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ECOLOGICAL AND ECONOMICAL RELATIONSHIPS OF THE AGRICULTURAL GAME DAMAGE

Thesis of Ph.D. dissertation

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Gödöllő

2014

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1. INTRODUCTION AND OBJECTIVES

Human-wildlife conflicts, including agricultural game damage, have a remarkably long history (CONOVER 2002). It is a worldwide problem even nowadays (GORDON 2009) especially when damage is done by wild ungulates. In Europe, crop damage is typically caused by wild boar *(Sus scrofa)* (CALENGE et al. 2004, HERRERO et al. 2006, SANTILLI et al. 2004, REIMOSER & REIMOSER 2010, BLEIER et al. 2012a) and red deer *(Cervus elaphus)* (CSÁNYI 2003a, TRDAN & VIDRIH 2008, BLEIER et al. 2012a). In North America white-tailed deer *(Odocoileus virginianus)* (IRBY et al. 1996), in Africa elephant (*Loxodonta africana*) (NAUGHTON-TREVES 1998), and in Asia wild boar (WANG et al. 2006) and elephant (*Elephant maximus*) (TISDELL & ZHU 1998) are responsible for a lot of crop damage.

According to the Hungarian hunting law (*Act on game conservation, management and hunting, LV/1996*), the Game Management Units (GMUs) are liable for the game management and compensation payments for damage caused by game within their areas (CSÁNYI et al. 2010). In the last three years the compensation payments for crop damage were exceeded 2 billion HUF per year (CSÁNYI 2011, 2012). Stakeholders' opinion is that the overabundant red deer and wild boar populations are responsible for the vast majority of crop damage (MÁTRAI & JÁRÁSI 1986, BUZGÓ 2006). However, a long term study based on large database and spatial analysis to prove this assumption still has not been carried out in Hungary.

It is often assumed that there is direct one-to-one relationship between any change in wildlife population and the amount of damage, however the rate of the damage is affected by some other factors, too (CONOVER 2002). For example the following features can also affect crop damage: the regenerating-ability of plants (BELSKY 1986), crop type (GENOV et al. 1995, GEISSER 1998), palatability of plants (CONOVER 2002), as well as the distance between agricultural and forest areas (BENCZE 1969a, LINKIE et al. 2007), the topographic factors (CAI et al. 2008), the field size, habitat structure and land cover types (DUDDERAR et al. 1989).

In order to understand the change in crop damage it is necessary to identify the factors that have an important role in this process. Based on all these, my main points in this thesis are as follow:

- Landscape-level examination of crop damage:
    - Is there any relationship between the amount of crop damage and (i) wild ungulates density, (ii) habitat structure, (iii) and the proportion of agricultural plants?
    - Can a model be created based on the important factors related to crop damage?

- Explore the spatio-temporal pattern of crop damage in sample area:
    - Which factors have an effect on crop damage and what is the spatio-temporal distribution of the damage?
    - Is there any relationship between the habitat use index of wild ungulates and the rate of crop damage?

2. MATERIALS AND METHODS

The methods introduced in the present thesis can be divided into two parts. The first part consists of statistical analysis of different available databases via examining landscape-level connections. The second part is based on data, which were collected in field studies.

2.1. Examination of landscape-level connections

2.1.1. Data sources

NGMD (National Game Management Database of Hungary):

The NGMD gathers, records and summarizes data on game populations and game management collected by the Game Management Units (GMUs) in Hungary (CSÁNYI 1998). The smallest unit of these data is the GMU itself, which can appear with different area sizes (average: 7690 ha, largest: 54760 ha) (LEHOCZKI et al. 2011b). The minimal area (3000 ha) is determined by law (*8. § (1) in the Act on game conservation, management and hunting, LV/1996*). NGMD prepares county-scale and nation-wide summaries in every year, which are available on the webpage of NGMD (www.ova.info.hu). Data stored in NGMD are also linked to GIS, so it is possible to perform spatial analysis based on the datasets (CSÁNYI et al. 2010). I have used the following datasets from the period between 1997 and 2011: hunting bag of red deer, wild boar and roe deer; and the compensated agricultural game damage expressed in HUF.

HCSO (Hungarian Central Statistical Office):

The following data were used from the HCSO database: total area of the counties, sown area of the main cultivated plants (maize, sunflower, wheat, other cultivated plants), distribution of land-use categories (forest, agricultural field, grassland, reed).

Corine Land Cover 2000 (CLC2000):

Landscape information (length of the forest edge) was received from the Hungarian CORINE (Coordinaton of Information on the Environment) Land Cover 2000 database (CLC2000, prepared by the Institute of Geodesy, Cartography and Remote Sensing, Hungary). The minimum mapping unit of CLC2000 is 25 hectares. Because of this, the forest strips, tree groups, and edges of other forest covered habitats (e.g. forest patch) with a small area do not appear in the databases applied in the analysis.

2.1.2. The used indices and other variables

Hunting bag density of red deer, wild boar and roe deer:

I have characterized the population density in several areas through hunting bag density in case of the three most common big game species. Distribution of red deer and wild boar is country-wide, but roe deer has not reached that scale yet. The application of bag density in scientific investigations has dual perception. The bag size or density can be considered as an index of population size but it has been also applied as an indicator of population density in many studies (SPITZ & LEK 1999, MILNER et al. 2006, GRAUER & KÖNIG 2009, LEHOCZKI et al. 2011a, BLEIER et al. 2012a). On the other hand, several studies have questioned the reliability of this method (PETTORELLI et al. 2007, MYSTERUD et al. 2007, IMPERIO et al. 2010). Bag data of the NGMD were used previously in modelling studies, which proved that, those data were applicable in describing regional trends and differences (CSÁNYI 1999, CSÁNYI & RITTER 1999, CSÁNYI 2003a).

I assumed that bias should not be considered in case of fine scale spatio-temporal patterns because I have used long term datasets (15 years) on a landscape scale (counties).

Compensation payments for crop damage per area units:

The scale of crop damage in the investigated period was described by the amount of compensation payments with consumer price index (CPI) correction. The compensation payment does not mean the total amount of the crop damage, but only the payment for the actually compensated damage. The damage compensation values of the pending court cases can appear in the databases one or more years later. The bias caused by this was eliminated by calculating and using the average compensation payment of the total examined period. In practice, damages are not always compensated financially. Barter business (e. g. compensation by venison or hunting) is often used as a solution. The present system does not provide any information on these alternative compensation methods, so I treated these values as if they do not have any impact on this analysis. To compare the counties I have used compensated crop damage values (HUF/1000ha) projected to agricultural fields (ha). With this method I could calculate the amount of compensated crop damage for 1000 ha agricultural field in each year.

Habitat structure was described by the following characteristics:

- Forest covered habitat ratio (%)
- Forest edge ratio (forest circumference 1000 ha / agricultural area 1000 ha): FELAA (Forest Edge Length to Agricultural Area) (BLEIER et al. 2012a).
- Relative proportion of agricultural area (agricultural area 1000 ha / forest area 1000 ha): AGRIFOR (BLEIER et al. 2012a).

Available cultivated plants were described by the following characteristics:

Availability of cultivated plants was described by the sown area ratio of the main cultivated plants (maize, wheat, sunflower and colza plus alfalfa as other category).

