

Relationships between wild ungulates density and crop damage in Hungary

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Abstract Game damage to agriculture represents one of the most important and most frequent human–wildlife conflicts worldwide. In Hungary and in the other European countries, damage caused by wild boar (*Sus scrofa*) and red deer (*Cervus elaphus*) is the most significant. The volume of damage is correlated with the population density of the game species, however, not exclusively. Since the growing expansion of wild ungulates is a general tendency in Europe, increasing conflicts can be envisaged. The objective of our study was to assess the possible relationships between the amount of agricultural game damage and big game population density considering some other factors (e.g. habitat structure, sown area of cultivated plants) by analysing wildlife management and land-use statistics for the 19 counties of Hungary from 1997 to 2008. According to the results, crop damage positively correlated with the population density of red deer and wild boar, with the length of forest edge, and the proportion of the sown area of maize. According to the regression model, these factors could be accountable for 74.2 % of the total agricultural game damage.

Keywords Human–wildlife conflicts · Red deer · Wild boar · Roe deer · Landscape structure · Cultivated plants

Introduction

Human–wildlife conflicts, including agricultural damage, have a remarkably long history (Conover 2002). It is a worldwide problem even nowadays (Gordon 2009) particularly damage by wild ungulates. In Europe, agricultural damage is typically caused by wild boar (*Sus scrofa*) (Calenge et al. 2004; Herrero et al. 2006; Santilli et al. 2004; Reimoser and Reimoser 2010) and red deer (*Cervus elaphus*) (Trdan and Vidrih 2008; Csányi and Lehoczki 2010). In spite of the fact that roe deer (*Capreolus capreolus*) is the most abundant cervid species occurring in most of Europe (Burbaite and Csányi 2009), the damage caused by roe deer is not considerable (Kałuziński 1982; Putman 1986). The white-tailed deer (*Odocoileus virginianus*) in North America (Linz et al. 2006), the elephant (*Loxodonta africana*) in Africa (Naughton-Treves 1998) and the elephant (*Elephant maximus*) in Asia (Tisdell and Zhu 1998) and moreover the wild boar (Wang et al. 2006) produce the largest damage.

Due to the increasing populations of wild boar, red deer and roe deer across Europe (Geisser and Reyer 2004; Milner et al. 2006; Keuling et al. 2008; Apollonio et al. 2010), it is important to get a closer view of the relationship between game density and crop damage size. A recent study in Luxembourg based on a long-term database revealed a strong correlation between the number of wild boar shot and the total amount of agricultural damage (Schley et al. 2008). However, a variety of other factors also influence the volume of game damage such as regenerating ability of plants (Belsky 1986), crop type (Genov et al. 1995; Geisser

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1998), palatability of plants (Conover 2002) as well as the distance between agricultural and forest areas (Naughton-Treves 1998; DeVault et al. 2007), the topographic factors (habitat structure) (Cai et al. 2008) and the field size and interspersions with surrounding land cover types (Dudderar et al. 1989).

Game damage to agriculture has been a major concern also in Hungary for many years (Bleier and Szemethy 2003). Whilst the compensation payments for crop damage in 1997 was 700 million Hungarian forint (HUF) (2.8 million euros), in 2008 already 1.5 billion HUF (6 million euros) in nominal value was paid countrywide (we used the 280 HUF/euro exchange rate consistently). In spite of the correction of the yearly inflation rate and the compensation payment not increasing, only those fluctuating above-mentioned total amounts are considerable (see Fig. 1).

Hungary is divided into more than 1,200 game management units (GMUs), and these are managed by hunting associations and forestry corporations. According to the Hungarian hunting law (Act on game conservation, management and hunting, LV/1996), GMUs are liable for the game management and compensation payments for damage caused by game within their areas (Csányi et al. 2010). In the opinion of hunters and stakeholders, the vast damage to agriculture is mainly caused by the overabundant red deer and wild boar populations (Bleier and Szemethy 2003). Between 1960 and 2005, the red deer harvest increased from 3,800 to 43,000, and the wild boar harvest increased from 8,300 to more than 90,000 countrywide; more details can be found in Csányi et al. (2010).

