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The Influence of Wild Boars on the Growth of Forest Trees and Stands: A Case Study of a Wild Boar Game Preserve

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Abstract – This research investigated methods for determining and quantifying the impact of wild boars on the increment and growth of forest trees and stands. The influence of wild boars on stand variables was observed in a wild game preserve established in central Slovakia in 2000 practicing intensive wild boar management. Long-term measurements obtained from two long-term research plots of sessile oak trees established in 1969 were used to monitor stand growth. Increments of trees were observed on tree ring cores coming from trees surrounded by differently damaged soil surfaces. Wild boars rooting the soil surface proved to have neither a positive nor negative influence on the mean diameter and height of the forest stands. Analysis of radial increments in 9 trees growing on sites with more intense, deeper, and permanent rooting in the soil profile located near a larger mud bath was also carried out. A more distinctive increment depression was found on one oak near the mud bath and on one beech where deeper soil surface rooting occurred.

wild boar game preserve / game damage / tree ring analysis / radial increment

Kivonat – A vaddisznó hatása a fák és a faállomány növekedésére – egy vaddisznóskert esettanulmánya. Módszertani vizsgálatokat végeztünk annak megállapítására, hogy a vaddisznók jelenléte milyen hatással van a fák és a faállomány növekedésére. Vizsgálatainkat egy 2000-ben létrehozott vaddisznóskert területén végeztük. Kiindulási alapnak a területen 1969-ben létrehozott két kocsánytalan tölgy hosszútávú kísérleti terület adatait használtuk fel. Olyan mintafákból vettünk évgyűrű mintákat, melyek környezetében a vaddisznók a talajfelszínt különböző mértékben kársították. A vaddisznók túrásának nem volt sem pozitív, sem negatív hatása a faállomány növekedésére. Kilenc további fa vizsgálatát is elvégeztük, melyeknél a talajfelszín túrása sokkal intenzívebb volt, illetve közelebb helyezkedtek el egy dagonyához. Itt egy tölgy és egy bükkfán figyeltünk meg jelentősebb növekedés csökkenést.

vaddisznóskert / vadkár / évgyűrű elemzés / átmérő növekedés

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1 INTRODUCTION

Forest stands are multifunctional communities of which wild game is an integral part. Though game populations and migrations generally occur naturally in forests, there are cases where game is unnaturally introduced into and supported within a restricted area. Game preserves are a good example of this. Economic considerations are at the forefront of most game preserves, but consequent increased game concentration per unit area and the possible negative influence on growth and production of forest stands must also be considered when introducing game into an environment. Published reports on forest stand damage caused by larger rodents (brown hare and wild rabbit) and also primarily by bigger mammals from the genus *Cervidae* (red deer, roe deer and fallow deer) (Ueckermann 1986, Nahlik 1995, Reimoser – Gossow 1996, Finďo 1998); Finďo – Petráš (2007, 2011) summarized current knowledge in this field. Therein, they provided a detailed ecological assessment of game living freely in natural environments including the feeding habits of the game and their negative influences on forest biotopes. These authors defined the extent of negative influence of game on forest stands and they instituted a methodology for damage calculation. Being cognizant of the latest knowledge on volume and value production of forest stands (Petráš – Mecko 1995, Petráš et al. 1996, Halaj – Petráš 1998), these authors also formulated the basis for this methodology. This was supplemented by experimental results of increment loss quantification following the browsing of young forest stand crowns (Finďo 1998) and also browsing and peeling of the bark from tree stems (Jöbstl 1987, Petráš 1996, Náhlik – Walter – Illés 1998, Čermák et al. 2009).

Although direct damage to crowns and stems by forest game has been relatively well studied, indirect methods of quantifying soil surface rooting and scarification of considerable portions of the soil profile were previously lacking. Wild boars are typically culprits of scarification; (Náhlik – Sándor 2003, 2005, 2012, Jánoska – Varju 2008). Finďo – Petráš (2007, 2011) quote this game on their list of animal species decreasing natural stand regeneration by excessive mast feeding. Within the concept of soil surface rooting, this game is more likely to be useful rather than harmful. These authors contend that better seed germination and better forest regeneration result in more favourable soil surface humidification. Although the intensity of soil surface rooting is not taken into consideration with this statement, this intensity certainly differs between wild boars living freely in the wild and those living in game enclosures.