2.1.3. Statistical tests

ANOVA

I have described every county with the average values of datasets regarding bag density of big game species, compensation payments for crop damage and sown area of the main cultivated plants between 1997 and 2011. Before calculating an average, the normality of the data was tested with Kolmogorov-Smirnov test. One-way ANOVA was used to compare the values for crop damage costs by each county (SAJTOS & MITEV 2007). Because of the difference of the examined variables Tamhane post hoc test was performed in case of paired data comparison.

Correlation and regression analysis

Paired correlation and regression analysis were applied to examine the factors may influence the compensation payments for crop damage.

Factor analysis

Principal components analysis (PCA) was used to investigate multiple connections and control multi-collinearity between the independent variables of the correlation analysis.

Multiple linear regression (regression model)

Principal factors (got as the result of PCA) were imported to the linear regression model.

2.2. Field studies

The research was carried out in two different areas, Segesd (Somogy county) and Sükösd (Bács-Kiskun county). The game managers are SEFAG Co. Ltd. at Segesd and Gemenc Co. Ltd. at Sükösd. The three most common big game species are red deer, roe deer and wild boar in both GMUs. According to the experiences of game managers, the amount of the game damage is considered remarkable year by year. The field studies were carried out between 2004 and 2007.

2.2.1. Study areas

Segesd

The area of the GMU covers 6772 ha, of which 6244 ha is suitable for game management activities. The forest covered habitat ratio is 62%, while the rate of the agricultural area is 35%. The average hunting bag size of the most important big game species in the investigated period (2004-2006) is: red deer 29,3/1000 ha, wild boar 34/1000 ha and roe deer 13,8/1000 ha. Sample fields were selected that were at least close or connected directly to a forest. The area of the A sample field was 17 ha and B sample field was 34 ha.

Sükösd

This GMU covers 24.720 ha, of which 24.277 ha is suitable for game management. The forest covered habitat ratio is 47.6%, while the rate of the agricultural area is 31%. The average hunting bag size of the most important big game species in the investigated period is: red deer 16,5/1000 ha, wild boar 14,5/1000 ha and roe deer 5,8/1000 ha. The examined cornfield was found directly next to a forest, its area was 93 ha. It had a unique shape and had only one straight side, which was contiguous to another cornfield. The remaining part of its border followed the wavy border of the forest.

2.2.2. Timing and method of data collecting

The field works were carried out during the whole growing season four times: I. period (from sowing to third leaf, May), II. period (from sixth to twelfth leaf, June-July), III. period (milk stage, August) and IV. period (mature, before harvesting, September-October). Sample method was systematic. In each 20th (Segesd) or 30th (Sükösd) corn row and in each 20th meter was one sample plot. The plots were 1 meter long part of corn row, where the total plants number, the damaged plants, the pellet groups, and the damage forms were examined. The pellet group of red deer and wild boar was counted on the sampling path. I have characterised the space use intensity of the sample fields by the pellet group density, as it is an accepted indicator in wildlife biology

(HUAPENG et al. 1997, HÄRKÖNEN & HEIKKILÄ 1999, NÁHLIK et al. 2003, MÅNSSON et al. 2012). Each damaged plot was marked with unique GPS coordinate to make possible the spatial analysis in GIS.

2.2.3. Processing of data

2.2.3.1. Determining the rate of damage

The rate of damage was described by recorded food supply (pcs.) and the damaged maize individuals (pcs.) The recorded data on damage rate and distribution of damage forms were summarized by each 5 sample plots because the data of the 1 meter long sections did not provide enough resolution to calculate the standard deviation of damage rate. However, for field studies 1 meter sections are easy to use. In other words, on the 1 meter long sample section usually 3-6 maize individuals can be found, one more or one less damaged individual can result 16% difference in the damage rate.

2.2.3.2. Calculation the distribution of damage forms

The damage forms were recorded in every survey periods. Based on these data, the distribution of damage forms can be calculated for every examined period.

2.2.3.3. Spatial analysis

The spatial distribution of game damage can be described based on the coordinates of the damaged sample points. Moreover, the distance from the forest edge can be measured to every damaged points, so we can analyse the spatial role of the forest in the forming of game damage. Handling of the spatial data, measuring the different distances and map visualisation were carried out in ArcGIS software.

3. RESULTS

3.1. Landscape-level (county-level) relationships

3.1.1. Crop damage by counties

The mean values of crop damage differed significantly among counties during the study period (ANOVA: $F_{18.266}=218.75$; $p<0.001$) (Fig. 1). In some counties (e.g. Békés, Csongrád), crop damage was around 65.000–10.000 HUF/1000ha on average each year, whereas in other counties (e.g. Fejér, Nógrád) it was significantly higher. Crop damage could even reach 1.000.000 HUF/1000ha in Somogy and Zala counties. According to the damage map, the most damages occurred in the south western part of the country, while the lowest crop damage were in the east and north east regions (Fig. 1.).

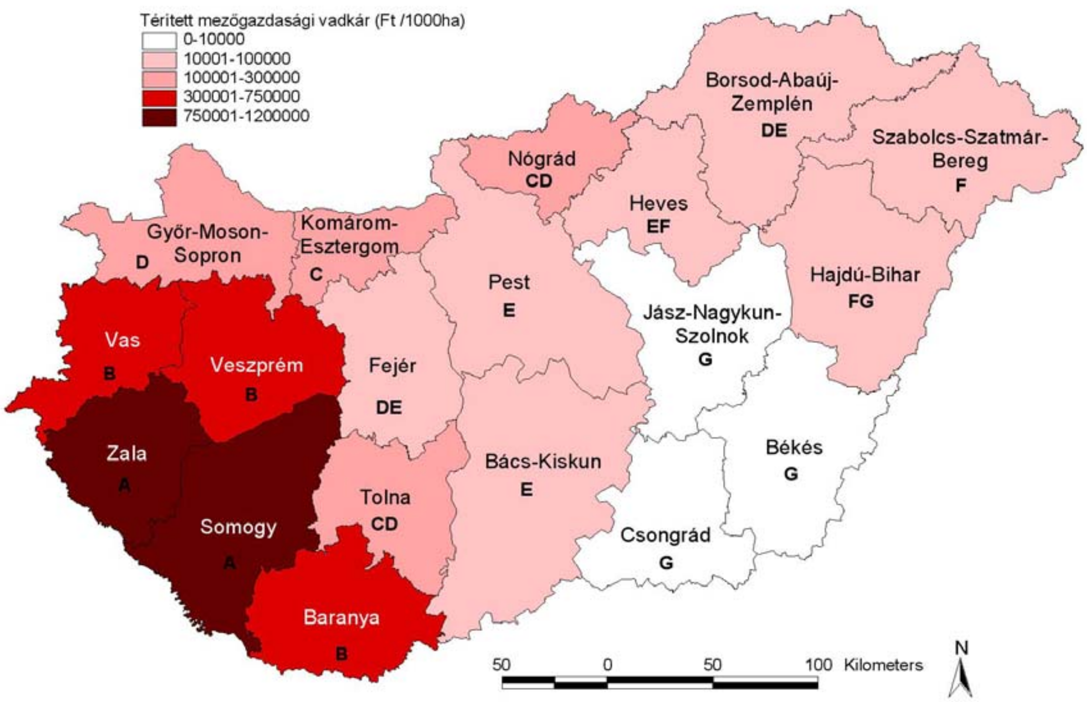

Figure 1. Mean values of compensated crop damage compared to the size of agricultural fields based on the data from 1997-2011 (HUF/1000ha) (different capital letters mean significant differences p<0.05, n = 15).