However, a long-term study based on a wide database is still lacking in Hungary. This fact made us feel prompted to prepare a long-term analysis based on the wildlife management database so that we can assess the contribution of the

most abundant game species (wild boar, red deer and roe deer) and some other factors to agricultural game damage in Hungary.

According to the law, game management should be based on the yearly plans, and each GMU has to report their own spring game census data, hunting bag and other management data (costs, incomes) (Csányi 1998, 1999a). Based on this data set, the main points to be responded to in this paper are: (a) Is there any relationship between the density of big game species and the amount of agricultural damage? (b) Do other factors (such as habitat structure, proportion of cultivated plants) affect the amount of agricultural damage?

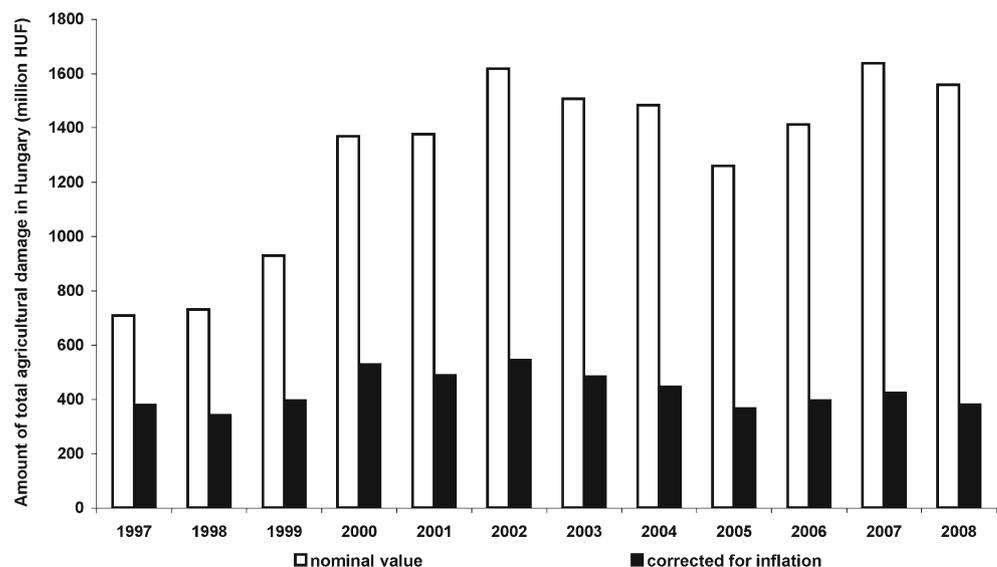
Materials and methods

Study area and data collection

The common reference unit of the used dataset is actually the 19 counties of Hungary (Fig. 2), as all information is aggregated at county level. Data used to characterise each county in the research period 1997–2008 are as follows:

- Amount of agricultural damage expressed in HUF; the nominal value of crop damage (1,000 HUF/km²) was corrected by the yearly inflation rate (time series were expressed on the 1997 year base.) Expressing game damage in HUF makes it possible to compare the different areas (Fig. 3) irrespective of the crop species or the type/nature of damage.
- Bag density (bag per square kilometre) of wild boar, red deer and roe deer (Fig. 2). Bag size of these species was counted for the forest and agricultural lands (bag per square kilometre).