The aim of this work is to investigate methods which will determine and quantify the impact of wild boars on the increment and growth of forest trees and stands. Specifically, in a wild boar game preserve with intense management. The focus is on observation of the wild boars' influence on tree increments of more tree species and with respect to soil surface damage intensity in immediate proximity to those trees.

2 MATERIAL AND METHODS

The material for this study emanates from two sources. The first source consists of repeated measurements on two permanent sample plots established in 1969, and currently located within the game preserve. The second source is composed of tree ring cores taken from the most attacked sites of trees growing in the game preserve.

2.1 The wild boar preserve

The wild boar preserve is located in the central part of Slovakia, on a forest enterprise area owned by the Technical University in Zvolen. Its total area is 254 ha; 243 ha of which are afforested. It was established in 1966–1971 to keep fallow deer, but in 2000 it was reworked to house wild boars. The population density of wild boars was increased gradually. In the first year there were only 6 boars, but after 5 years, their population increased to 215. The population is currently around 210–240 individuals, making the density 1 wild boar per 1.1–1.2 ha. As a result, the influence wild boars exert on forest stands was expected to occur after the period of 2000–2005.

The total area of the wild boar preserve is fenced. The game preserve is located at an altitude varying from 320 to 490 m. The growing season lasts 224 days, while the mean annual temperature is 10.9°C. This area receives 700 to 800 mm annual precipitation. SE to SW exposures prevail. The geological base is formed from andesite. There are middle-deep soils with 25–30% proportion of soil skeleton which rises up to the surface in some sites of the game preserve. Soil surface is covered with a thin layer of fallen leaves and in some places with thermophile plants and sparse brush undergrowth. The composition of the trees is 80% *Fageto quercetum* (FQ), 18% *Querceto fagetum* (QF) and 2% *Fagetum pauper* (Fp). sessile oak (*Quercus petrea* Liebl.) and the turkey oak (*Quercus cerris* L.) that are more than 70-years-old prevail throughout the entire game preserve. These tree species combined represent 65% of the tree species in the game preserve.

2.2 Long-term research plots

Two long-term research plots (LTP) were established to conduct long-term research on forest production and for construction of domestic yield tables in the 1969 state-wide programme. The sample plots are situated at approximately 400 m altitude. LTP No. 100 is 0.33 ha in area, and LTP 105 has 0.24 ha. Intense rooting of the soil surface caused by wild boars searching for food was determined by the last two measurements on both LTPs in 2005 and 2010. The sessile oak is the main tree species on sample plots, together with rare mixture of hornbeam (*Carpinus betulus* L.) and small-leaved lime (*Tilia cordata* Mill.). All trees on the sample plots are permanently numbered and each was repeatedly measured in 5-year intervals for diameter, sociological tree position, quality and mechanical stem damage. Although tree heights were generally recorded only during the first and last measurements, additional measurements were taken for height curve construction. Models of the height curves were derived from the Michajloff (1943) function:

$$h(d) = 1.3 + a \cdot exp\left(\frac{-b}{d}\right) \tag{1}$$

where: h and d are for tree height and diameter,
a and b indicate regression parameters.

A deviated position in some repeated measurements was discovered during detailed tree height analysis. Some height curves intersected and the distance between neighbouring curves was disproportionately large or small. Therefore, the following equation of Michajloff function modified by Petráš et al. (2012) was used:

$$h(d,t) = 1.3 + p_1 \cdot t^{p_2} \cdot exp\left(\frac{-p_3 \cdot t^{p_4}}{d}\right) \tag{2}$$

where: h, d – tree height and diameter,
t – stand age,
$p_1 – p_4$ – regression parameters.