Increase in crop damage in different counties, were proved significantly in case of Győr-Moson-Sopron ($r=0.686$; $p<0.01$), Hajdú-Bihar ($r=0.638$; $p<0.05$), Nógrád ($r=0.553$; $p<0.05$), Szabolcs-Szatmár-Bereg ($r=0.655$; $p<0.01$) and Tolna ($r=0.596$; $p<0.05$) counties (marked red in Fig. 2 and Fig 3.). Damage neither increased nor decreased in the other 14 counties (from 1997 to

2011). However, in some counties (e.g. Fejér, Zala) large fluctuations can be observed among the years (Fig. 2 and 3).

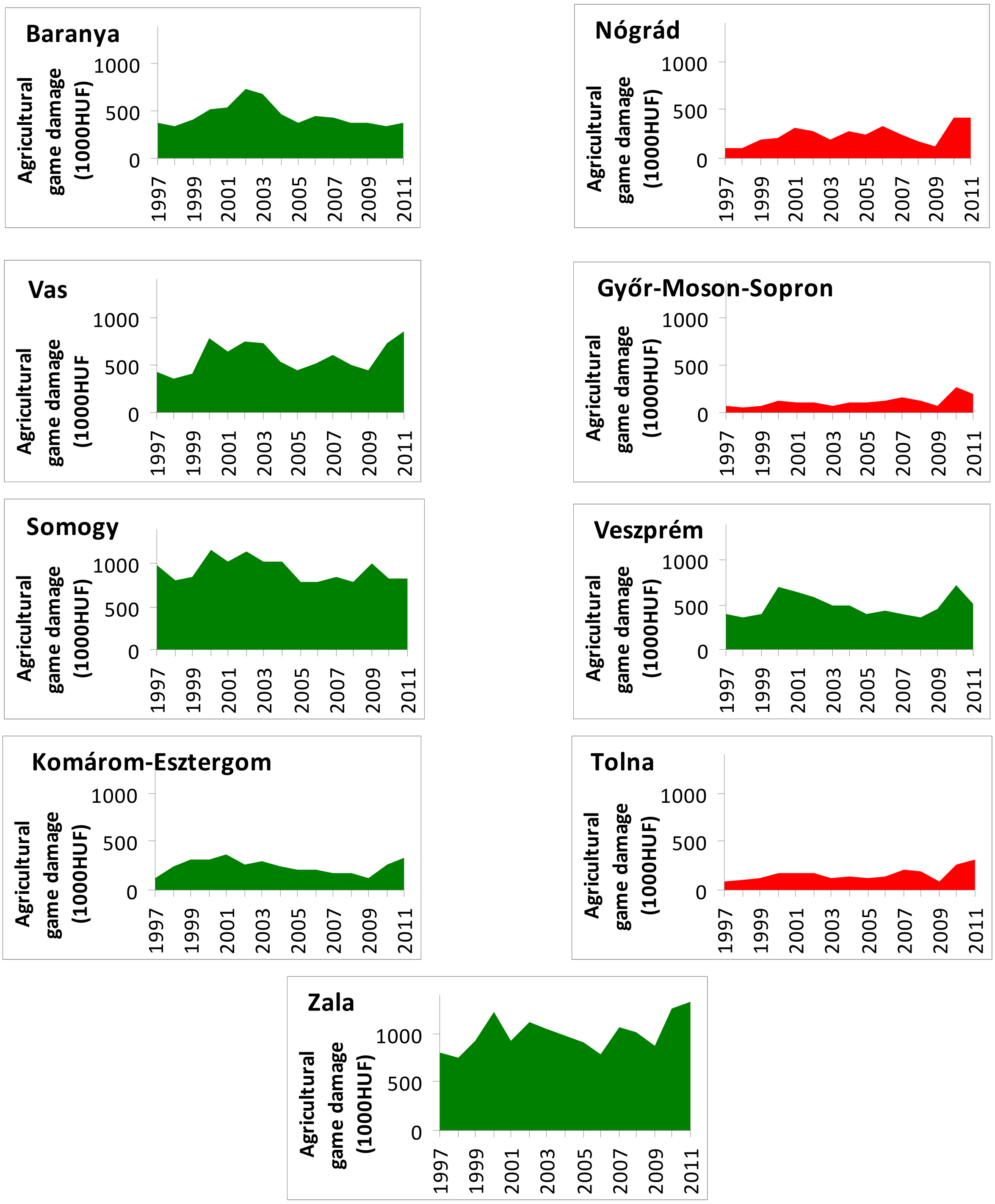

Figure 2. Crop damage (1000 HUF/1000ha) between 1997 and 2011 for counties that exceed the 100,000 HUF/1000ha damage value.

