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Crop damage by wild boar (*Sus scrofa* L.) depending on the crop composition in Central-Eastern Poland

PAWEŁ PIEKARCZYK[1], KATARZYNA TAJCHMAN[2]*, OLGIRDA BELOVA[3] AND MACIEJ WÓJCIK[1]

[1] *Regional Directorate of State Forests in Lublin, Czechowska 4, 20-950 Lublin, Poland*
[2] *Department of Animal Ethology and Wildlife Management, Faculty of Animal Sciences and Bioeconomy, University of Life Sciences in Lublin, Akademicka 13, 20-950 Lublin, Poland*
[3] *Department of Forest Protection and Game Management, Lithuanian Research Centre for Agriculture and Forestry (LAMMC), Liepų str. 1, Girionys LT-53101, Kaunas district, Lithuania*

* *Corresponding author: katarzyna.tajchman@up.lublin.pl; phone: +48 814456848*

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Abstract

The aim of this study was to analyse the damage caused by wild boar *Sus scrofa* to crop fields located in the central-eastern Poland in relation with the crop composition. A significant increase in the grassland area and in the area under cultivation of total cereals, vegetables, fruit, and root crops ($p \leq 0.05$) was revealed on the study area. The volume of damage caused to legumes, industrial plants, vegetables, and fruit increased simultaneously with the increase in the surface area under these plant groups ($p \leq 0.05$). The compensation payment has markedly positively correlated with the damaged area of grassland, cereals, maize, root crops, legumes and an increase in the total damage ($p \leq 0.05$). The number of compensations has a significant effect on the number of wild boars harvested on the studied areas ($p \leq 0.05$). The number of wild boars and the number of harvested wild boars were strongly negatively correlated with the area of maize cultivation ($p \leq 0.05$). The level of wild boar hunting increased markedly simultaneously with the increase in the damage caused by these animals ($p \leq 0.05$). Moreover, it was shown that the number of harvested wild boars increased considerably with the increase in the number of wild boars on the study area ($p \leq 0.05$). The level of damage to cereals, maize, and industrial plants decreased significantly with an increase in the total area and forest area in the study territory ($p \leq 0.05$).

Keywords: *Sus scrofa*, impact on crops, damage, recommendations

Introduction

An increase in the abundance of the wild boar (*Sus scrofa*) populations, which directly leads to an increase in conflicts between farmers and wildlife managers, has been reported worldwide (Schley et al. 2008, Geisser and Reyer 2010, Saito et al. 2011, Massei et al. 2015, Lombardini et al. 2017). Recently, wild boars have exhibited a tendency towards year-round reproduction, while previously it occurred only in the autumn and winter period (Zawadzki 2011, Albrycht et al. 2016, Dziki-Michalska and Drozd 2018). This is a result of availability of energy-rich food, which contributes to faster fat deposition and readiness for reproduction of less than 1-year-old individuals (Baubet et al. 2003, Bieber and Ruf 2005, Fonseca et al. 2011, Borowik et al. 2013). These changes result in disturbances within the wild boar population, i.e., a visible excess of females, piglets, and yearlings (Kozdrowski and Dubiel 2004). In 2010, the wild boar population in Poland was estimated at 118,000 animals (GUS 2016), but this number increased to 264,800 individuals in 2015 (GUS 2020). A number of studies indicated wild boars' preference for high-energy food; correspondingly, animals prefer easily accessible energy-rich arable fields rather than food in the natural forest habitats, which is hardly achievable and requires more time (Baubet et al. 2004, Barrios-García and Ballari 2012, Ballari and Barrios-García 2014). However, Fournier-Chambrillon et al. (1995) showed that the wild boar diet consisted of 57% of wild food, in which acorns of the Holm oak (*Quercus ilex*) and maize (*Zea mays*) accounted for 47% and 32%, respectively. Nevertheless, it was found that if a heavy mast was missing, the share of aboveground vegetation, including agricultural crops in the diet increased (Leránoz 1983). Wild boars are highly versatile omnivores and consume a wide variety of food, which

is affected by food supply and availability (Herrero et al. 2005, Giménez-Anaya et al. 2008, Ballari and Barrios-García 2014, Rutten et al. 2020). Despite they consume food of animal origin, the main components of the diet are Fagaceae: *Quercus* sp. acorns, *Fagus sylvatica* beechnuts, *Castanea sativa* chestnuts, and agricultural products (Irizar et al. 2004, Herrero et al. 2006, 2008). In Poland, relatively high quantities of acorns are consumed by wild boars in seasons when oak produces moderate amounts of nuts: they account for 52% of forest food among piglets, 90% among yearlings, and 96% among adults. Acorns make up one third of the overall examined food content in piglets, 40% in yearlings, and 50% in adults. However, sweet stone fruits, pears, and apple tree wildings make up a large part of the wild boar's diet. During the winter, the supply of beetroot, maize, and barley, the large amount of farmland food in wild boar stomachs accounted for only two percentage points less than the forest food in the overall diet composition (47.3% and 49.4%, respectively) (Wlazełko et al. 2009). Energy requirements, food availability, and seasonal and geographical variations are the major factors influencing food selection by wild boar. These factors may also interact with human activities (e.g., agricultural crops, supplementary feeding), further influencing the diet composition (Ballari and Barrios-García 2014). Although the share of agricultural food changes seasonally, this type of wild boar food (Herrero et al. 2006, Giménez-Anaya et al. 2008, Wlazełko et al. 2009, Novosel et al. 2012, Ballari and Barrios-García 2014, Zeman et al. 2018) caused human-wildlife conflicts.