For its derivation, parameters a and b in equation (1) were expressed with dependence on stand age (t), and an independent regression model was derived from equation (2) for each LTP. The QC.Expert statistical package (Kupka 2003) was applied and the accuracy and precision of derived models was thus evaluated. Basic stand variables were calculated from the number of trees in each 1 cm diameter class and from the height curve models. There were hectare variables such as the number of trees (*N*), the basal area (*G*) and the stand volume (*V*). Mean stem variables such as the tree mean volume (*v*), diameter (d_g) and height (h_g) and the same variables of upper stem were derived from those hectare variables. Their development was compared with the development of yield table models (Halaj – Petráš 1998).

2.3 Tree ring cores

Changes in tree growth were examined by tree ring series. *Table 1* shows that 9 examined trees comprised 6 sessile oak (*Quercus petrea* Liebl.) trees, 2 silver firs (*Abies alba* Mill.) and 1 European beech (*Fagus silvatica*). While most of these trees were in a crown level position, with one being dominant and two intermediate, the crowns of two additional trees were cramped by neighbouring crowns. Tree rings were taken from trees growing on sites heavily attacked by wild boars. Seven trees are located at the position where wild boars both fed on supplementary given fodder and secured larger bedding. Another two trees are located at another site, near the bigger mud bath. One core was taken from each tree at breast height, and tree ring widths were measured by a digital positioner, connected on-line to a computer. Tree-ring series were synchronized, dated, and analysed in detail. Comparison was made between tree ring curves and variability of annual radial increments prior to 2000, before implementation of the game preserve for wild boars, and also after that period, when wild boars intensely influenced the plot. This research method was based on the work of several authors; primarily that of Fritts (1976), Schweingruber (1983), Pollanschütz (1986), Petráš et al. (1993) and Petráš – Mecko (2011). These authors confirmed that changes in growth conditions are best indicated by changes in radial increments; where trees form thinner tree rings with lower variability in worsening growth conditions, and vice versa.

Table 1. Basic data on trees of which tree ring cores were taken

Number of the tree	Tree species	Tree diameter d (cm)	Tree class	Crown	Notice
1	oak	47	2	free	
2	oak	35	2	suppressed	
3	fir	35	3	free	
4	oak	33	2	suppressed	
5	fir	72	1	free	
6	oak	43	2	free	
7	beech	39	3	free	
8	oak	46	2	free	at the mud bath
9	oak	41	2	free	at the mud bath

3 RESULTS AND DISCUSSION

3.1 Changes in oak stands growth

Measured tree heights were individually equalized for each LTP, dependent on their stand diameter and height, using nonlinear least squares in compliance with the model (2). One height measurement proved incorrect for each LTP. The following systematic methods were employed. (1) On LTP 100, tree heights were lowered on the fourth measurement by approximately 1.0–1.5 m, and (2) on LTP 105, higher heights were measured on the first occasion. In both cases, these measurements were excluded from the regression equation. The equation parameters (*Table 2*) are very favourable. Determination coefficients R^2 are relatively high and these reveal that the model explains 93–95% of observed height variability. Standard errors of the equation are relatively low s_h (1.13–1.32 m) for the same reason. The model height curves (*Figure 1*) have a typical fan shape, where tree heights increase non-linearly with broader diameter and higher stand age.

Table 2. Parameters ($p_1 – p_2$) and statistical characteristics of regression equation of height curves models

Plot	p_1	p_2	p_3	p_4	n	R	R^2	s_h (m)
LTP 100	2.1186	0.6390	0.5211	0.6732	905	0.9632	0.928	1.32
LTP 105	0.9495	0.7999	0.3479	0.7550	656	0.9761	0.953	1.13

Note: LTP – long-term research plots; n – number of measured heights;
R – correlation coefficient; R^2 – coefficient of determination; s_h – standard errors.