Fig. 1 The amount of total agricultural game damage in Hungary



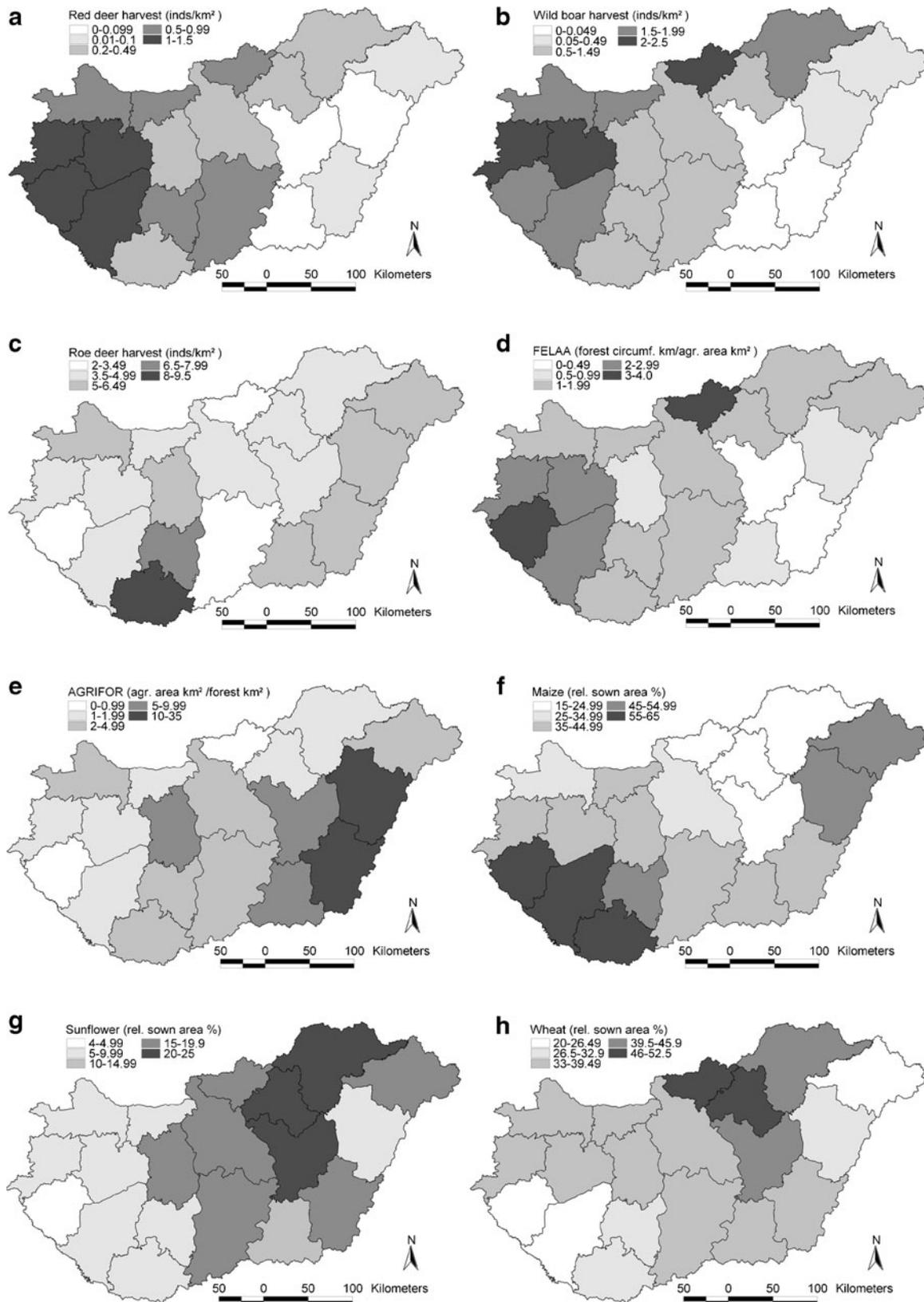
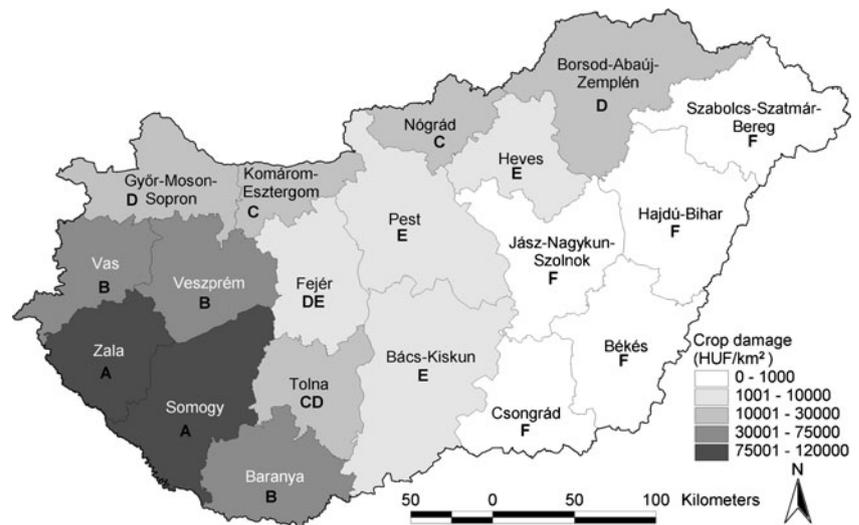


