Using a national digital soil database to predict roe deer antler quality in Hungary

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Abstract
Roe deer *Capreolus capreolus* (Linnaeus 1758) play a key role in the life of rural hunting enterprises. There are numerous factors affecting antler quality and they can be examined from different scientific approaches. In the present work we searched for relation among a nationwide digital soil database and a digital nationwide antler database. Researches in this field are concentrating on quantitative measures of soil fertility, on general differences among regional soil conditions. The results were obtained by completing a spatial analysis of the national digital soil map (Agrotopography Map of Hungary, mapping scale of 1:100,000) and roe deer antler weight information maps covering the whole area of Hungary. Based on our results we can state that it was possible to show the effects of soil physical parameters on antler weights. As the result of using the General Linear Model soil physical parameters are explaining 42.5% of the variance of antler weight ($F_{68,1133} = 12.316$, $p < 0.001$, $R^2 = 0.425$).

Key Words
Physical soil parameters, antler weight, *Capreolus capreolus*.

Introduction
The roe deer (*Capreolus capreolus* Linnaeus 1758) is native in Hungary (Sempéré *et al.* 1996). Sexual dimorphism of the roe deer is not as significant, concerning their size (bucks weight 20-30kg vs. does 15-25 kg) (Andersen 1998), as in case of other species. The most significant difference between the 'bucks' and 'does' is that bucks grow antler. In the normal case this antler is upstanding, 15-25cm long, with two or three short tines. Compared to other deer species (Cervidae), compared to their body size their antler is smaller both in ratio and tine number (Lister *et al.* 1998). Antlers are the bony appendages that are cast and fully regenerate every year and grow from two attachment points on the skull called a pedicle (Goss 1983).
The development, size and quality of antlers are influenced by numerous factors. It is not fully known what effects are more important but environmental effects and furthermore feeding condition are considered as among them (Bailey 1984; Goss 1983; Azorit *et al.* 2002) unlike hereditary characteristics (Hartl *et al.* 1995; Harmel 1982). The quality of the food has good relation with the soil, its physical and chemical characteristics.

Bailey (1984) emphasizes the importance of soil among the habitat components effecting the antler development of the roe deer. He summarizes the relationship of soil and game population and calls attention to the influence of soil in game management. Jacobson (1982) found positive connection between the soil element content and deer weight and reproductive capacity. Higher soil fertility resulted bigger antler size (Dunkeson and Murphy 1953; Sweet *et al.* 1952). Researches with *Odocoileus virginiaus* proved that for using antler-based, selective-harvest criteria for reaching maximum antler size it worth considering the soil characteristics of the given area, too (Strickland *et al.* 2001; Strickland and Demarais 2000).

The purpose of the present research is to prove differences in antler characteristics of the roe deer with different soil physical parameters. We fulfill this task with spatial analyses of the digital soil type and antler characteristic map covering the whole area of Hungary.

Methods
Trophy measurement data
In Hungary it is obligatory to show the antler of the shot roe deer bucks to the trophy scoring committee. The data of the evaluated trophies is collected and stored by the National Game Management Database of Hungary (Ministry of Agriculture and Szent István University).

The National Game Management Database of Hungary handles the borderlines (as spatial information) of the game management units (GMUs) and their changes, thus the spatial connection of the trophy data is solved. To describe a game management unit, we used the average of the left and right beam length (cm) and weight (g) data from the database, using the CIC (International Council for Game and Wildlife Conservation) trophy scoring formula (Whitehead 1981). In the research we used the data of the 4 to 6 years old bucks (n=117426), shot in the period between 1997 and 2006. We used the average of the 10 year data because this sorted out the differences caused by changing weather and wild management (Azorit *et al*. 2002).
1202 game management units cover the area of Hungary. These units have data for beam length (cm) and weight (g).