Table 3. Development of basic stand variables from repeated measurements on LTP

Year of measurement	Age	Values per 1 ha			Mean stem			Upper stem (10%)		
		V	N	G	v	d	h	v	d	h
		(m^3)	(pcs)	(m^2)	(m^3)	(cm)	(m)	(m^3)	(cm)	(m)
LTP 100										
1969	56	194	1318	27.26	0.147	16.39	18.50	0.385	24.18	21.37
1974	61	211	1179	27.67	0.179	17.50	19.53	0.488	26.33	22.68
1979	66	231	923	27.60	0.250	19.74	21.10	0.660	29.49	24.20
1984	71	268	801	29.70	0.335	21.97	22.55	0.837	32.23	25.58
1995	82	345	687	34.07	0.503	25.41	25.10	1.194	36.62	28.15
2005	93	435	638	39.36	0.682	28.31	27.29	1.619	40.88	30.60
2010	98	474	605	41.33	0.784	29.79	28.34	1.833	42.76	31.67
LTP 105										
1969	48	102	3881	26.30	0.026	9.70	12.10	0.109	15.90	15.28
1974	53	122	3522	27.29	0.035	10.50	13.01	0.153	17.77	16.66
1979	58	145	2312	26.48	0.063	12.60	14.77	0.237	20.75	18.35
1984	63	177	1723	27.64	0.102	14.75	16.53	0.341	23.61	19.95
1995	73	255	1314	32.96	0.194	18.29	19.37	0.545	27.77	22.63
1999	78	286	1032	34.02	0.277	20.76	21.10	0.648	29.44	23.85
2005	84	340	973	37.68	0.350	22.47	22.48	0.805	31.74	25.38
2010	89	379	898	39.71	0.422	23.98	23.69	0.934	33.39	26.57

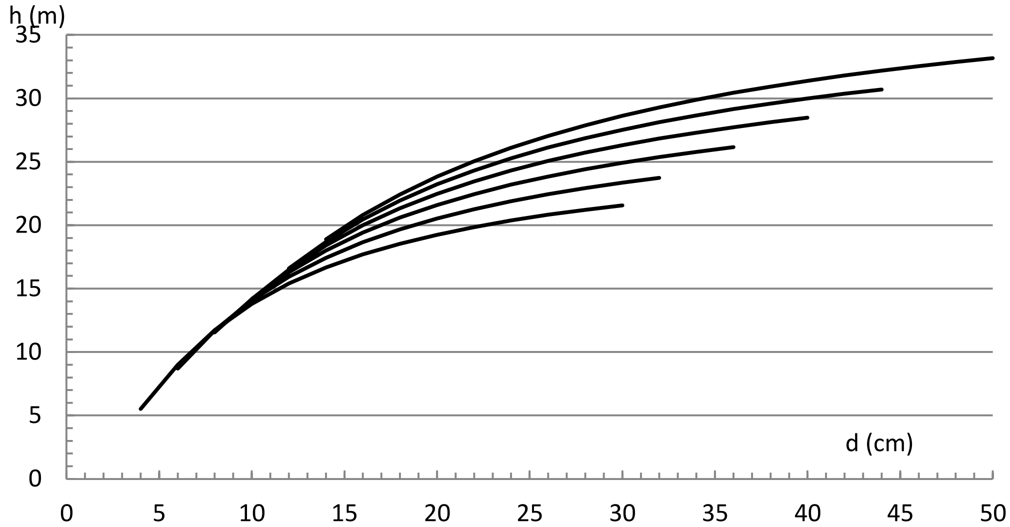

Figure 1. Height curves model for trees 50–100 years old on the LTP 100

Oak stand growth was evaluated by the continuous development of their growth variables (*Table 3*). Although hectare variables such as the number of trees (*N*), the basal area (*G*) and the stand volume (*V*) result from growth processes, these also significantly depend on stand density. More remarkable negative influence of wild boars on the density of mature stands cannot be expected at a wild boar density of 0.83–0.94 per 1 ha of the game preserve, only on the growth conditions of individual trees, so their influence was assessed via changes in tree mean diameter (d_g in *Figure 2*) and mean height (h_g in *Figure 3*). Development of these characteristics on both LTPs was compared with model development yield tables (Halaj – Petráš 1998), and thus LTP 100 was assigned to site class 26 and LTP 105 to class 22. However, the actual mean diameters, and especially the mean heights, displayed a more abrupt course on these LTP than that in the model yield tables. Following the establishment of the game preserve in the year 2000, increased significant influence of wild boars on the stands growth was expected. At that time, LTP 100 was approximately 90-years-old and LTP 105 was 80. However, comparison of the actual and the model curves failed to definitively prove that wild boars negatively or positively influenced the growth process of oak stands through trampling effects on the soil surface.