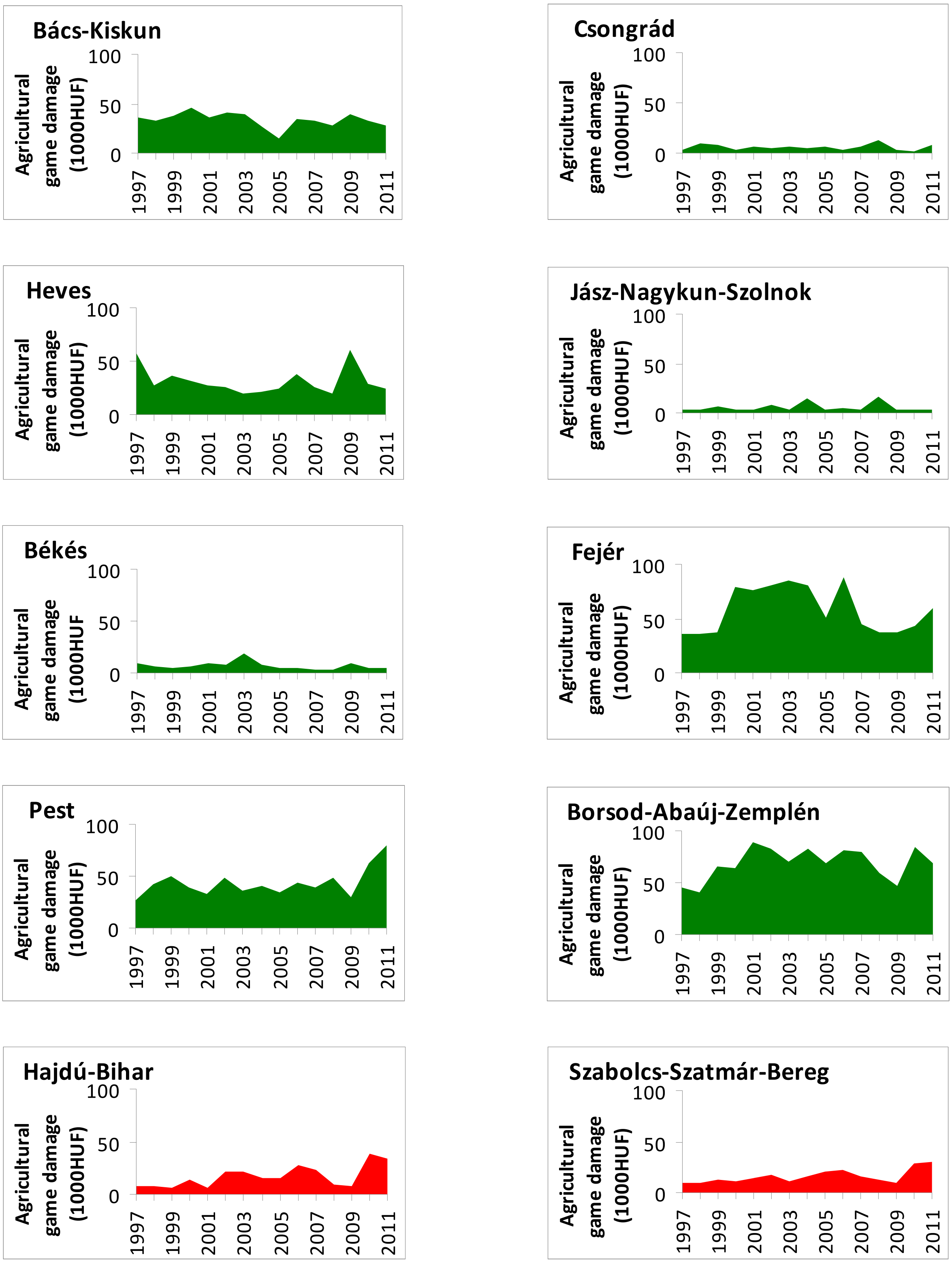

Figure 3. Crop damage (1000 HUF/1000ha) between 1997 and 2011 for counties that do not exceed 100,000 HUF/1000ha damage value.

3.1.2. Factors related to crop damage

The examined influencing factors were the following: hunting bag density of red deer, wild boar and roe deer; relative proportion of agricultural area (AGRIFOR; agricultural area in square kilometres/forest area in square kilometres); forest edge ratio (forest edge length to agricultural area (FELAA)), relative sown area of wheat, maize, sunflower and other cultivated plants in total agricultural area.

Positive exponential relationship can be observed between the bag density and crop damage in case of red deer (Fig. 4., $R^2 = 0.856$; $p < 0.01$; $n = 19$).

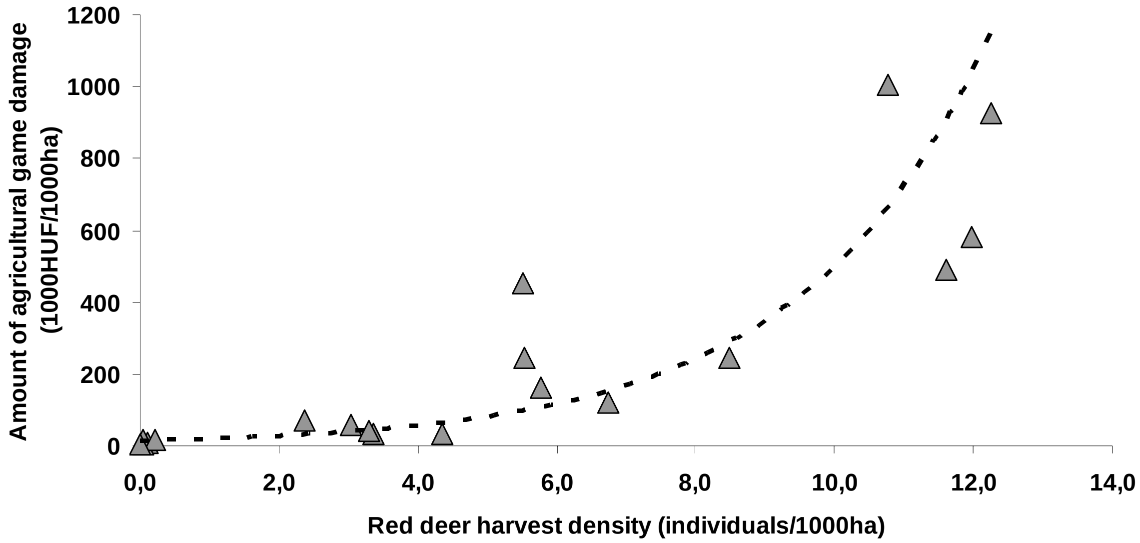

Figure 4. The relationship between red deer bag density and crop damage (1997-2011) (R^2= 0.856; p<0.01; n=19).

Positive exponential relationship can be seen between the bag density and crop damage in case of wild boar (Fig 5., R^2= 0.751; p<0.01; n=19).

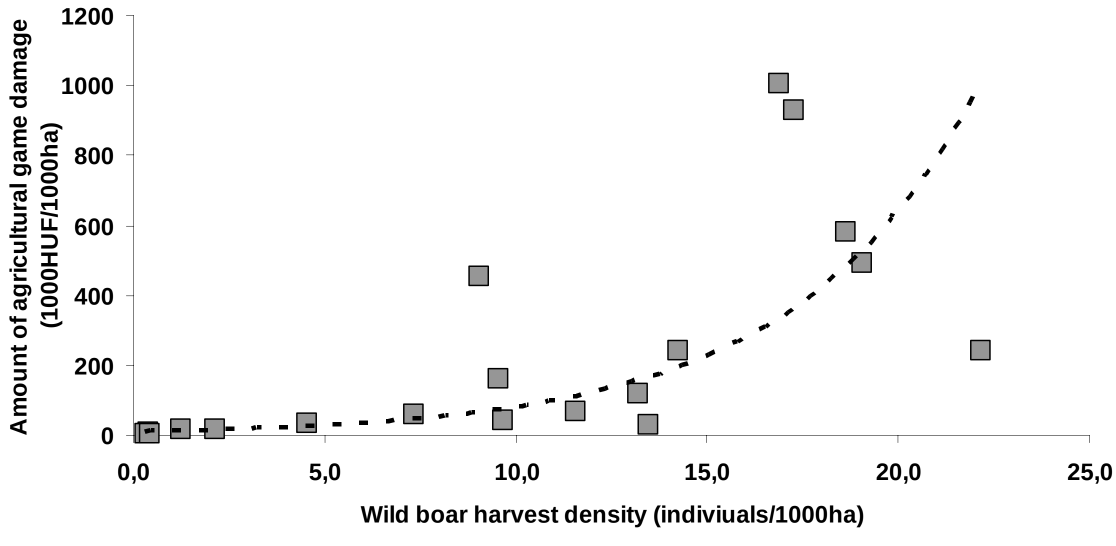

Figure 5. The relationship between wild boar bag density and crop damage (1997-2011) (R^2= 0.751; p<0.01; n=19)

There was no significant relationship between roe deer bag density and crop damage (R^2= 0.002; p=0.3863, ns; n=19).