Various methods are used to frighten away animals from crop fields to minimize damage to crops. One method is the use of chemicals; however, despite their affordable price and availability, their effectiveness is negligible (0.4%) (Schlageter 2013, Węgorek et al. 2014). The wild boar is highly adaptable to changes in environmental conditions due to rapid learning and habituation (Belova 2001, Dziki-Michalska and Drozd 2018). The most effective method for crop protection against damage caused by wildlife is the use of electric fences (Schlageter 2013). As suggested by Lombardini et al. (2017), the decrease in the forest cover and the increase in monocultural croplands are significant factors stimulating damage caused by wild boars. Moreover, the hunting prohibition in areas adjacent to forests causes a considerable increase in the damaged area under agricultural crops (Fonseca 2008, Amici et al. 2012).

The wild boar is the most troublesome species, as due to its food preferences, it is responsible for 95% of damage to agricultural crops in Croatia, 90% in Italy, 87% in France, and 60% in Slovenia. Damage caused by wild animals generates large economic losses, which amount to approximately 80 million € each year. In countries, where they are compensated, the amount of the compensation increases with increasing animal density (Valente et al. 2020). The conflict of interest between farmers and game managers is a notable problem, especially in Poland, where in accordance with the Law on Hunting of the Republic of Poland, it is stated "the tenant or hunting district manager – most often a hunting association – is obliged to compensate for damage caused to crops and agricultural products by wild boars (...)" (Dz.U. 1995 Nr 147 poz. 713). In the hunting year 2017/2018, the number of compensations paid was 19,777.03 thousand €, i.e., by 2,980.48 thousand € (17.7%) more than in 2016/2017 and by 3,775.45 thousand € (23.6%) more than in 2015/2016. Most compensations (over 85%) were paid by the Polish Hunting Association. The other damages were covered by the Polish State Forests Holding (Najwyższa Izba Kontroli 2019). To improve strategies for prevention of agricultural damage, better understanding of the determinants of the damage caused by wild boar is needed. Therefore, we aimed to analyse damage caused by *Sus scrofa* in central-eastern Poland in 2013–2018 with reference to the crop composition in the study area and the wild boar abundance and harvest size. In addition, we have made recommendations for farmers and wildlife managers to minimize damage.

Material and methods

Study area

The study was conducted in seven State Forests' Game Breeding Centres (SF GBC) in Central-Eastern Po-

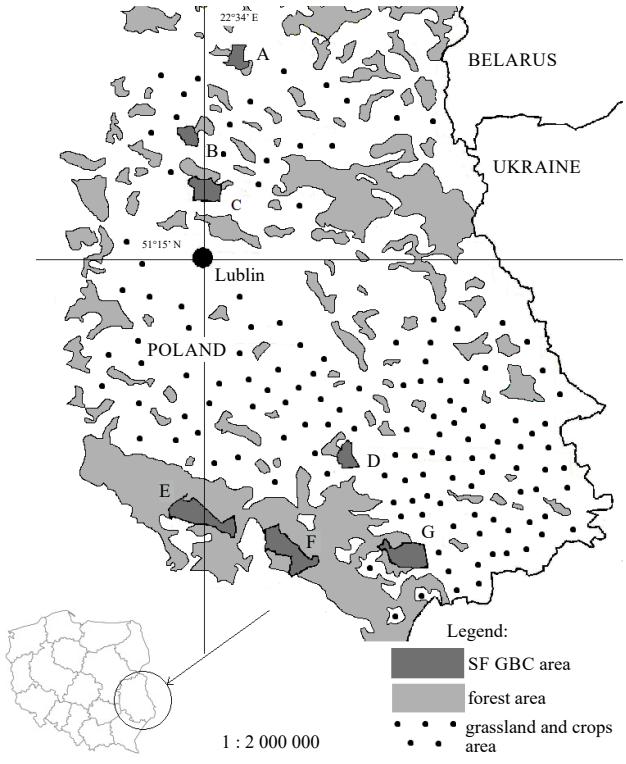

Figure 1. The study area: A) SF GBC Suchowola, B) SF GBC Rawityn, C) SF GBC Kozłówka, D) SF GBC Nowiny, E) SF GBC Lasy Janowskie, F) SF GBC Puszcza Solska, G) SF GBC Pańków

land (Lubelszczyzna) (Figure 1). These areas were established by virtue of the Law on Hunting of the Republic of Poland (Dz.U. 1995 Nr 147 poz. 713). They are managed mainly by the Polish National Forests and the Polish National Hunting Association. Game management serving specific purposes is conducted with precise rules in the area. The aim is to provide sustainable management of wildlife habitats considering the inseparability of wildlife and flora, keeping numbers related to damage caused by wildlife (Pałubicki et al. 2013).

The forest cover of the Central-Eastern Poland represents 23% of the total area of 2,695.9 ha. The dominant forests are fresh mixed forest (19.77%), fresh deciduous forest (17.98%), fresh mixed-pine forest (12.83%), and fresh pine forest (10.43%). The dominant species are pine (*Pinus sylvestris* L.) (68%), oak (*Quercus robur* L.) (14.33%), alder (*Alnus glutinosa* L.) (6.19%), and birch (*Betula* spp.) (5.63%) (Trampler et al. 1990). Agricultural lands constitute 70.5% in Lubelskie voivodship (USL 2018). In 2014–2018, the crop composition in Lubelskie voivodship was as follows: the largest area was under cereals, i.e., on average 126,272.13 ha in total, which accounted for 62.06% (including wheat 30.09%, oats 4.66%, maize 4.93%, and other crops 22.39%). A substantially smallest area was under root crops, i.e., 2,765.40 ha (1.36% in total, including potatoes 0.82%, and other plants 0.54%) (Table 1).

The climate varies between the moderate-transition zone in the northern part and the zone of foothill lowlands and valleys in the south. The mean annual precipitation was 750 mm, the average annual temperature was 9.3°C in 2014–2018 (IMiGW 2014–2018). During the five seasons, the cultivated land area under the analysed crops increased by 369,780.35 hectares, which promotes an increase in crop damage (Czyżowski et al. 2009).