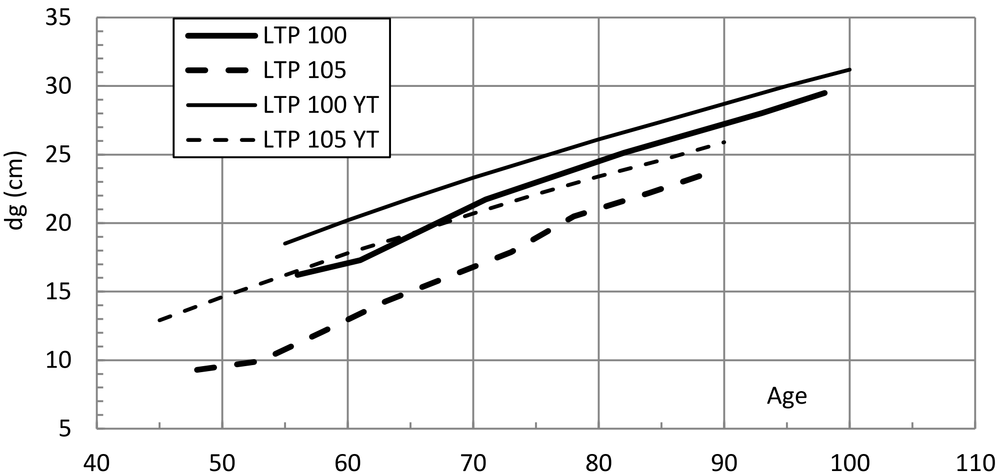

Figure 2. Comparison of mean diameter dg development (bold) on LTP 100 and 105 with the model one (thin) by yield tables (Halaj – Petráš 1998)

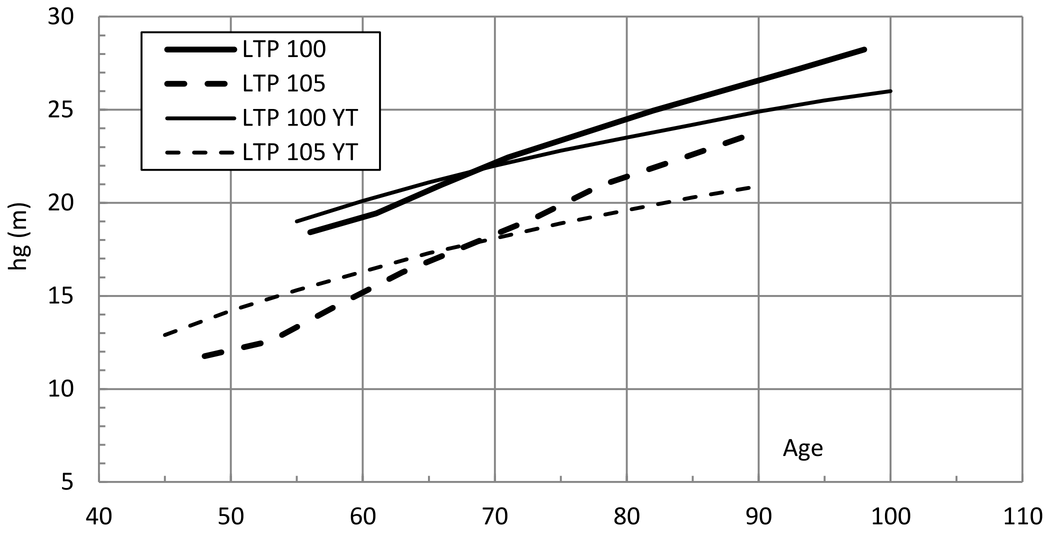

Figure 3. Comparison of mean height development hg on LTP 100 and 105 with the model one by yield tables (Halaj – Petráš 1998)