Positive exponential relationship can be detected between the proportion of forested area and crop damage (Fig. 6., R^2= 0.621; p<0.01; n=19).

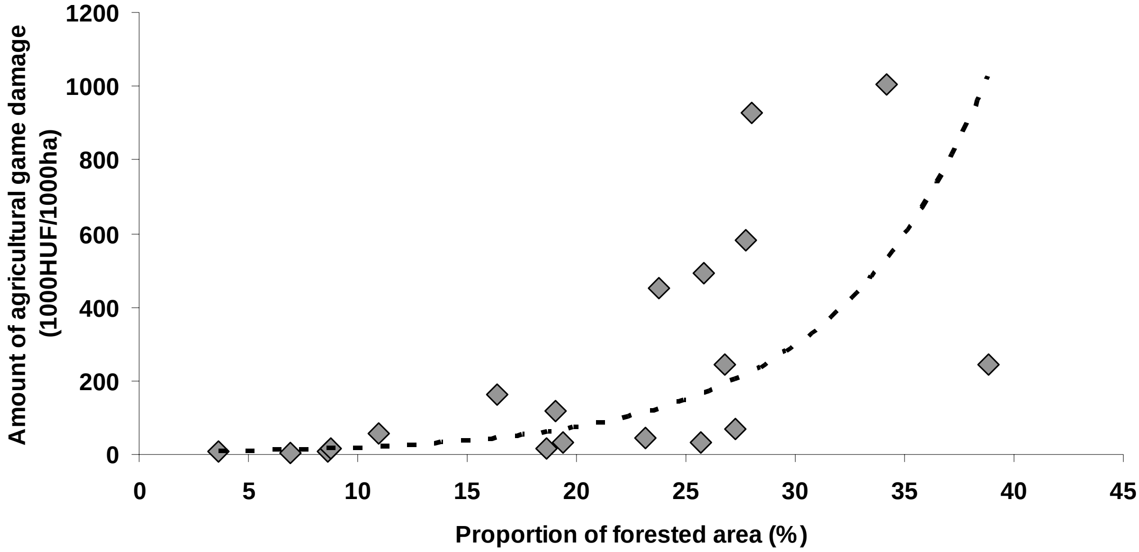

Figure 6. Relationship between the proportion of forested area and crop damage (1997-2011) (R^2= 0.621; p<0.01; n=19).

Positive exponential relationship can be detected between forest edge ratio and crop damage (Fig 7., R^2=0.557; p<0.01; n=19).

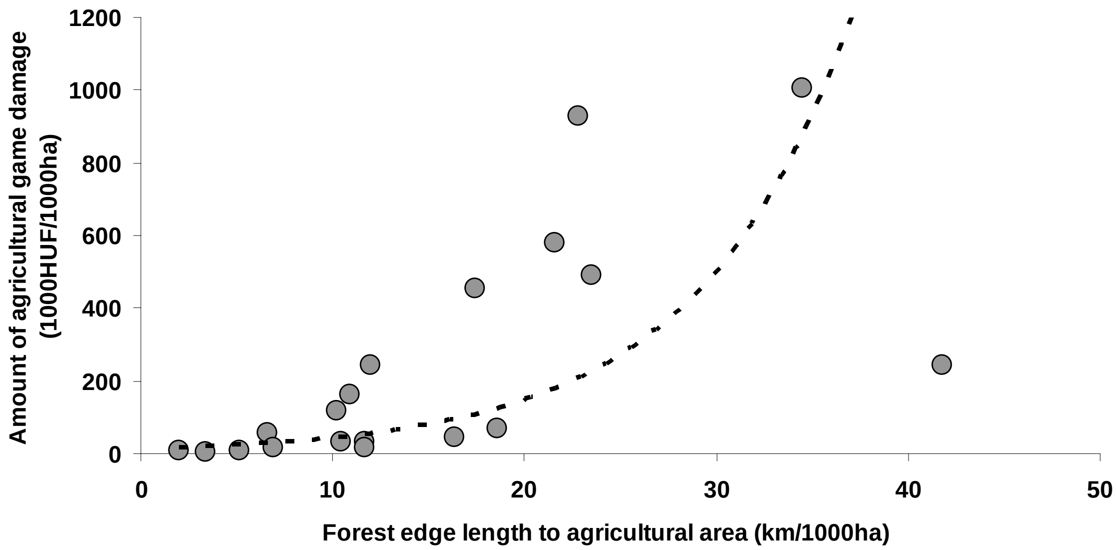

Figure 7. Relationship between forest edge length to agricultural area and crop damage (1997-2011) (R^2=0.557; p<0.01; n=19).

Positive exponential relationship can be observed between relative sown area of maize and crop damage (R^2=0.248; p<0.05; n=19), while negative exponential relationship can be justified between relative sown area of sunflower and crop damage (R^2=0.509; p<0.01; n=19).

3.1.3. The principal component analysis

Based on the results of component analysis (with varimax rotation) I have determined the following factors: I. game density-habitat structure (variance: 3.684; explanatory variable: 61.4%); II. cultivated plant availability (variance: 1.655; explanatory variable: 27.6%).

The components in factor I. are wild boar and red deer bag density, FELAA and AGRIFOR. The factor loadings varied between 0.791-0.971. The bag density of red deer had medium level, the bag density of wild boar had strong level in factor I. In case of factor II. only the relative sown area of maize and sunflower showed a significant effect (Table 1.).

Table 1. The factors of principal component analysis

	Factor I.: game density and habitat structure	Factor II.: cultivated plant offer
Variance	3,6840	1,6550
Explanation percentage	61,4	27,6
Wild boar bag	*0,971*	0,085
Forest cover	*0,958*	-0,008
FELAA	*0,916*	0,050
Red deer bag	*0,791*	0,498
Proportion of maize area	-0,113	*0,918*
Proportion of sunflower area	-0,294	*-0,902*

3.1.4. Linear regression model

Input data for the regression model was obtained from the principal component factor analysis. Factor I. meant the bag density of red deer and wild boar, and the characteristics of habitat structure, while factor II. showed the cultivated plant availability. Factor I. and II. as the independent variables in the linear regression model together explained 80.3% of the standard deviation in crop damage. Thus, based on the model, these two factors are accountable for the crop damage with 80.3%.

3.2. Field studies

3.2.1. Temporal distribution of crop damage

Crop damage showed a significant increase during the whole field survey period at Segesd (A and B fields) (Fig. 8.). Damage showed significant difference among sample areas in different periods throughout the year (ANOVA: Segesd A: $F_{2.275}$=48.87; p<0.001; Segesd B: $F_{3.687}$=82.336; p<0.001; Sükösd: $F_{3.1232}$=22.759; p<0.001). In case of Sükösd, the damage increased only until August (Fig. 8.) but with lower extent than Segesd A and B fields. In each period and in all three areas the standard deviation was high, which shows that the rate of the damage in the sample points was very different.