Data collection

We used the data of the crop composition in Lubelskie voivodship obtained from the Lublin Regional Office of the Agency for Restructuring and Modernisation of Agriculture. The data comprised detailed information on the exact kind of crops and the cultivated area in each of Lublin Powiats from the beginning of 2014 to the end of 2018. Each of the records was assigned to a particular crop according to a scheme. Plant species were divided into cereals, namely wheat (*Triticum aestivum*), oats (*Avena sativa*), maize (*Zea mays*) etc., grassland, namely meadows and pastures, root crops, namely potatoes (*Solanum tuberosum*), carrots (*Daucus carota*), turnips (*Brassica rapa*) etc., papilionaceous plants, namely field beans (*Vicia faba*), peas (*Pisum*), lentils (*Lens culinaris*), beans (*Phaseolus*) etc., industrial crops, namely rape (*Brassica napus*), sugar beet (*Beta vulgaris*) etc., and vegetables and fruits (Table 1). No electric fences were applied.

Additionally, we analysed the information provided by the Game Breeding Centres within the Regional Directorate of State Forests in Lublin about the area of damage caused to agricultural crops by wild boars, the type of damaged crops, the level of compensations, and the numbers and culling of wild boars carried out in compliance with the Law on Hunting of the Republic of Poland (Dz.U. 1995 Nr 147 poz. 713) and the Regulation of the Minister of Agriculture and Rural Development

Table 1. Crop composition in Lubelskie voivodship in 2014–2018

Type of crop		Period of growth	2014	2015	2016	2017	2018	Average	Percentage (%)
Grassland (ha)		All year	4929.78	4380.37	4784.42	6161.76	6196.83	5290.63	2.60
Cereal crops (ha)	Wheat (*Triticum aestivum*)	September–July/August	48232.29	52606.47	53130.45	71267.82	80888.03	61225.01	30.09
	Oat (*Avena sativa*)	March–July/August	5293.34	5641.04	6874.28	11997.55	13389.04	9475.48	4.66
	Maize (*Zea mays*)	April–October	9453.61	8380.78	8933.37	10478.46	12863.95	10022.03	4.93
	Others	March–October	34248.28	35259.58	39631.85	56835.32	61773.04	45549.61	22.39
	In total	-	91934.18	101887.87	108569.95	150579.15	168914.06	126272.13	62.06
Root crops (ha)	Potatoes (*Solanum tuberosum*)	April–September	1636.86	1572.53	1461.75	1729.23	1957.74	1671.62	0.82
	Others	April–September	966.79	1188.38	1091.60	1020.58	1201.53	1093.78	0.54
	In total	-	2603.65	2760.91	2553.35	2749.81	3159.27	2765.40	1.36
Fodden plants (ha)		April–October	5608.18	5773.96	5957.64	8914.69	9407.13	7132.32	3.51
Papilionaceous plants (ha)		March–July	10693.86	11461.19	9493.45	11299.63	10942.43	10778.11	5.29
Industrial crops (ha)	Rape (*Brassica napus*)	August–June	12501.78	11355.27	19749.12	24950.19	30213.22	19753,92	9.71
	Others	Whole year	13274.73	14961.28	18844.01	21510.78	21813.68	18080.90	8.89
	In total	-	25776.51	26316.55	38593.13	46460.97	52026.90	37834.82	18.59
Vegetables and fruits (ha)		April–October	4337.52	5597.12	7250.17	13407.82	14629.00	13562.61	6.67
In total (ha)		-	145883.68	158177.97	177202.11	239573.83	265275.62	197222.64	-

Table 2. Type of crops and area of damage caused by wild boars on the areas supervised by the State Forests' Game Breeding Centres (SF GBC) in 2014–2018

Type of crop	State Forests' Game Breeding Centres						Average	Percentage (%)
	Lasy Janowskie	Puszcza Solska	Kozłówka and Rawityn	Pańków	Suchowola	Nowiny		
Grassland (ha)	26.87	7.86	255.74	22.00	17.33	3.06	55.48	41.16
Cereal crops (ha)	5.15	4.3	174.34	91.78	13.24	29.18	52.99	39.31
Maize (Zea mays) (ha)	0.74	0	35.78	0.86	4.64	18.22	10.04	7.45
Root crops (ha)	0.63	0.38	19.97	13.38	0.96	0.57	5.98	4.44
Fodder plants (ha)	0.81	0	0	0.004	0	0	0.13	0.1
Papilionaceous plants (ha)	0	1.99	2.45	39.63	0	1.55	7.60	5.64
Industrial crops (ha)	0	1.15	0	0.32	0.89	5.38	1.29	0.96
Vegetables and fruits (ha)	0	1.56	0.4	5.83	0	0	1.29	0.96
In total	34.2	17.24	488.28	173.80	37.06	57.96	134.76	-

(Dz.U. 2018 poz. 290). The data covered five hunting seasons from 2013/2014 to 2017/2018. They were provided by the management of SF GBC Lasy Janowskie, SF GBC Puszcza Solska, SF GBC Kozłówka and Rawityn, SF GBC Pańków, SF GBC Suchowola, and SF GBC Nowiny (Table 2, 3). The area of individual crops in districts, where SF GBCs occurred, was compared to the damaged area. The number of wild boars was determined in a wildlife survey performed in the forest area, based on sampling population (driving census) (Fonseca et al. 2007, Bobek et al. 2013). Hunter Clubs members were responsible for culling and damage assessment in accordance with the Law on Hunting of the Republic of Poland (Dz.U. 1995 Nr 147 poz. 713) as described by Fonseca et al. (2007).