3.2 Changes in individual trees growth

Changes in tree growth were examined by tree ring series. Even when formation of tree rings is unambiguous in our climatic conditions, there are individual cases where tree rings vary. Two rings may form in some years, while no rings form or are scarcely recognizable in other years. Therefore, tree ring series were synchronized and dated to discover and eliminate these particularities. The percentage of parallelism in increment trends (Jačka 1989, Petráš et al. 1993) was calculated for all pairs of tree rings series apparent over the last 50 years. Results of this calculation delivered the wide range of 39–83%. Only 4 pairs of tree ring series exhibited less than 50% parallelism. Here, oaks with free crowns recorded the highest values up to 68–83%, while suppressed fir and beech ring series registered lower parallelism. This lower parallelism percentage confirmed that the tree ring series are correct.

In-depth analysis of tree ring series proceeded from our knowledge and experience. When growth conditions of examined trees change, the tree responds with changed increments. Thus, as conditions improve, both tree increments and variability increase, while their increments and variability are smaller in worsening conditions (Pollanschütz 1986, Petráš – Mecko 2011, Bošeľa et al. 2013, 2014). The timing of changes in growth conditions is also important. A sudden change in conditions induces radically larger or smaller increments in the increment curve. This knowledge was employed to investigate the actual influence of wild boars on radial increments in all 9 trees. The trees were divided into three groups for precise illustration. The first group comprised three oaks with long-term balanced increments and natural variability in the range of 1 to 4 mm (*Figure 4*). Despite considerable variability in increments, it was not possible to confirm marked depressions or increased increments in these trees during the 1965–2012 period. The second group included oak trees which experienced radial increments (*Figure 5*). The curves for trees number 2 and 4 indicate that more distinctive increment depressions occurred after 1980 or 1990, and they maintained this similar condition after the year 2000. From reasons stated above, we can conclude that neither depression was due to negative influences of wild boar activity near the trees, but rather was due to other causes. The most likely cause lies in the worsened position of the tree with respect to crown space. However, an exception to this is oak tree number 8 which grows on the lower side of the mud bath which has an approximate diameter of 4–5 m. This oak tree maintained its approximately balanced increments until 2005, and then a marked depression occurred with increments decreasing from 1.3 mm to 0.4 mm. This was the minimum value recorded since 1930 in the entire study period. Since the crown of this tree is in the crown-level position, we can assume that this depression occurred because of the negative influence of the mud bath which is permanently filled with water and deep mud. In connection with this assumption, we stress the fact that oak tree number 9 (*Figure 4*), which has no increment depression, is located almost at the same distance from the mud bath, but on the upper aspect and thus negates a permanently wet root system. The third group consists of two firs and one beech tree (*Figure 6*). Fir tree number 5 is dominant; being the thickest of all trees. Since its increment variability is relatively broad, it is difficult to presume that the reason for its sudden increment depression over the last 3 years is due to wild boar activity. However, the situation with the beech tree is entirely different. This beech tree suffered distinct depression in 2005–2012, with following bigger increments between 1980 and 2004. Hence, the possibility certainly exists that negative influences emanated from wild boar activity.