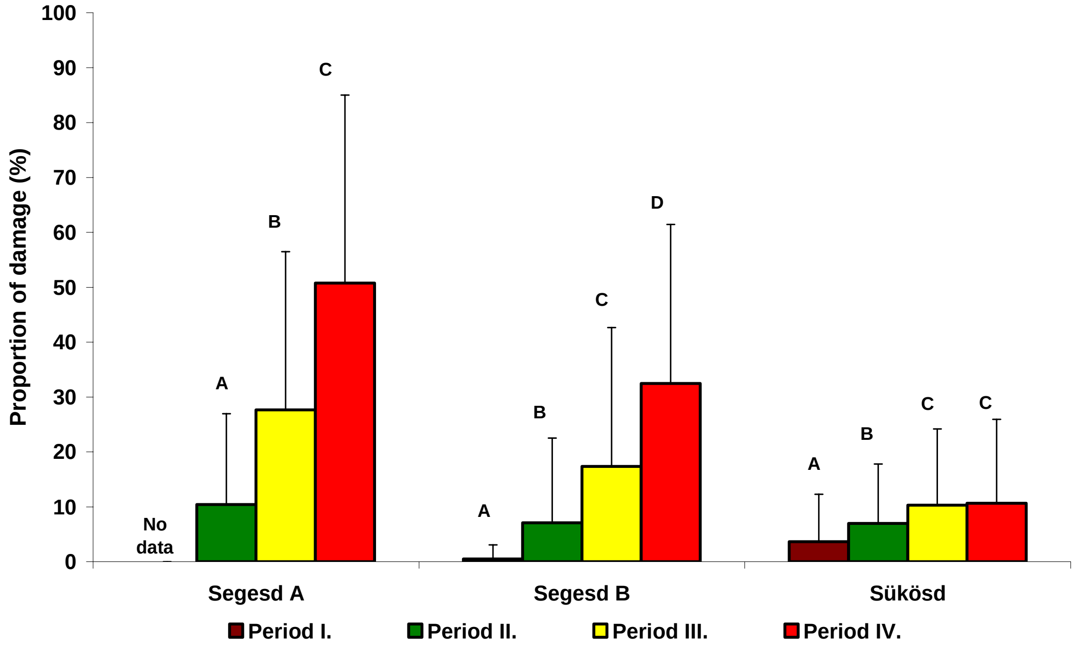

Figure 8. Crop damage at the study areas in each period (capital letters mean significant differences (Bonferroni test, p<0.01) within the areas compared between the periods).

3.2.2. Spatial distribution of crop damage

The spatial distribution of the damage was not even on the sample fields. The crop damage on sample points decreased exponentially with distance from the forest edge on all three fields (Fig. 9.). The majority of crop damage (60-90%) occurred 0 to 300 meters proximity to the forest, and the sample points affected by game damage were extremely seldom from more than 500 meters from the forest.

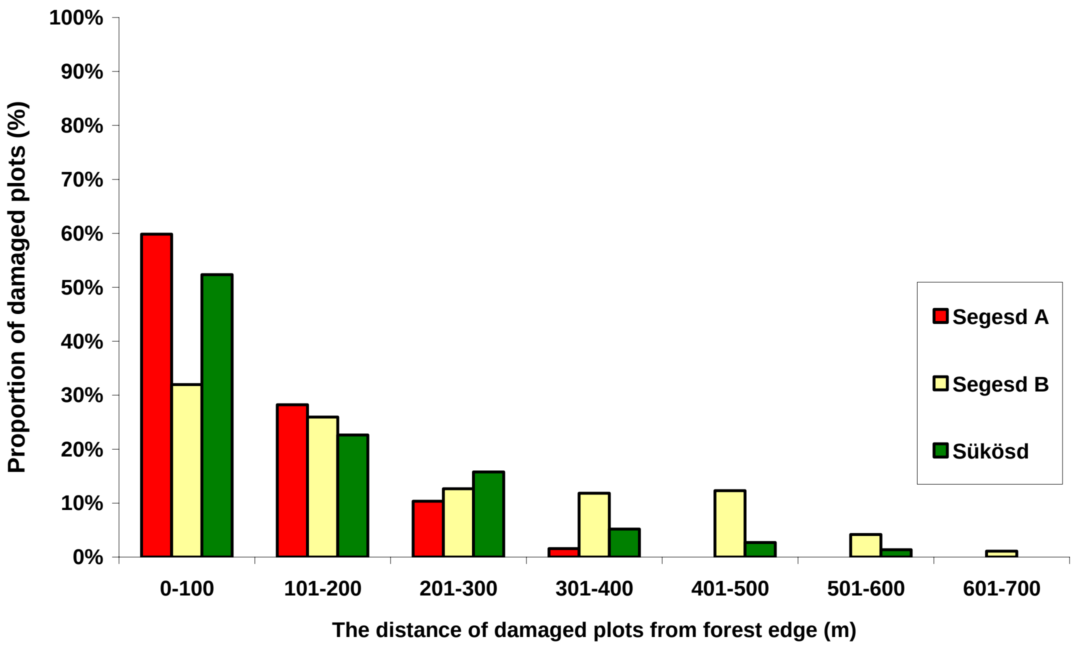

Figure 9. Spatial distribution of the sample points affected by game damage compared with distance from the forest edge.

3.3. New scientific results

1. I have quantified the compensated amount of crop damage and projected it to the extent of agricultural fields at certain counties of Hungary. The most affected regions by agricultural game damage are in south west Hungary (Zala and Somogy county), while the least affected are in south eastern part of the country (Békés and Csongrád county). The amount of compensated crop damage among more affected regions was sometimes twice as big as the cost in less affected regions.

2. I have demonstrated that crop damage is in a positive relationship with the size of red deer and wild boar bag density. I used hunting bag density as an index for population density and found that the density of both species affects the crop damage.

3. I have proven that the proportion of forested area within the habitat and forest edge length to agricultural area was positively correlated with the crop damage.

4. I have found that crop damage is highly dependent on the distance from the forest edge, moreover, within the damaged area the extent of crop damage is in relation with the intensity of habitat use of red deer and wild boar.

5. My analysis confirmed several crucial factors that affect crop damage, like habitat structure (ratio of forested areas and forest edge length), the red deer and wild boar population density, and cultivated plant availability.

4. CONCLUSIONS AND SUGGESTIONS

4.1. Differences in game damage among Hungarian counties

Crop damage shows remarkable differences among different territories in Hungary. Actual, game damage is concentrated on a few counties like Zala, Somogy and Vas. On the other hand there are some places in the country (Great Hungarian Plain and Tiszántúl) where damage is insignificant. The five most involved counties are Zala, Somogy, Vas, Veszprém and Baranya. These regions represent only 24% of the area of Hungary, however 75-80% of the total crop damage reported from these counties (BLEIER & SZEMETHY 2003, CSÁNYI 2003, CSÁNYI 2004). Based on these results I can state that this problem is not a nationwide problem it only affects some counties. Understanding the differences shown in the counties ecology, habitat structure, forestry, agriculture and wildlife management could help to solve the problem of game damage locally (BLEIER et al. 2006b).

In previous studies we have found that crop damage shows increase only if we count with nominal value. When we correct game damage for inflation damage has not increased (BLEIER et al. 2012a).