Statistical analysis

The analysed values were presented as mean values and standard deviation in the case of measurable parameters and as cardinality and percentage in the case of non-measurable variables. The normality of the distribution of variables in the analysed groups was verified using the Shapiro-Wilk test. The correlation between two variables of the area damaged by wild boars and the area of crops and compensation paid, the number of wild boars, and the number of harvested wild boars were assessed using Spearman's rank order correlation. The correlation between two variables of the area damaged by wild boars, compensation paid, the number of wild boars, and the number of harvested wild boars to the total area of SF GBC and the forest area of SF GBC were determined using Spearman's rank order correlation. The statistical analyses did not consider fodder plants, as there were no precise data and the damage to these plants was estimated at only 0.1%. In turn, maize was distinguished, as this cereal is the most preferred food of wild boars (Amici et al. 2012, Jarolímek et al. 2014, Zeman et al. 2018). The significance level was set at $p \leq 0.05$. The database was processed, and statistical analyses were performed using a STATISTICA 9.1 Software package (StatSoft 2009).

Table 3. Total area, forest area and total area of crops damaged by wild boars and the amount of compensation paid within the hunting seasons from 2013/2014 to 2017/2018 by the State Forests' Game Breeding Centres (SF GBC)

State Forests' Game Breeding Centres	Total area of SF GBC (ha)	Forest area of SF GBC (ha)	Hunting season	Compensation paid (€)
Lasy Janowskie	20041	17035	2017/2018	1012.55
			2016/2017	1729.88
			2015/2016	580.60
			2014/2015	1116.88
			2013/2014	6583.29
In total				**11 023.20**
Puszcza Solska	19823	16651	2017/2018	3431.10
			2016/2017	4354.67
			2015/2016	6311.07
			2014/2015	2163.10
			2013/2014	2134.07
In total				**18 394.00**
Kozłówka and Rawityn	18837	9552	2017/2018	22619.24
			2016/2017	22142.98
			2015/2016	29524.00
			2014/2015	21904.90
			2013/2014	17142.86
In total				**113 333.98**
Pańków	16419	8209	2017/2018	14992.04
			2016/2017	13620.06
			2015/2016	13844.14
			2014/2015	7226.94
			2013/2014	6105.06
In total				**57 931.10**
Suchowola	6750	1890	2017/2018	1007.18
			2016/2017	1110.87
			2015/2016	3672.30
			2014/2015	2239.20
			2013/2014	2525.57
In total				**10 555.12**
Nowiny	6519	1499	2017/2018	6338.94
			2016/2017	8393.18
			2015/2016	6033.42
			2014/2015	2592.19
			2013/2014	2206.52
In total				**25 564.25**

Results

The highest level of damage was observed on the area of grasslands and pastures, i.e., on average 55.48 ha (41.16%), followed by the area of cereals – on average 52.99 ha (39.31%, where maize representing 7.45%). The lowest level of damage was caused to rape and sugar beet, vegetables and fruits, i.e., on average 1.29 ha (0.96%) (Table 2).

The highest total compensation in the hunting seasons 2013/2014–2017/2018 was paid by SF GBC Kozłówka and Rawityn, Pańków, and Nowiny (113,333.98 €, 57,931.10 € and 25,564.25 €, respectively); although they cover a large total area (18,837 ha, 16,419 ha and 6,519 ha, respectively), they include a small forest area (9,552 ha, 8,209 ha and 1,499 ha, respectively). Substantially lower compensation was paid by SF BGC Puszcza Solska, Lasy Janowskie, and Suchowola (18,394.00 €, 11,023.20 € and 10,555.12 €, respectively) with similar total areas (19,823 ha, 20,041 ha and 6,750 ha, respectively), but forests covering their largest parts (16,651 ha, 17,035 ha and 1,890 ha, respectively) (Table 3).

The largest area in individual counties was under cereal plantations, followed by industrial plants, but the area of damage to cereals was much larger compared to industrial plants. Smaller average areas were covered by grasslands and pastures as well as root species, but the damage to the grasslands was higher than in the case of root crops. The average total compensation paid by SF GBC was 7,821.96 €. The average number of wild boars was 70 in SF GBC, and the average number of harvested boars in SF GBC was 91 individuals (Table 4).

The trend in the size of the crop cultivation area and damage caused by wild boars over time were analysed. A markedly increase in grasslands and pastures, total cereals, vegetables and fruit, and total crops ($p \leq 0.05$) in Lubelszczyzna was revealed. In Lasy Janowskie Forests, the area under maize crops increased significantly, while that of legumes decreased ($p \leq 0.05$). The area of cultivation of legumes in Puszcza Solska Forests patently decreased ($p \leq 0.05$), and the area of cultivation of cereals, industrial plants, vegetables, and fruit increased considerably in Pańków ($p \leq 0.05$). The area of grasslands and pastures as well as maize cultivation increased significantly ($p \leq 0.05$) in Suchowola, whereas maize cultivation was the only area that increased in Nowiny ($p \leq 0.05$). The damage to cereals and maize increased markedly ($p \leq 0.05$) only in Nowiny. The level of compensations significantly increased in Pańków and Nowiny ($p \leq 0.05$), while the number of wild boars increased in Kozłówka and Rawityn ($p \leq 0.05$). A considerably increase in the number of harvested wild boars was recorded only in Pańków ($p \leq 0.05$) (Table 5).

The relationship between the total area of damage and the area of cultivation of individual crops was analysed. The area of damage to grasslands and pastures significantly decreased with the increase in cultivation of grasslands and pastures, maize, root crops, and industrial crops ($p \leq 0.05$). The area of damage to cereals increased markedly with the increase in legume plantations ($p \leq 0.05$). The magni-

Table 4. Mean crops (ha), area of damage (ha), crop compensations paid (€), number of wildboars and number of wild boars culled in the State Forests' Game Breeding Centres