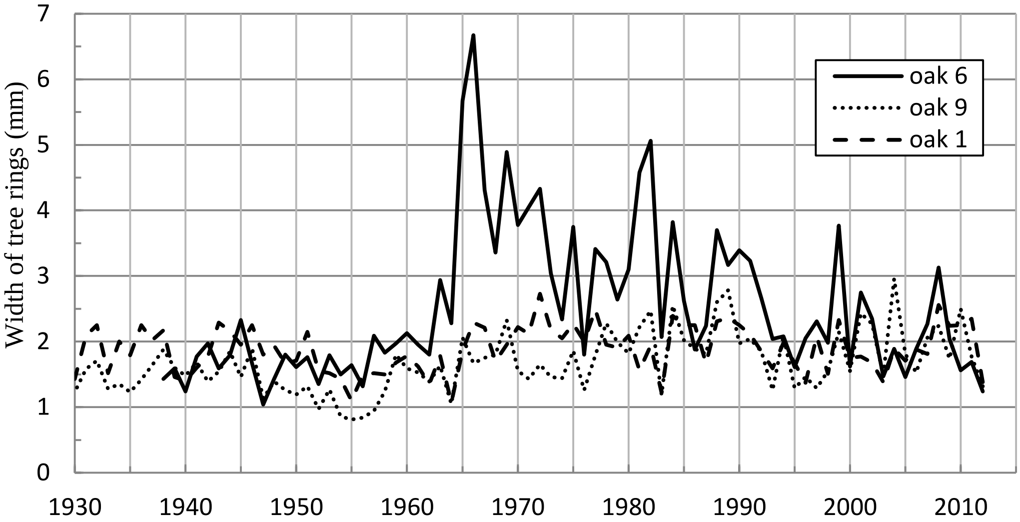

Figure 4. Radial increments of the oaks no. 1, 6 and 9 without any significant changes in the observed period

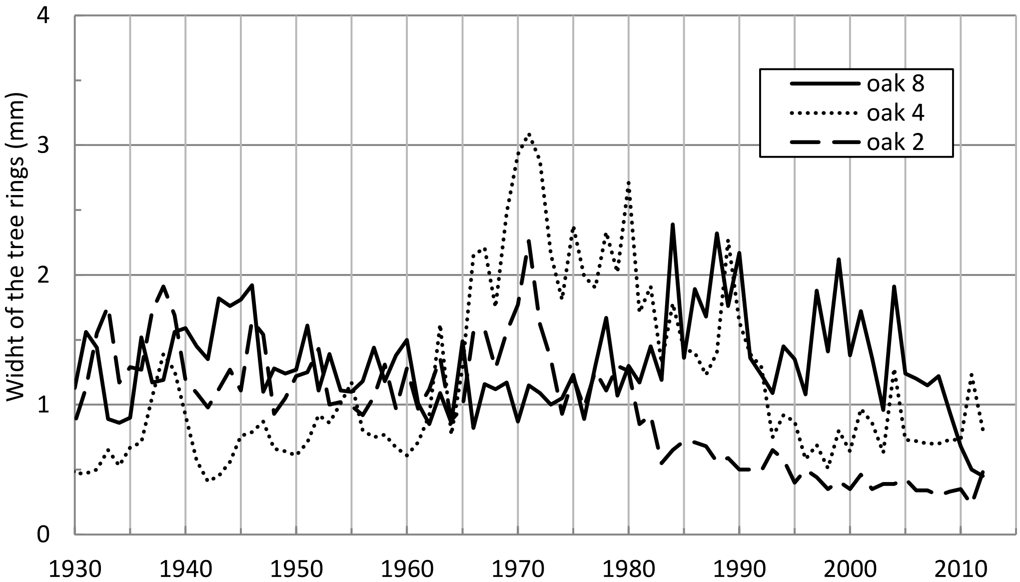

Figure 5. Radial increments of the oaks no. 2, 4 and 8 with more significant changes in the observed period