Soil data
For spatial analyses, we used the only nationwide available digital soil information map (Agropotpography Map), prepared by the Hungarian Academy of Sciences, Research Institute of Soil Science and Agricultural Chemistry (HAS-RISSAC). The database of the map is prepared at the scale of 1:100 000 (Várallyay 1985). In the present study we only used physical data (parent material, soil hydrology and texture).

Spatial analyses
We used ESRI software (ArcInfo, ArcView) for spatial analyses. To analyze soil data on the area of the game management units we used the union command of the software (Zeiler 1997) that computes the geometric intersection of two polygon coverage. Finally we have received the 1202 dataset for the 1202 game management units for statistical analyses. The database contains the proportion of the main soil types and the trophy data for each given game management units.

Statistical analyses
The null hypothesis of the applied statistical analysis is that connection between the two parameter group can be proven. We used cluster analyses to prepared clusters of the independent variable (parent material, texture and soil water management) for the examined cases (in this case for the 1202 game management units) and analyzed the differences of the dependent variables (antlers weight) for these clusters. First the number of the groups was determined with Ward's hierarchical cluster method. The suitable group was manually chosen based on the dendrograms and icicle plots, on the number of elements in the groups and on the distance of the groups. After the determination of the necessary number of groups, K-means (quick) cluster analyses method was chosen to classify the 1202 units into one of the formerly determined clusters. Finally differences between antler weights among the soil determined clusters were examined with analyses of variance (ANOVA). For comparison of the clusters in pairs Duncan's multiple comparison procedure, Duncan post hoc test was used.

Results

The prepared clusters based on parent material
Analyses of parent material resulted in five clusters. Cluster 1 is dominated by loess deposits (84.7%); Cluster 2 dominated is by clay (62.2%); Cluster 3 dominated is by Tertiary and older sediments (73.8); Cluster 4 is influenced by glacial and alluvial sediments (85.4%) and Cluster 5 by limestone and dolomite (33.2%), loess sediment (17.1%) and andezite, basalt and riolite (16.9%).

Analyses of soil texture resulted six clusters. Cluster 1 is dominated by loamy sand (37%), loam (24.9%) and not or partially weathered (84.7%); Cluster 2 by clayey loam (74.5%); Cluster 3 by high (20-40%) organic matter content (56.8%); Cluster 4 by loam (83.4%); Cluster 5 by sand (71.9%) and loamy sand (17%) and Cluster 6 by clay (64%) and clayey loam (20.8%) texture.

Analyses of hydrophysical properties resulted eight clusters. Cluster 1 is dominated by medium infiltration rate and hydraulic conductivity, big water holding and good water retention capacity (69.6%); Cluster 2 is dominated by weak infiltration, very weak hydraulic conductivity, strong water retention capacity, soils with very unfavourable, extreme water regime (64.2%); Cluster 3 is dominated by very big infiltration rate and conductivity, weak water storage and very weak water retention capacity soils (68.1%); Cluster 4 is dominated by big infiltration capacity and conductivity, medium water retention capacity, weak water holding soils (67.8%); Cluster 5 is dominated by medium infiltration capacity and weak conductivity, big water storage and strong water retention capacity soils (65.5%); Cluster 6 has good infiltration capacity and conductivity, very large water storage capacity and water retention capacity (60.6%); Cluster 7 is represented by shal-

low soils with extreme water regime (64.4%) and Cluster 8 is characterized by good infiltration and conductivity capacity, good water storage capacity and good water retention capacity soils (75.6%).
The cluster center values in the table representing the percentage of each cluster composing variable in the GMUs.

Analyses of the clusters based on parent materials, soil texture and soil water management properties show significant differences among clusters concerning antler weights (Table 1.).