	Area crops and damage		Total		2014		2015		2016		2017		2018	
			M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Crops	Grassland	(ha)	881.77	289.30	821.63	312.48	730.06	283.37	797.40	293.72	1026.96	272.75	1032.81	231.65
	Cereals		20905.95	9705.70	16204.59	8195.20	16981.31	8906.30	18094.99	8507.96	25096.53	9103.91	28152.34	10297.57
	Maize		1670.34	780.54	1575.6	809.43	1396.80	702.86	1488.90	688.86	1746.41	810.41	2143.99	914.84
	Root crops		460.90	238.43	433.94	220.31	460.15	272.44	425.56	273.22	458.30	233.51	526.54	265.03
	Papilionaceous plants		1796.35	2163.27	1782.31	2056.84	1910.20	2238.28	1582.24	1986.09	1883.27	2606.43	1823.74	2661.43
	Industrial crops		6305.80	5751.28	4296.09	4303.64	4386.09	4115.57	6432.19	6339.06	7743.49	6721.49	8671.15	7248.74
	Vegetables and fruits		1507.39	1087.47	722.92	506.20	932.85	514.60	1208.36	689.48	2234.64	1127.30	2438.17	1294.47
	In total		31858.17	17329.59	24261.47	14817.57	25400.67	15434.15	28540.75	16899.40	38443.19	17529.54	42644.75	19157.91
Damage	Grassland		11.10	19.50	13.7	20.18	6.54	10.97	10.08	17.40	11.41	21.36	13.73	29.59
	Cereals		10.60	14.58	5.32	6.14	13.37	19.89	12.19	15.83	13.19	19.82	8.94	9.97
	Maize		2.01	4.82	0.90	1.14	5.03	9.93	1.61	2.91	0.95	1.27	1.55	3.19
	Root crops		1.24	1.86	0.77	0.93	1.68	3.08	1.48	2.12	1.14	1.55	1.10	1.44
	Papilionaceous plants		1.52	3.44	0.59	1.40	0.39	0.96	2.11	4.53	2.90	4.94	1.62	3.96
	Industrial crops		0.26	0.56	0.02	0.03	0.03	0.04	0.61	0.70	0.40	0.82	0.24	0.59
	Vegetables and fruits		0.26	0.62	0.06	0.14	0.12	0.24	0.48	0.80	0.19	0.30	0.46	1.12
	In total		24.93	32.87	20.47	26.32	22.13	33.61	26.94	34.15	29.20	42.92	25.90	37.07
Compensation paid		(€)	7821.96	8487.15	6189.22	6126.09	6557.13	8333.51	9828.32	11283,45	8496.95	8851.15	8113.26	9723.76
Number of wild boars			70	48	73	56	65	47	62	42	71	48	80	60
Number of wild boars shot			91	53	75	65	72	36	95	55	111	75	99	56

Note: *M* stands for mean; *SD* stands for standard deviation.

Table 5. Trend in changes in the size of crops, damage, and compensations, number of wild boars, and culling over time in the SF GBCs (the table shows only significant dependencies, $p \leq 0.05$)

Analyzed variable and time		*R*	*P*
	In total		
Crops	Grassland	0.383	0.036
	Cereals	0.454	0.011
	Vegetables and fruits	0.732	<0.001
	Sum	0.468	0.009
	SF GBC Lasy Janowskie		
Crops	Maize	0.900	0.037
	Papilionaceous plants	–0.900	0.037
	SF GBC Puszcza Solska		
Crops	Papilionaceous plants	–0.900	0.037
	SF GBC Kozłówka and Rawityn		
Number of wild boars		0.900	0.037
	SF GBC Pańków		
Crops	Grassland	0.900	0.037
	Industrial crops	0.900	0.037
	Vegetables and fruits	0.900	0.037
Compensation paid		0.900	0.037
Number of wild boars shot		0.974	0.004
	SF GBC Suchowola		
Crops	Grassland	0.900	0.037
	Maize	0.900	0.037
	SF GBC Nowiny		
Crops	Maize	0.900	0.037
Damage	Cereals	0.900	0.037
	Maize	0.900	0.037
Compensation paid		0.900	0.037

Note: *R* stands for Spearman's rank order correlation; * values of correlation coefficients which are statistically significant at $p \leq 0.05$.

tude of damage to legumes increased considerably with an increase in the surface area of grasslands and pastures as well as plantations of cereals, root crops, legumes, industrial plants, and vegetables and fruits and with an increase in the total area of crops ($p \leq 0.05$). The area of damage to industrial plants increased patently with an increase in grasslands and pastures, cereals, root crops, legumes, and industrial plants and with an increase in the total area of crops ($p \leq 0.05$). Damage to vegetables and fruit was found to increase with an increase in root crops, legumes, industrial crops, vegetables, fruits, and the total crop cultivation area ($p \leq 0.05$). The total damage increased markedly with the growth of legume crops ($p \leq 0.05$) (Table 6). A significant positive correlation was found between the compensations and the level of damage caused in the grasslands and pastures and plantation of cereals, maize, root crops, legumes, and the increase in the sum of damage ($p \leq 0.05$) (Table 6). The level of compensations considerably determined the number of harvested wild boars in the study areas ($p \leq 0.05$). The number of wild boars and the number of harvested animals were strongly negatively correlated with the area under maize cultivation ($p \leq 0.05$). The number of harvested wild boars increased significantly simultaneously with the increase in damage caused by these animals to the grasslands and pastures and to the plantations of cereals, root crops, legumes, vegetables, and fruit and with the increase in the total level of damage ($p \leq 0.05$). Moreover, it was shown that the number of harvested wild boars increased patently simultaneously with the increase in the number of wild boars in the study area ($p \leq 0.05$) (Table 6).