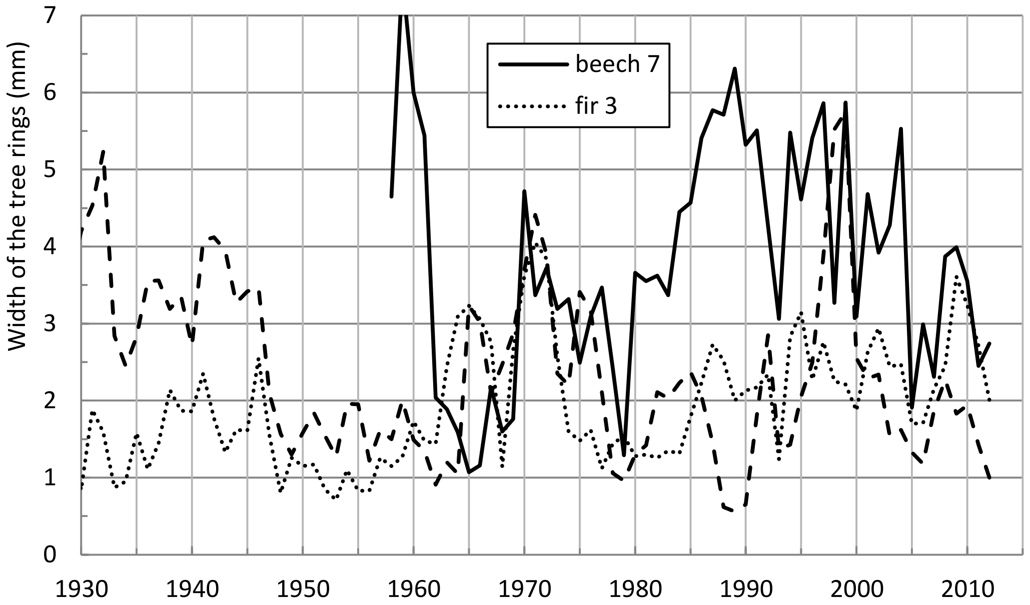

Figure 6. Radial increments of firs no. 3 and 5 and the beech with no. 7 with more significant changes in the observed period

On the basis of obtained results, we can state that soil surface rooting by wild boars cannot definitely be considered responsible for positive or negative influences. This certainly depends on scarification extent, depth, and intensity. In our two LTPs, there was whole-scale rooting, but only on the surface, with accompanying disruption of soil litter. The soil profile was not disturbed to a deep level in any area. In addition, although the approximate ten-year observation period of this study is relatively short, our intention is to continue monitoring these LTPs while the game preserve is maintained. This study has confirmed that analysis of radial increments on tree ring series is an appropriate and beneficial methodology designed for particular trees and their biotopes. Future research will enable increased precision in the study of these trees and their biotopes, and long-term monitoring of increased number of trees and tree species is pertinent.

4 CONCLUSION

The objective of this work was to investigate methods which will determine and quantify the impact of wild boars on the increment and growth of forest trees and stands. Their influence on hectare and mean stand variables was observed in a game preserve with intensive wild boar management. Long-term measurements obtained from two long-term research plots of sessile oak trees served as a basic material for this observation. Tree increments of more tree species were observed on tree ring cores coming from differently damaged soil surface surrounding those trees.

Results showed that shallow rooting of the soil surface caused by wild boars has no influence on oak stand growth. The development of mean heights and diameters on both the permanent sample plots observed over 41 years is continuous, without significant changes after the year 2000 when the game preserve for wild boars was established in this locality.

A significant influence of wild boars was proven only on radial increments in some individual trees. Deeper rooting of the soil surface had no effect on eight of the nine examined trees; these were six oak and two fir trees. However, the remaining beech tree proved an exception, exhibiting increment depression over the last seven years. Mud baths installed for the wild boars in this game reserve had different effects on the surrounding trees. Radial increments on an oak growing on the lower side of the larger mud bath which was permanently filled with water and deeper mud decreased quite significantly after 2005.

Our results indicated that it is possible to expect negative influence on forest tree increment resulting from wild boars activity, and that this is only a question of extent and intensity. We can state that it cannot be considered as damage a priori. With respect to the small amount of empirical material available herein, it is necessary to consider the achieved results as preliminary results. The method based on observation of whole-stands growth changes on the basis of long-term measurements obtained from long-term research plots is not sufficiently sensitive to the whole-area rooting of the soil surface by wild boars. It is hard to assume whether it would be suitable for comparison of growth changes with a control variant, i.e. without any rooting. The method of observation of radial increments on tree ring cores is more sensitive and persuasive. It is based on the ability of individual trees to respond to changed growth conditions.

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