Fig. 2 The spatial mitigation of the major predictor variables: **a** red deer harvest density, **b** wild boar harvest density, **c** roe deer harvest density, **d** forest edge length to agricultural area (*FELAA*), **e** the relative proportion

of agricultural to forest area (*AGRIFOR*) and the percentage share of the area covers of main cultivated plants: **f** relative sown area of maize, **g** relative sown area of sunflower and **h** relative sown area of wheat

Fig. 3 The spatial mitigation of agricultural damage in Hungary by counties (the various different capital letters mean significant differences between the counties, $p < 0.05$)



Habitat structure was described by the following characteristics: (a) relative proportion of agricultural area (AGRIFOR; agricultural area in square kilometres/forest area in square kilometres); (b) forest edge ratio (forest edge length to agricultural area (FELAA), forest circumference in kilometres/agricultural area in square kilometres) and (c) relative sown area of the main cultivated plants (wheat, maize, sunflower) and other ones (barley, oat, potatoes, rape, peas etc.) in total agricultural area (Fig. 2).

Population data (hunting bag) of red deer, wild boar, roe deer and compensation payment data for agricultural damage collected by the GMUs were received from the National Game Management Database (Csányi et al. 2010). Data were also linked to the geographic information system (Lehoczki et al. 2011b).

Information on forest sizes and agricultural areas, on the sown area (maize, sunflower, wheat) and the yearly inflation rates were provided by the Hungarian Central Statistical Office (HCSO 2008). Landscape information (length of the forest edge) was received from the Hungarian CORINE Land Cover 2000 database (CLC2000, prepared by the Institute of Geodesy, Cartography and Remote Sensing, Hungary).

Statistical analysis

Statistical tests were performed with InStat (GraphPad, San Diego, CA, USA), SPSS 14.0 for Windows software (SPSS Inc., Chicago, IL, USA) and GeoDa (Anselin et al. 2006) software. The normality of the distribution of each variable was tested with a Kolmogorov–Smirnov test and showed normal distribution to all data. One-way ANOVA was used to compare the yearly (1997–2008, $n=12$) values for crop damage costs by each county ($n=19$); the pair wise data comparison was performed by Tukey’s multiple comparison procedure (Tukey’s post-test).

From the 12-year research period (1997–2008), the mean values were calculated for crop damage costs, bag density, AGRIFOR and FELAA, as well as the relative sown area of cultivated plants for all 19 counties. Correlations were calculated to show the separate interest of each predictor variable. We used the mean values for the following pairs of variables: game bags and crop damage, habitat structure (AGRIFOR and FELAA) and crop damage, as well as relative sown area of the main cultivated plants and crop damage for each county.

The principal components analysis (PCA) with varimax rotation was used to investigate multiple connections and control multi-collinearity between the independent variables. First, ordinary least squares (OLS) regression models were used to explain crop damage variation by the resulting variables (FAC1–FAC3, see “Results”) of PCA. To control the spatial dependence, the models were re-estimated with the GeoDa software’s Spatial Lag Model (SLM), more often used in ecological studies (Anselin 2002; Piha et al. 2007; Lehoczki et al. 2011a). In SLM, a spatial lag variable was used as a supplementary explanatory variable to control the spatial dependence. This is the weighted mean of a variable for neighbouring spatial units of the observation unit in question (Anselin 1999). The Moran’s Index (Moran’s I) that is commonly used to assess spatial autocorrelation in the residuals was 0.06 ($P=0.059$) creating a spatial weight file (queen contiguity) in GeoDa, where -1 is indicating perfect dispersion, $+1$ perfect correlation and zero values a random spatial pattern (Anselin 1999).