Table 6. Comparison of the area under crops and damage caused by wild boars, compensations, number of wild boars, and number of harvested wild boars

	Analyzed variable	Crops								Compensation paid	Number of wild boars	Number of wild boars shot
		grassland	cereals	maize	root crops	papilionaceous plants	industrial crops	vegetables and fruits	In total			
Damage	Grassland	–0.474 *P*=0.008*	–0.292 *P*=0.117	–0.407 *P*=0.025*	–0.399 *P*=0.028*	–0.044 *P*=0.817	–0.574 *P*<0.001*	–0.034 *P*=0.858	–0.330 *P*=0.075	0.668 *P*<0.001*	0.253 *P*=0.177	0.611 *P*<0.001*
	Cereals	0.037 *P*=0.842	0.350 *P*=0.057	–0.274 *P*=0.141	0.085 *P*=0.653	0.514 *P*=0.003*	–0.032 *P*=0.865	0.037 *P*=0.847	0.281 *P*=0.132	0.919 *P*<0.001*	0.195 *P*=0.302	0.573 *P*<0.001*
	Maize	–0.135 *P*=0.478	–0.047 *P*=0.804	–0.181 *P*=0.339	–0.255 *P*=0.173	–0.076 *P*=0.689	–0.061 *P*=0.749	–0.184 *P*=0.329	–0.073 *P*=0.699	0.386 *P*=0.035*	–0.085 *P*=0.655	0.085 *P*=0.655
	Root crops	0.145 *P*=0.451	–0.346 *P*=0.065	–0.019 *P*=0.921	–0.019 *P*=0.921	0.320 *P*=0.090	–0.213 *P*=0.265	0.034 *P*=0.859	0.091 *P*=0.639	0.793 *P*<0.001*	0.218 *P*=0.254	0.669 *P*<0.001*
	Papilionaceous plants	0.404 *P*=0.027*	0.457 *P*=0.011*	0.088 *P*=0.644	0.533 *P*=0.002*	0.654 *P*<0.001*	0.542 *P*=0.001*	0.471 *P*=0.008*	0.562 *P*=0.001*	0.374 *P*=0.042*	0.075 *P*=0.693	0.363 *P*=0.048*
	Industrial crops	0.474 *P*=0.008*	0.613 *P*<0.001*	0.161 *P*=0.393	0.572 *P*<0.001*	0.568 *P*=0.001*	0.636 *P*<0.001*	0.093 *P*=0.623	0.646 *P*<0.001*	0.255 *P*=0.173	0.007 *P*=0.967	–0.033 *P*=0.861
	Vegetables and fruits	0.115 *P*=0.543	0.257 *P*=0.170	0.021 *P*=0.914	0.408 *P*=0.025*	0.587 *P*=0.001*	0.378 *P*=0.039*	0.445 *P*=0.013*	0.372 *P*=0.043*	0.352 *P*=0.056	0.067 *P*=0.725	0.419 *P*=0.021*
	In total	–0.088 *P*=0.641	0.179 *P*=0.341	–0.330 *P*=0.074	–0.059 *P*=0.755	0.416 *P*=0.022*	–0.172 *P*=0.365	0.027 *P*=0.886	0.128 *P*=0.501	0.972 *P*<0.001*	0.247 *P*=0.187	0.604 *P*<0.001*
Compensation paid		0.025 *P*=0.893	0.209 *P*=0.266	–0.321 *P*=0.083	–0.045 *P*=0.811	0.502 *P*=0.004*	–0.080 *P*=0.673	–0.046 *P*=0.805	0.167 *P*=0.376	-	0.198 *P*=0.294	0.549 *P*=0.001*
Number of wild boars		0.113 *P*=0.550	0.036 *P*=0.847	–0.718 *P*<0.001*	–0.045 *P*=0.811	–0.085 *P*=0.652	0.006 *P*=0.975	–0.108 *P*=0.568	–0.002 *P*=0.990	0.198 *P*=0.294	-	0.465 *P*=0.009*
Number of wild boars shot		–0.179 *P*=0.342	0.106 *P*=0.574	–0.456 *P*=0.011*	–0.062 *P*=0.743	0.108 *P*=0.569	–0.139 *P*=0.463	0.201 *P*=0.286	0.088 *P*=0.642	0.549 *P*=0.001*	0.464 *P*=0.009*	-

Note: * values of correlation coefficients which are statistically significant at $p \leq 0.05$.

The correlations between the damage caused by wild boars and the cultivated area in the individual SF GBCs were analysed. It was shown that the area of damage to grasslands and pastures decreased markedly with the increase in the cultivated area under these crops in SF GBC Puszcza Solska ($p \leq 0.05$). However, the level of damage to cereals increased patently with an increase in the cereal cultivation area in SF GBC Nowiny ($p \leq 0.05$) and significantly declined with the increase in the maize cultivation area in SF GBC Suchowola ($p \leq 0.05$). Moreover, in SF GBC Nowiny, the level of damage to maize increased markedly with the increased area of cereal and total crop plantations ($p \leq 0.05$). The level of damage caused to vegetables and fruit recorded in SF GBC Pańków increased considerably when their cultivation area increased ($p \leq 0.05$). The compensation sums increased patently with the increase in the level of damage caused in grasslands and pastures in SF GBC Janów Lubelski, Puszcza Solska, and Suchowola ($p \leq 0.05$). Furthermore, the amount of compensations increased with the rise in the level of damage to cereals in SF GBC Pańków and with the increased damage to industrial plants in SF GBC Nowiny ($p \leq 0.05$). The compensations also increased markedly with the increase in the level of damage to fruit and vegetables in SF GBC Puszcza Solska and Pańków and with the increase in the total damage noted in SF GBC Pańków and Nowiny (Table 7).