Temporal changes in crop damage could be observed only in five counties. In case of Hajdú-Bihar and Szabolcs-Szatmár-Bereg counties there is an increase in red deer and wild boar population in the last several years based on the data collected from NGMD. The three other areas (Tolna, Nógrád and Győr-Moson-Sopron) also have a significant population of the two above mentioned species. Based on hunting bag data (NGMD), red deer and wild boar bag increased in all hunting regions. Thus, I conclude that only this connection cannot explain every difference in game damage.

4.2. Factors influencing agricultural game damage

Based on my results red deer and wild boar hunting bag density correlates with the increase of game damage. Similar connection cannot be shown in case of roe deer. I have used, hunting bag density as an index of population density, thus deer and boar densities and it correlated with the increase of crop damage. GORYŃSKA (1981), SPITZ & LEK (1999) and SCHLEY et al. (2008) showed similar correlation between wild boar densities and crop damage. Deer are also likely to make such damages (red deer, fallow deer, roe deer, muntjac, see at: PUTMAN & MOORE 1998; WHITE et al. 2004; white-tailed deer: VECELLIO et al. 1994; wapiti: HEGEL et al. 2007, BROOK 2009). VECELLIO et al. (1994) also found that the damage itself depends not only on the densities but on the concentration of big herds on agricultural fields. Despite the previous studies with red deer and roe deer no survey was carried out to investigate the long-term effect of density increase at a large scale. CONOVER (2002) states that the correlation between population density and crop damage is not linear, but logistic. My results confirm this hypothesis when red deer and wild boar are considered. This study highlight the fact that in a long time scale population density is going to be one of the major influencing factors of crop damage.

In agreement with previous studies (KAŁUZIŃSKI 1982, PUTMAN 1986, JACQUEMART et al. 1989), my analysis also showed that roe deer do not have a major effect on crop damage. Roe deer influence might be smaller because in summer and early spring they foraging individually or in small groups (BRESIŃSKI 1982, BAO et al. 2005, BLEIER et al. 2011), thus temporal and spatial effect should be less devastating on cultivated plants (BLEIER et al. 2012a). Furthermore, cereals can regenerate from the winter and spring browsing of roe deer (PUTMAN 1986).

Many studies reported that crop damage is influenced by a lot of factors beside the population density of a given species (DUDDERAR 1991, CONOVER 2002, PUTMAN et al. 2011). Forest coverage was an important factor too, however in this case we should draw carefully. We do not know how the game damage would have been changed in case on 60, 70 or 90% of forest cover. My recent data suggest that higher forest cover is followed by increasing crop damage. Naturally, this correlation is only true for some extent because higher forest cover also means lower coverage of cultivated lands. Owing to this, game species could not physically cause more damage after a threshold. In an extreme example: if we have an area with complete (100%) forest cover we do not have crop damage.

Forest edge length to agricultural area (FELAA) was in a positive relationship with the changes in crop damage. This finding is comparable with other studies, where researchers find that the distance from forest edge can highly influence crop damage (NAUGHTON-TREVES 1998, BLEIER et al. 2006b, DEVAULT et al. 2007). Furthermore, the presence of different habitat edges can have an effect on habitat use of wild boar (THURFJELL et al. 2009) and red deer (BLEIER et al. 2008). If we have a high FELAA we obviously will have a large area of cultivated fields that are directly contact with forest edge, and this situation is extremely favours for high crop damage.

My data show that the proportion of sown area of maize was in a positive relationship with crop damage. Other authors also mentioned the important role of maize (BLEIER & SZEMETHY 2003, SCHLEY & ROPER 2003, HAJAS 2005, SCHLEY et al. 2008, CAI et al. 2008). Wild boars often feed on cultivated plants especially on maize (HERRERO et al. 2006), in fact, sometimes high preference could be shown to maize (CAI et al. 2008). One study (SZEMETHY et al. 2003) suggests that maize is a food item in red deer diet at a mixed agricultural and forest habitat with a proportion of 18% at August. Although, the consumption of some plants depends on other food items availability, too (ELLIS et al. 1976, GENOV 1981, CASSINI 1994). Thus, in some case maize consumption can differ highly among different regions based on not only the density, but on other available food items.

The role of maize is also important because of its long term during the vegetation period and because it is fairly sensitive to grazing (OBRTEL & HOLIŠOVÁ 1983). Also, wild ungulates can hide in high maize stands (SCHLEY et al. 2008, KEULING & STIER 2010).

In my study, the relative sown area of wheat and other cultivated plants could not be related to crop damage, but sunflower affected the crop damage negatively. Results might be surprising knowing that wheat and sunflower are well known food items for ungulates (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, so increase in the maize area will entail decrease in the area of other plants. Thus, the negative correlation between crop damage and the sown area of sunflower might be affected by the positive correlation of the sown area of maize.

The two factors calculated using principal component analysis show the game damage ecological background. Based on this result, the more fragmented the forest and the longer the forest edge is, the larger is the area exposed to crop damage. Furthermore, the damage is influenced by the population densities of wild boar and red deer, as well as sown area of cultivated plants.

4.3. Crop damage in maize (types, damage ratio and temporal distribution)

In May, the negligible amount of crop damage in maize could be because of the development stage of the plant. At Segesd, maize did not grow out at that time, and at Sükösd the plants were in a three-leaf stage. Rooting by wild boars was the most frequent damage type. The seeds had been eaten, sometimes in a whole row. Browsing damage only occurred at Sükösd where the leafs were “pinched” off by the deer.

The second field survey showed twice as big crop damage than the first one. Browsing of the not fully developed green plants were the most common type of damage. As a special damage type consuming the internodium also occurred.

In August, the food availability increased with the almost developed corncob in its milk stage. Preference of the corncob was shown in previous studies (SCHLEY et al. 2008), thus the most crop damage occurred on the cobs, unsurprisingly. The cobs are not only attractive for ungulates but smaller body sized animals too, like badgers (MOORE et al. 1999).

The last field survey also showed a high corncob damage, which means that the fully developed cob is also a palatable and attractive food source. This has been shown by other Hungarian studies too (MATOS 2006). Radio-telemetry studies find that wild boars are likely to visit maize fields from August to November (KEULING & STIER 2010).

The spatial distribution of crop damage was highly influenced by the distance from the forest edge. This was previously shown in case of other species like capybara (*Hydrochoerus hydrochaeris*) (FERRAZ et al. 2003), Southern pig-tailed macaque (*Macaca nemestrina*) (LINKIE et al. 2007), groundhog (*Marmota monax*) and white-tailed deer (DE VAULT et al. 2007). However, there are studies where this spatial distribution cannot be observed (STEWART et al. 2007). This might be in connection with the special location of the study areas. In this case, the crop damage did not decrease with the distance from the forest edge because the opposite edge of the agricultural field was a dense shrubby vegetation next to a canal, where most preferred shrubs of the red deer could be found. Due to this, crop damage occurred at a 20-50 m wide band from the edges of the maize field (MATOS 2006).