Results

The mean values of agricultural game damage differed significantly by county during the study period (ANOVA: $F_{18,209}=220.893$; $p < 0.001$) (Fig. 3). In some counties (e.g.

Békés, Csongrád), crop damage amounted up to around 650–1,000 HUF/km² (2.6–4 euros/km²) on average each year, whereas in other counties (e.g. Fejér, Nógrád), it was significantly higher and top damage surpassed even a value of 95,000 HUF/km² (378 euros/km²) in Somogy and Zala counties (Fig. 3). The total area of the top five counties affected by crop damage (Baranya, Somogy, Vas, Veszprém and Zala) covers only 24 % of Hungary, yet accounts for 75–80 % of the total Hungarian agricultural game damage (Fig. 3). The spatial distribution of crop damage is not homogeneous in Hungary; its extent is decreasing from the direction of southwest to the direction of eastern region of the country (Fig. 3).

The relationship between hunting bag density and crop damage differed considerably depending on the given species. The correlation was significant and positive with the red deer ($r=0.783$, $p<0.001$) and wild boar ($r=0.575$, $p<0.01$); however, it was non-significant with the roe deer ($r=0.332$, $p>0.05$).

Among habitat structure variables, AGRIFOR showed a non-significant correlation ($r=-0.332$, $p>0.05$) whereas FELAA correlated positively ($r=0.674$, $p<0.01$) with crop damage. The crop ratio correlated positively with game damage in the case of maize ($r=0.570$, $p<0.01$) but negatively in the case of sunflower ($r=-0.673$, $p<0.01$). The corresponding correlation in the case of wheat ($r=-0.397$, $p>0.05$) and other crops ($r=0.132$, $p>0.05$) was non-significant.

The PCA resulted in three components being retained, representing 34.7, 26.3 and 22.4 % of the variability of the initial predictors. The most important component, FAC1, included the number of wild boar (+) and red deer (+) shot, moreover the FELAA with positive sign (+) and the AGRIFOR with negative (-). In FAC2 the relative sown area of maize (+) and sunflower (-) and in FAC3 the relative sown area of wheat (+) and other (+) crops were determinative (Table 1). Based on the result of PCA, the bag of wild boar and red deer are higher in those counties, where the value of FELAA is higher (the cumulated forest circumference is higher) and where the value of AGRIFOR is lower, namely the proportion of agricultural area relative to the forest is lower (the area of forest is higher).

According to the best regression model (SLM; Table 2), the amount of agricultural game damage was determined by the FAC1 and FAC2 ($R^2=0.742$; $p<0.001$). This result showed that the bag density of wild boar and that of red deer, FELAA and AGRIFOR, as well as the relative sown area of maize and sunflower might be jointly responsible for 74.2 % of total agricultural damage (Table 2).

Based on the results of PCA and SLM, agricultural game damage is in strong positive relationship with the number of wild boar and red deer shot, with the FELAA and with the relative sown area of maize. The AGRIFOR and the crop

Table 1 Eigenvalues, share of total variance, factors and factor loadings after varimax rotation

	FAC1	FAC2	FAC3
Variance	3.129	2.367	2.019
Explanation percentage	34.768	26.299	22.429
WILD BOAR	0.908	0.154	0.281
FELAA	0.892	0.068	-0.110
RED DEER	0.744	0.546	0.174
AGRIFOR	-0.715	-0.004	0.027
ROE DEER	-0.631	0.439	-0.278
SUNFLOWER	-0.171	-0.956	-0.025
MAIZE	0.009	0.765	-0.630
OTHER	0.095	0.068	0.945
WHEAT	0.081	-0.586	0.727

RED DEER red deer bag density, *WILD BOAR* wild boar bag density, *ROE DEER* roe deer bag density, *FELAA* forest edge length to agricultural area, *AGRIFOR* the relative proportion of agricultural to forest area, *MAIZE* crop ratio of maize, *SUNFLOWER* crop ratio of sunflower, *WHEAT* crop ratio of wheat, *OTHER* crop ratio of other

ratio of sunflower have a negative effect on the amount of crop damage. The relative sown area of wheat and other cultivated plants had no effect on game damage.