Table 7. Comparison of the area of crops and damage caused by wild boars, compensations, number of wild boars, and number of culled wild boars in the individual State Forests' Game Breeding Centres (the table shows only significant dependencies, $p \leq 0.05$)

A pair of variables	*R*	*P*
SF GBC Lasy Janowskie		
Compensation paid and damaged grassland	0.900	0,037*
SF GBC Puszcza Solska		
Damaged grassland and grassland crops	–0.900	0.037*
Compensation paid and damaged grassland	0.900	0.037*
Compensation paid and damaged vegetables and fruits	0,894	0.041*
SF GBC Kozłówka and Rawityn		
Number of wild boars and cereal crops	0,900	0.037*
Number of wild boars and industrial crops	0,900	0.037*
Number of wild boars and vegetable crops and fruits	0,900	0.037*
Number of wild boars and crops in sum	0,900	0.037*
SF GBC Pańków		
Damaged vegetables, fruits and vegetable crops, and fruits	0,900	0.037*
Compensation paid and damaged cereals	0,900	0.037*
Compensation paid and damaged vegetables and fruits	0,900	0.037*
Compensation paid and damage in sum	0,900	0.037*
Number of wild boars and number of wild boars shot	–0.947	0,014*
SF GBC Suchowola		
Damaged cereals and maize crops	–0.900	0.037*
Compensation paid and damaged grassland	0,900	0.037*
Number of wild boars and grassland crops	–0.900	0.037*
Number of wild boars and maize crops	–0.900	0.037*
SF GBC Nowiny		
Damaged cereals and cereal crops	0.900	0.037*
Damaged maize and cereal crops	0.900	0.037*
Damaged cereals and crops in sum	0.900	0.037*
Compensation paid and damaged industrial crops	0.872	0.037*
Compensation paid and damaged crops in sum	0,900	0.037*

Note: *R* stands for Spearman's rank order correlation; * values of correlation coefficients which are statistically significant at $p \leq 0.05$.

Table 8. Comparison of the area of damage caused by wild boars, compensations, number of wild boars, and number of harvested wild boars on the total area of the SF GBCs and the forest area of the SF GBCs

	Analyzed variable	Crops		Crops	
		R	*p*	*R*	*p*
Damage	Grassland	0.205	0.276	0.205	0.276
	Cereals	–0.384	0.035*	–0.384	0.035*
	Maize	–0.608	<0.001*	–0.608	<0.001*
	Root crops	–0.163	0.395	–0.163	0.395
	Papilionaceous plants	–0.121	0.522	–0.121	0.522
	Industrial crops	–0.580	<0.001*	–0.580	<0.001*
	Vegetables and fruits	0.044	0.813	0.044	0.813
	In total	–0.228	0.223	–0.228	0.223
Compensation paid		–0.231	0.219	–0.231	0.219
Number of wild boars		0.188	0.317	0.188	0.317
Number of wild boars shot		0.080	0.673	0.080	0.673

Note: *R* stands for Spearman's rank order correlation; * values of correlation coefficients which are statistically significant at $p \leq 0.05$.

The number of wild boars significantly declined with the increase in grasslands and pastures and the area of maize cultivation in SF GBC Suchowola ($p \leq 0.05$). In turn, it increased with the increase in the cultivation area under cereals, industrial plants, vegetables, and fruit in SF GBC Kozłówka and Rawityn ($p \leq 0.05$). The number of wild boars in SF GBC Pańków patently decreased with the increase in the number of culled individuals ($p \leq 0.05$) (Table 7).

Given the differences between the total area and the forest area managed by SF GBCs, the size of damage was compared between these areas. A significant decline in the damage to cereals, maize, and industrial plants was found to accompany the increase in the total surface area and the forest areas of the study sites ($p \leq 0.05$) (Table 8).

The analyses were also focused on the type of damaged crops in each month of the five hunting seasons. In March and April, grasses and cereals were the main crops damaged by wild boars. In May and June, the damage to these crops declined with a simultaneous upward trend in the damage to root crops (mainly potatoes) and industrial plants (rape and sugar beet). In July and August, the damage to cereal crops evidently predominated. After the harvest (September, October), root crops and grasses were exposed to the highest level of damage. In October and November, the greatest damage was caused by wild boars to maize (70–90%) (Figure 2).

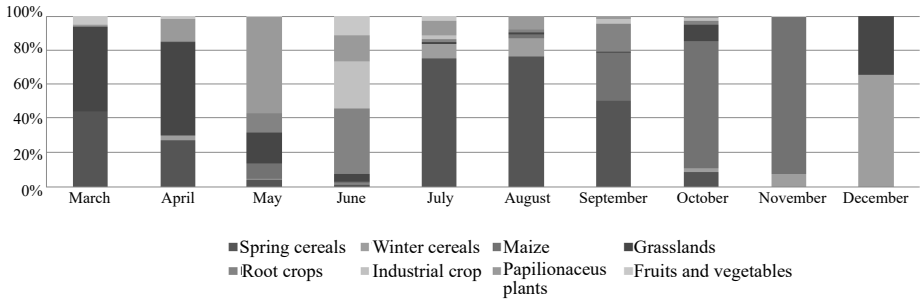

Figure 2. Structure of individual crops damaged (%) by wild boar in the studied areas depending on the month

Discussion

Over the years, wild boar food preferences have changed. For example, potatoes were the main food of wild boar in the '70s and '80s, (Drozd 1988) and maize in the '90s (Dubas 1996), whereas grasses and cereals are reported to be preferred by boars at present (Bobek et al. 2017). This confirms the findings of the behavioural plasticity and ability of the wild boar to adapt to changing environmental conditions (Nasiadka and Janiszewski 2015).

The meadows and pastures offered undoubtedly the most attractive feed to wild boars in Central-Eastern Poland; similar results were reported from Luxembourg (Schley et al. 2008) and France (Klein et al. 2007). As regards damage to grasslands, compensations were most often requested in spring and winter. This type of damage was noted in autumn in Italy (Macchi et al. 1992) and almost exclusively in winter in Luxembourg and in the UK (Schley et al. 2008). As shown by Baubet et al. (2004), this phenomenon is associated with faster soil thawing in such areas than in forests and with the easy access to roots, tubers, and invertebrates in the upper soil layer in early spring (Baubet et al. 2003). This was largely related to the growth trend in grasslands of central-eastern Poland in the case of total cereals. However, the activity of wild boars in pastures may be beneficial, since it affects the rooting and can contribute to their environmental and productive value (Bueno et al. 2011) and extensive grazing by livestock (Bueno et al. 2010).

