forest District compared to the Drawsko Forest District.

- Tree shape differed between stand types:
  Trees in fodder stands were shorter and broader, likely due to long-term browsing pressure, while those in control stands were generally taller and more slender.

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Popular science summary

Trees fields for the deer

From the very beginning, humans have been one of the most disruptive forces in nature. Over time, we've shaped and reshaped ecosystems to fit our needs — and this includes how we manage forests and interact with wild animals, such as deer. Modern agriculture and changes in forest management have often created conditions that help deer populations grow. In recent decades, deer numbers have increased significantly in many areas, leading to more frequent conflicts between humans and wildlife. One of the most noticeable problems is browsing damage — when deer feed on young trees in managed forests. Hunting is commonly used to control deer populations, but in many cases it's not enough to reduce the damage. That's why, in Central Europe — including countries like Poland — more and more forest landowners are setting up special feeding areas, known as fodder stands, to help steer deer away from valuable forest crops

But, what exactly is a fodder stand? A fodder stand is a specific forest management method designed to attract local cervids populations to feed in designated areas, rather than causing damage to commercial forest plantations. It may sound simple, but in practice, it's much more complex. To be effective, fodder stands must be more appealing to deer than the surrounding forest. This means carefully selecting tree and shrub species that match the feeding preferences of local wildlife. The right species composition is key to drawing animals away from economically valuable stands. What makes fodder stands unique compared to other wildlife feeding methods is that the food is naturally available as forage — living vegetation growing in the forest environment. Unlike fodder fields or supplementary feeding, where crops such as corn or beetroot are provided by humans, fodder stands rely on plants that are already part of the ecosystem. They are especially important during the late winter and early spring, just before vegetation begins to grow again. This is the period when the demand for woody browse is at its highest, and when animals are most likely to cause serious damage in production forest areas.

In this study, I focused on comparing how wild ungulates use fodder stands in western Poland. I collected data from five individual fodder stands and compared them with nearby commercial forest areas that had no game protection measures in place. The analysis included several key factors: visitation rates by animals, browsing intensity, tree and species preferences. By comparing these elements, the study aimed to better understand whether fodder stands effectively attract deer and reduce pressure on economically important forest stands.

The results of the data analysis supported my hypothesis: fodder stands were more frequently used by cervids compared to nearby commercial forest stands. What was determined based on following conclusions: (1) browsing intensity was higher in fodder stands, (2) tree shape inventory showed that trees in the fodder stands tended to be wider and lower in height, a likely response to long-term and repeated browsing by the cervids. Species preference analysis lead to another important conclusion that (3) broadleaf species are more in favor of cervids in comparison with coniferous.

This research can serve as a useful tool for forest landowners who are currently facing serious browsing damage in their commercial stands. Fodder stands, as described in this study, offer a promising strategy to redirect deer activity away from economically valuable areas. However, successfully establishing such stands requires careful planning , particularly in choosing the right species composition. Plant selection should be tailored not only to local environmental conditions but also to the specific deer species present and the forest areas that need protection.

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Appendix 1- List of hunting ground managers contacted from State Forest Company (SFC), Polish Hunting Association (PHA) and Poznań University of Life Sciences

No.	Manager	Do they practice?	Did they practiced	Number of hunting districts	Area (ha)	
1	Drawsko Pomorskie Forest District	Yes	Yes	2	32 399,98	SF
2	Okonek Forest District	No	Yes	1	9 753	SF
3	Złotów Fprest District	No	No	1	7 751	SF
4	Hunting Club no. 1 "Daniel" Lipka	No	Yes	2	9 889	SF
5	Czempiń Research Station	No	Yes	3	13 842	PH
6	Łopuchówki Forest District	No	No	1	10 051	SF
7	Zielonka Experimantal Hunting Station	Yes	Yes	1	13 488	U
8	Kujań Hunting Grounds	Yes	Yes	2	12 608	PH
9	Głusko Forest District	Yes	Yes	2	18 797,70	SF
10	Drawno Forest District	No	Yes	1	8 569,18	SF
11	Podanin Forest District	No	Yes	1	25 445	SF
12	Trzciel Forest District	Yes	Yes	1	13 663,13	SF
13	Hunting Club "Szarak" Międzybórz	Yes	Yes	1	5 062	HC
14	Hunting Club "Wieniec" Mirosławiec	No	No	3	14 415,58	HC
15	Hunting Club "Mazur" Warszawa	No	No	1	2 995,13	HC
16	Hunting Club OKM	No	No	1	6 658,43	HC
17	Hunting Club "Potok Cybowo"	No	No	1	2 899,08	HC
18	Huntig Club "Wrona" Wronki	No	No	2	8 759	HC
				27	217 046,21	

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