Discussion

Hunting bag data have been used as an indicator of population density in several studies (Spitz and Lek 1999; Milner et al. 2006; Grauer and König 2009; Lehoczki et al. 2011a). However, recent papers have already emphasised that this variable does not provide reliable information every time (Pettorelli et al. 2007; Mysterud et al. 2007; Imperio et al. 2010). Notwithstanding, in our study the hunting bag data seemed to be good indicator of population density due to the large scale of space and time of the analysis (making the finer difference identification unnecessary). The relationship between the “real” game population density and crop damage could be significant in case of red deer and wild boar.

Table 2 The results of OLS regression models and SLM regression model

Model	Variables	df	K	AIC	R ²
OLS I	FAC1, FAC2, FAC3 ^a	15	4	163.8	0.758
OLS II	FAC1, FAC2	16	3	164.7	0.717
SLM	FAC1, FAC2	15	4	165.4	0.742

df degrees of freedom, K number of model parameters, AIC Akaike information criterion, R² coefficient of determination, SLM Spatial Lag Model

^a The FAC3 seemed to have a non-significant effect in the model, $p=0.134$

This relationship is known in case of wild boar (Goryńska 1981; Spitz and Lek 1999; Schley et al. 2008) in other countries.

In Europe, several studies have dealt with the damage caused by Cervidae (Putman and Moore 1998; Doney and Packer 2002; Wilson 2003; Wilson et al. 2009), but no similar large-scale database study has been conducted in case of red deer and roe deer. The relationship between damage by deer to agricultural crops and deer density has also been assumed in a previous study (White et al. 2004). However, no significant correlation has been found in case of moose (*Alces alces*) between its density and damage level in Sweden when analysing forest damage and browsing pressure (Hörnberg 2001). Notwithstanding, former surveys have revealed a relationship between population density of white-tailed deer and wildlife damage. Notably, a direct relationship was found between white-tailed deer population size and the damage to tree plantations (Scott and Townsend 1985) and also to wildflowers (*Trillium* spp.) (Augustine and Frelich 1998). Moreover, crop damage has increased with the white-tailed deer density, and intense damage is usually associated with large groups of deer congregating on small agricultural fields (Vecellio et al. 1994). In light of the above studies, this relationship was also expectable with the red deer as it was supported by our results.

The roe deer is essentially a woodland species (Hewison et al. 1998), but it has settled in agricultural areas all over in Europe in the last 60 years (Andersen et al. 1998; Burbaite and Csányi 2009). Yet, they have not caused any significant crop damage in our study, in good agreement with the most previous surveys (Kałuziński 1982; Putman 1986; Jacquemart et al. 1989). This phenomenon is probably related to the social organisation of roe deer: It lives solitary or in small family groups in summertime and early autumn (Bresiniński 1982; Bao et al. 2005) and thereby its damage to cultivated plants appears non-significant in space and time as well. Naturally, there are also special cases when the roe deer is capable of causing considerable damage, in strawberry fields or in vegetable gardens for example (Ruusila and Kojola 2010).

It can be concluded that level of agricultural damage is considerably affected by the population density of wild boar and red deer. On the other hand, we cannot maintain that there is a direct one-to-one relationship between the population density and the amount of damage. Furthermore, we have to take into consideration that this is not the only factor defining the severity of crop damage—as Conover (2002) has already called attention to this fact. Our results have demonstrated a positive correlation of game damage with the relative sown area of maize. Otherwise, the maize has been identified as an important factor interfering with agricultural game damage (Bleier and Szemethy 2003; Schley