Additionally, as already mentioned, mainly wheat and maize were the preferred food of the wild boar populations, which is reported as one of the main sources of conflict with farmers worldwide (Ballari and Barrios-García 2014, Lombardini et al. 2017, Zeman et al. 2018, Valente et al. 2020), especially as the level of compensation is the most dependent on these species. This was also confirmed by analyses of the stomach contents of wild boars, where corn, wheat, barley, and alfalfa accounted for over 75% (Herrero et al. 2006). Therefore, when wild boar feed on maize, the grassland is not damaged (Schley et al. 2008). This indicates a special preference for high-energy feed in summer and early autumn (Zawadzki 2011). Similarly, Barrett (1978) suggests that consumption of high carbohydrate-rich food leads to increases in damage to grasslands, as carbohydrate-rich food increases the need for protein of animal origin (Baubet et al. 2004). Moreover, the study conducted in Lubelszczyzna showed that the number of wild boars and the number of harvested animals were strongly negatively correlated with the area under maize cultivation. This may be related to the height and density of this plant species, which make it difficult to notice wild boars. Wild boars spend more time in maize fields because maize plants are higher and, therefore, provide better cover during the day than other cereals (Geisser 2000). The resulting damage is more pronounced due to consumption but mainly due to trampling. This was also indicated by Kristiansson (1985) and Bouldoire and Havet (1981).

Individual species of plants are consumed when they achieve the highest nutritional value and when they are collected (Giménez-Anaya et al. 2008). Farmers reported damage to maize and cereals occurring immediately after planting and development of seeds, which is in line with results reported in Spain (Herrero et al. 2006), Luxemburg (Schley et al. 2008), Croatia (Łabudzki and Wlazełko 1991), and Switzerland (Geisser 2000), but not in Italy (Macchi et al. 1992).

The positive correlation between the total area of damaged agricultural crops and the density of wild boars in crop cultivation areas is evident. Similar conclusions were made not only in Poland (Goryńska 1981, Łabudzki et al. 2009, Frąckowiak et al. 2013, Bobek et al. 2017) but also in other countries, e.g., in Switzerland (Baettig 1988), France (Spitz and Lek 1999), Italy (Amici et al. 2012), or Hungary (Bleier et al. 2012).

The forest cover and areas managed by foresters and hunters are important factors in reducing the area of crop damage. Obviously, this is related to the fact that forest areas not only provide a shelter but are also a natural source of food (e.g., beech or oak fruits), which can minimize the percentage of crop damage (Bobek 1973, Bobek 2017). Large forest fragmentation has an adverse effect on the magnitude of damage caused by wild boars foraging in small groups (Rodríguez-Estevez et al. 2010, Wei et al. 2017). A similar effect was noted in Lubelszczyzna. The present study may confirm the assumptions that wild boars can be confined to a specified area under sufficient food supply, especially maize (Cellina 2008, Zeman et al. 2018). This practice began to be introduced in many European countries, e.g., Austria and Germany (Arnold 2005), France (Klein et al. 2007), and Luxembourg (Schley et al. 2008). This is a controversial method, and many researchers recommend ceasing the supplementary feeding of wild boars (Schley 2000, Bieber and Ruf 2002, Arnold 2005, Bieber and Ruf 2005, Gortázar et al. 2006). In some countries, e.g., in Lithuania, the supplementary feeding is forbidden and only baiting is allowed (Belova 2016).

Agricultural damage caused by wild boar *Sus scrofa* has given farmers a negative impression of management of the areas by foresters and hunters. To mitigate the damage and the related socio-economic conflicts, drive-hunting involving experienced local hunters were used as a population control method in a protected Iberian wetland (Amici et al. 2012). However, the intermittent population control through hunting has led to a substantial increase in the wild boar population accompanied by an increase in crop damage (Giménez-Anaya et al. 2016). This underlines the importance of continuous control.

A very positive phenomenon is the fact that the number of compensations significantly determined the number of wild boars that were culled in central-eastern Poland, as shown in other studies (Schley et al. 2008). Moreover, the intensity of wild boar hunting increased with the increase in the damaged area and the number of wild boars present in the study area. This highlights the good management of the wild boar population in SF BGCs and the attempts to mitigate conflicts with farmers.

Hunting aimed at the control of the population size of this species will be one the best methods for limitation of damage, as demonstrated by Bieber and Ruf (2005), Servanty et al. (2008), and Vassant (1994), especially as hunting wild boars is allowed all year round and there are thus no potential limitations. Moreover, this indicates that all factors contributing to the increase in wild boar populations are also likely to contribute indirectly to an increase in agricultural damage. Therefore, in view of the influence of the wild boar population size of damage levels, a substantial reduction of wild boar populations seems to be a priority of wild boar management also in Poland.

Our recommendations for reducing damage follow those proposed by Schley et al. (2008), i.e., reduction of the wild boar population and regulation of compensation payments. Feeding supplementation for wild boars is very controversial and, since we have not studied it, we do not recommend this method. Moreover, annual crops preferred by wild boars such as maize and non-trichomatous cereals should ideally be planted further away from forests, as also recommended by Bouldoire and Havet (1981) and Vassant (1994), while grasslands can be located closer to the forest area. Such repellents as visual, chemical, or acoustic repulsive substances are effective for a short time due to rainfall or the quick habituation of the wild boar (Vassant 1994). The suitability of electric fencing is controversial: Vassant and Boisaubert (1984) present it as a useful tool, whereas Geisser (2000) seems less convinced. Moreover, our study shows that such measures as electric fences for prevention or reduction of damage (especially to maize and cereals) must be applied for a short period, namely after sowing and especially as soon as the crops are in milk, or during yielding in the case of other crops (fruit and vegetables, industrial crops). Otherwise, such measures only consume resources without substantial contribution to reduction of damage. Interestingly, in Luxemburg (Schley et al. 2008), if the mean damage levels were the same in each area as in the rest of the country, the damage compensation paid out would thus be lowered by more than a third. It seems that such a practice might also be considered in Poland.

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