Table 1. Significant differences among the clusters concerning antler weight

Clusters	Weight	SD	CV (%)	SSD	Weight	SD	CV (%)	SSD	Weight	SD	CV (%)	SSD
	Clusters based on parent material				Clusters based on soil texture				Clusters based on soil water management properties			
Cluster 1	305,1	26.71	8.8	d	282.4	29.69	10.5	a	282.6	28.28	10.0	b
Cluster 2	286,3	27.02	9.4	b	294.3	34.53	11.7	b	308.7	26.09	8.4	e
Cluster 3	262,9	26.62	10.1	a	288.4	29.19	10.1	a b	294.4	28.50	9.7	c d
Cluster 4	296,6	27.31	9.2	c	294.5	29.51	10.0	b	300.2	27.19	9.1	d e
Cluster 5	258,2	24.77	9.6	a	296.4	28.94	9.8	b	291.8	35.01	12.0	b c d
Cluster 6					315.5	22.261	7.1	c	22.3	31.08	10.8	b c
Cluster 7									264.5	24.91	9.4	a
Cluster 8									307.9	25.04	8.1	e

SD = Standard deviation, CV = Coefficient of variation, SSD = sign of significant difference
*(different letters mean significant difference, Duncan post hoc-teszt, $p<0.05$).

Effects of different parent materials on antler weight
Antler weights are the smallest in Cluster 5 (average 258.18g) and in Cluster 3 (average 262,86). These are significantly different from all other clusters. Cluster 2 is characterized by an average 286.31g antler weight is significantly different from other clusters. Cluster 2 has the second highest antler weight values (average 296.63g) and it is significantly different from other clusters. Cluster 1 has the biggest antler weight values (average 305.09 g) and it is significantly different from other clusters.

Effects of different soil textures on antler weight
Antler weights are the smallest in Cluster 1 with the smallest average value (282.38g). Values of Cluster 1 are significantly smaller than the values in other clusters (except Cluster 3). Cluster 3 with an average of 288.43g antler weight is significantly differs only from Cluster 6. Average values of Cluster 2 (294.27g), Cluster 4 (294.47) and Cluster 5 (296.37g) are statistically higher than Cluster 1 and smaller than Cluster 6. The average values of Cluster 6 (315.54g) is significantly higher than all other clusters.

Effects of different soil water regime characteristics on antler weight
Cluster 7 is characterized by the significantly smallest average antler weight (264.47g). Average antler weight in Cluster 1 (282.61g) is significantly different from other clusters. Cluster 6 with an average of 287.83g antler weight is significantly higher than values of Cluster 7, smaller than values of Cluster 4, 8 and 2 but do not differ from Cluster 1,5, and 3. Average antler weight in Cluster 5 (291.82g) is statistically different from Cluster 7, 8, and 2. Average antler weight in Cluster 3 (294.35g) is significantly different from Cluster 7,1,8, and 2. Average antler weight in Cluster 4 (300.21g) is significantly higher than values of Cluster 7,1, and 6. Average antler weights in Cluster 8 (307.92g) and Cluster 2 (308.70g) are statistically higher than all other clusters except Cluster 4.

Conclusion
The biggest antler weights were found on soils formed on loess, glacial or alluvial sediments. Regarding antler weights worst soils for antler weight gain are Tertiary and older sediment, limestone and dolomite. Analyses of soil texture proved clay and loamy clay to have the best affects on antler weights growing. No differences could be proved among other texture types. Examination of water regime types resulted contradiction. Based on the analyses of water regime we can state that the biggest antler weights were found on soils with big infiltration and conductivity, medium water holding and weak water storage capacity. Water regime type of the clay texture (resulted the biggest antler weights during the analyses of soil texture) resulted small antler weights. The effects of water regime are greatly affected by the amount of precipitation and its spatial and monthly distribution. From this point of view the results with clayey soils are not contradictory because where there are clayey soils in Hungary, there are the biggest precipitations or those soils are water affected, geographically low laying soils.

It was possible to show the effects of soil physical parameters on antler weights. As the result of using the GLM soil physical parameters are explaining 42.5% of the variance of antler weight ($F_{68,1133}$ = 12.316, p # 0.001, R^2 = 0.425).

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