Based on my results the crop damage was extremely high in a 100 m zone from the forest edge. This does not mean that there was no damage in the middle of the field. Sometimes huge patches could be seen on the fields, which are typical damage types caused by wild boar rooting and trampling. It was proved that boar sounders can live in one single maize field for up to two months (KEULING & STIER 2010). During this time they can easily trample the vegetation in large areas.
The number of sample points affected by crop damage was decreasing with the distance from the forest edge. Based on a radio-telemetry study on red deer hinds, it has been shown that home ranges were expanded forward agricultural fields at the vegetation period (May-November). The average distance from the forest edge was 300-500 m (BLEIER et al. 2006b). Therefore, theoretically we can determine the point from game species only rarely occur on the field, so the crop damage will be moderate after a certain distance. Modell on crop damage showed that 1 km zones from the forest edge were the places where the most damage occurred. These results with conjunction of my own findings led me to conclude that forest edge length to agricultural area (FELAA) are of outstanding importance in case of crop damage.

My research also proved that the number of deer droppings and wild boar faeces had a positive relationship with the rate of crop damage. This raises the question: is crop damage density dependent? Many studies used dropping densities to characterize population densities of a given species (HÄRKÖNEN & HEIKKILÄ 1999, NÁHLIK et al. 2003). This was the most reliable method to calculate population density in an enclosure (HUAPENG et al. 1997). Furthermore, this method worked well for population estimation even when abiotic features have changed (RIVERO et al. 2004). TSUJINO & YUMOTO (2004) also used this method to calculate sika deer population density and used the calculated data for estimating game damage on saplings.
The field surveys with statistical analysis together help us to understand the connections among different features responsible for crop damage. Based on my results, I can state that wherever there are forests suitable for game populations and there are agricultural fields nearby, crop damage will

eventually occur. I can conclude based on this and on the above mentioned findings that the crop damage characterized mostly by the following features: habitat structure, food item availability, red deer and wild boar densities, and the sensitiveness of crops for game damage.

In Hungary, forest cover is going to increase in the near future. For 2035 the forest cover might increase up to 25% (SOLYMOS 2000), this will surely be beneficial for game species. Thus, I think we will face more and more situations where habitat structure will favour for red deer and wild boars, hence crop damage is going to increase.

4.4. Practical recommendations

Game managers usually do not have any means to control the factors affecting crop damage. Agriculture is usually not managed simultaneously with game management and in favour for wildlife. In case of forestry this situation could be more intense. Forestry and wildlife management are separated from each other, just like agriculture from the other two. This means that the management of an ecosystem and its resources are handled separately, different managers use different resources (BLEIER et al. 2012b). Game managers in most situations do not have any effect on the distribution of agricultural fields or the sown area of the crop. Also, game managers cannot influence the sown crop type, however studies have shown that different crops have different sensitiveness for damage (GYENEI et al. 2013), and game species food preference may also vary (SZAKÁCZKI 2007).

Hunters and game managers usually only have the tools for manage the densities of game populations. However, the wise use of this tool is highly questionable. Game populations were increasing in the last thousand years, with a few exceptions like wars. The well-known defence possibilities like constructing fences or electric fences are expensive and not always effective. The cost of these defence possibilities is important because in an economical point of view game densities also provide income for the manager. The cost should not be higher that the income provided by the game species. We must consider that the crop damage might not decrease with the decreasing red deer or wild boar population, but we will definitely have less “commodity”. This may led to a situation when the game managers will not have enough animals to sell or hunt to create profit, but the crop damage will still be the same. Managers need to find the best practice where the profit is higher than the loss from crop damage, but each sector (agriculture, forestry) will be satisfied with the compensation. It would be highly advisable to create and maintain test game management units (GMUs) (BLEIER 2004), where the effect of each defence method (like fencing) and procedure (like habitat and crop management) could be examined.

It is important to note that all costs related to game management is now to be paid by the game managers, with the exception of the 5% cost of game damage, which should be paid by the stakeholders. On the other hand the yield, came from a game population, is beneficial for every sectors. I think we should consider game populations as a beneficial and renewable natural resource for all sectors to solve problems related to crop damage. It is recommended to evaluate these factors and find out which sector benefit from which yield. We can also discuss who are responsible to certain damages (disadvantage) and yields (advantage) (BENCE 1969a, PORUBSZKY 2006).

Game managers should evaluate crop damage relations in their own GMU, especially focusing on the damage done by different species. My results indicated that both species (red deer and wild boar) can cause significant crop damage, but the damage caused by each species could differ in a given area or GMU. Thus, managers should specify which species cause the damage and how large the damage is. Only after this evaluation they can conclude to the importance of each species. A good indicator for this can be the projected game damage on a given species divided by its population density (CSÁNYI 2004). These evaluations can hugely affect the management decisions (e.g. control by population decrease).

Areas with the greatest damage should be recognized by the game managers (BARNA et al. 2007) and targeted management plan should be carried out. The plan must highlight the importance of alternative land use. However, to decide the land use type farmers, stakeholders, foresters, wildlife managers and even the research sector should be involved.

5. PUBLICATIONS RELATED TO THE TOPIC OF THE DISSERTATION

5.1. Publications in scientific journals with impact factor

BLEIER, N., LEHOCZKI, R., ÚJVÁRY, D., SZEMETHY, L., CSÁNYI, S. (2012): Relationships between wild ungulate density and crop damage in Hungary. Acta Theriologica, 57:351-359.p. DOI: 10.1007/s13364-012-0082-0 (IF 2012: 0.949)

KATONA, K., KISS, M., BLEIER, N., SZÉKELY, J., NYESTE, M., KOVÁCS, V., TERHES, A., FODOR, Á., OLAJOS, T., RASZTOVICS, E., SZEMETHY, L. (2013): Ungultae browsing shapes climate changes impacts on forest biodiversity in Hungary. Biodiversity and Conservation (22):1167-1180.p. DOI:10.1007/s10531-013-0490-8 (IF: 2.264)

5.2. Publications in scientific journals without impact factor

BIRÓ, ZS., KATONA, K., BLEIER, N., LEHOCZKI, R., ÚJVÁRY, D., SZILÁGYI, ZS., MARKOLT, F., SZEMETHY, L. (2012): A kőrösladányi vadaskert vaddisznó állományának hatása a védett növényekre. Természetvédelmi Közlemények, 18: 67-76.p.

KATONA, K., SZEMETHY, L., NYESTE, M., FODOR, Á., SZÉKELY, J., BLEIER, N., KOVÁCS, V., OLAJOS, T., TERHES, A. ÉS DEMES, T. (2007): A hazai erdők cserjeszintjének szerepe a nagyvad-erdő kapcsolatok alakulásában. Természetvédelmi Közlemények, 13: 119-126.p.

5.3. Publications in Hungarian scientific journals

BLEIER, N., SZEMETHY, L., CSÁNYI, S. (2010): A nagyvadfajok állománysűrűsége és a mezőgazdasági vadkár közötti kapcsolat. Vadbiológia, 14: 1-12.p.

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CSÁNYI, S., LEHOCZKI, R., SCHALLY, G., BLEIER, N., SONKOLY, K. (2006): Az őz élőhely-használata alföldi, mezőgazdasági környezetben. Vadbiológia, 12: 7-20.p.

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KATONA, K., SZEMETHY, L., MÁTRAI, K., BLEIER, N., OROSZ, SZ. (2006): Feeding habits of red deer in Hungarian forested and agricultural areas. 6th International Deer Biology Congress, Csehország, Prága.

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