and Roper 2003; Schley et al. 2008; Cai et al. 2008). Wild boar usually feeds on field crops, particularly maize in an intensive agro-ecosystem (Herrero et al. 2006). Moreover, wild boar especially prefers maize (Cai et al. 2008), which is fairly sensitive to grazing (Obtel and Holišová 1983). However, in the food of red deer cultivated plants represented a minor item in agro-ecosystems—e.g. proportion of maize was not more than 10 % (Szemethy et al. 2003), although in Czech Republic maize played a reportedly important role in red deer nutrition in late summer and in autumn (up to 11–18 %) (Prokešová 2004). The above apparent contradiction can be explained by the fact that importance of a certain food resource depends greatly on the availability of other food resources—varying to a great extent by the habitat (Ellis et al. 1976; Genov 1981; Cassini 1994). On the other hand, maize can be damaged by big game for the longest term during the vegetation period compared to sunflowers and wheat (Bleier et al. 2006) and wild ungulates can hide in the high maize stand (Schley et al. 2008; Keuling and Stier 2010). Moreover, based on its yield per hectare and prevailing price, the maize is the most valuable cultivated plant; therefore, it by itself can have high influence on the yearly amount of agricultural damage.

In our study, the relative sown area of wheat and other cultivated plants could not be related to game damage, but that of sunflower affected it negatively—notwithstanding that wild ungulates consumed these plants (Genov et al. 1995; Herrero et al. 2006; Kamler et al. 2009). The effect of wheat and sunflower can be explained with the crop rotation. Notably, the size of the cultivated area is constant and thus increases in the maize area will entail decreases in the area of other plants.

The strong relationship found between FELAA and crop damage in our study shows that habitat structure is an important factor in agricultural damage caused by wild ungulates. Forest coverage of a certain area defines the occurrence of red deer (Csányi 1999b; Milner et al. 2006) and wild boar. Although hiding is the most important factor for wild boar (Meynhardt 1982) that is provided basically by forests, they can also find good cover in agricultural fields (Keuling 2010). Several studies showed that the extent of agricultural damage is decreasing dramatically with the distance from the forest (Naughton-Treves 1998; Bleier et al. 2006; DeVault et al. 2007). The edge effect in habitat use of wild boar was demonstrated (Thurfjell et al. 2009), and it was also shown in case of red deer in our previous study (Bleier et al. 2008). Moreover, in Canada, 90 % of damage caused by wapiti (*Cervus canadensis*) occurred within a 3-km zone of forest area (Brook 2009). The above results indicate that habitat structure is an important factor contributing to crop damage.

In light of our study, the more fragmented the forest and the longer the forest edge is, the larger is the area exposed to

crop damage. However, the proportion of agricultural to forest area did not seem to be affective on the extent of damage. If the proportion of agricultural area is fairly large, the risks of damage are relatively low—because most of the fields are located far away from the forest habitats used by wild boar and red deer.

Consequently, in those areas where the forest patches are sufficiently large for a stabile red deer and wild boar population density and the agricultural fields within that are easy to reach due to habitat structure, damage will arise. Severity of damage depends on the availability of the cultivated plants and the population density of red deer and wild boar in the related area. Furthermore, growing a higher proportion of preferred crops and/or plants sensitive to damage may also predispose damage. The implementation of afforestation plans envisaged for 2035 (Solymos 2000) may also promote the spreading of these two species increasing thereby the risks of agricultural damage in Hungary. Consequently, conflicts among stakeholders will remain or even become more intense in the future.

Conclusions

1. In practice, wildlife managers cannot modify or mitigate the impacts of all factors contributing to crop damage. Naturally, it is not in their power to interfere with habitat structure or the choice of cultivated plants. Their opportunities are confined to the management of game populations and the use of damage prevention or damage reducing methods (e.g. electrical fences or supplemental feeding).
2. The size of game populations is important as incomes correlate closely with the size of the hunting bag. In our opinion, the best solution seems to be that wildlife managers make their own decision alternatively in this context. If they can pay compensation for damage caused by big game—i.e. the management can afford this cost—no population reduction is needed. If the damage cost is extremely high, the managers have no choice but to reduce the game density. However, in connection with these thoughts, we have to empathise the importance of cooperation among stakeholders.
3. We strongly urge wildlife managers to measure the damage in their management unit to differentiate the damage between wild boar and red deer. With this information, it is possible to reduce only the population density of the species sharing with the greater part in the damage. Wildlife managers should also consider the value of the species and the profit they produce—in comparison with the caused damage.

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