

Thesis for the Doctor of Philosophy (PhD) degree

**LAND HISTORICAL EVALUATION AND THE ESTIMATION OF THE  
ANIMAL CARRYING CAPACITY AT A PROTECTED GRASSLAND**

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## 1. INTRODUCTION, RESEARCH OBJECTIVES

Agricultural production is going on at the significant part of the total area of Hungary, thus it is understandable that nature conservation activity is dependent on the cooperation with agriculture. This new cooperation of agriculture and nature conservation is not only the consequence of the interdependence of these two activities, but with joining the EU it is obligation and national interest as well. Therefore Hungarian lawmaking unambiguously created the possibility for the harmonization of these two sectors (*Tardy*, 1997). The conservation and if it is necessary, the restoration of the protected areas are amongst the important elements of the management methods of these areas. These activities cannot be achieved without ecological farming methods. However a viable activity from also an economic view can be only imagined with the harmonization of agricultural and nature conservation interests, as the efficiency of agriculture decisively depends on the state and quality of the environment, and thus of nature resources.

According to *Béri et al.* (2004), from a nature conservation point of view, the grassland management systems own the biggest importance of the inland agricultural systems in Hungary, because the major part of the protected plant and animal species are attached to them. From the extensive grasslands in Hungary more than 200 thousand hectares are under nature protection. With this size, grasslands amount approximately 25% of the Hungarian protected areas. In the conservation of these areas grazing animal husbandry could own a determinative role, as grazing animals are important members of the biocoenosis of grasslands. The opinion of *Bodó* (2005) is in keeping with the previous statement, according to which if we evaluate grazing, besides the facts that this is the primeval form of animal husbandry and a method to produce healthy animal products profitably, the role of grazing animals in the management of protected areas is increasingly emphasized. *Stefler & Vinczeffy* (2001) have the same opinion, according to the authors, the protected grasslands came to the front recently, as at these areas nature conservation activity gets priority because the use of artificial fertilizers and other grass management methods are forbidden, and grazing is restricted in time and space. According to *Bodó* (2005), nature conservation professionals often state that production nearly negligible besides this important activity. *Szemán* (2008) also thinks that in case the technology of grass management serves conservation interests, there is no use to stick to the profit oriented utilization of the grass yield. The opinion of *Kárpáti* (2001) is that there is a high need for a nature conservation grassland management, where the aim is not to reach the possibly highest economic

advance but to conserve the biodiversity, and through this the habitats of protected species.

*Sz. Tóth* (2001) reckons that giving up traditional farming could be a significant loss either in a nature conservation or in a cultural view, therefore working out the appropriate grass management method is an important task. However since the Hungarian experiences in grass management among these circumstances is rather few, furthermore there are numerous difficulties that are not characteristic at agricultural grasslands (e.g. yield fluctuation increase due to the cropyear effect, the nutrient content of the grass plants decreases, heavy weeding occurs) new grass management systems are necessary (*Stefler & Vinczeffy*, 2001). *Béri et al.* (2004) also think that elaborating a proper grazing method for a certain pasture is an important research task. The opinion of *Margóczy* (2004) is similar, according to which the preservation of the nature conservation values thus the biodiversity of grasslands is an essential task of grass management nowadays, however to find the correct methods is not easy, it should be worked out for each association empirically by taking the traditions into consideration.

With respect to the opinions of the cited authors, the overall aim of my research is to perform land historical examinations at the close territory of the great pasture of Hajdúbajos and to estimate the animal carrying capacity of this pasture by using a grass production model, in order to formulate nature conservation management suggestions to this area. For all this it is necessary:

- to obtain and systematize meteorological data of the examination area to create the input database of the grass production model;
- to carry out a botanical survey and by the botanical data to prepare a coenological database for stating the character species of the pasture and to formulate the management suggestions;
- to gather data on the realized grass production throughout a set of test mowing;
- to collect archival data and perform GIS examinations for the sake of forming management propositions.

By the collected data my further objectives:

- to validate the finished grass production model;
- with the help of the model to estimate the optimal stocking rate;
- to state management suggestions to the examined protected pasture.

My results are expected to be usable in elaborating the management strategy and planning the habitat reconstruction activities of the examined pasture and by this perhaps of other protected grasslands as well.

## 2. MATERIALS AND METHODS

### 2.1. The method of model development

The algorithms necessary for modelling the grass production had been integrated into MS Excel programme. The algorithms were inserted to the model in two large groups, as functions (*Atmosphere, Soil, Plant*) and processes (*Weather, Soil, Plant*). During the elaboration of the model realized data should be taken into consideration, therefore I created the input weather database of the model by data of true meteorological surveys.

As the results of the model are more precise if they are close to reality, the validation of the model was carried out by using the grass production data collected on an exact protected pasture.

### 2.2. The collection of the data that are necessary for elaborating the grass production model and for formulating the management suggestions

#### 2.2.1. Obtaining weather data and creating the input model database

In the grass production model the global solar radiation data [ $\text{MJ m}^{-2} \text{day}^{-1}$ ], the daily minimum, maximum and average temperature [ $^{\circ}\text{C}$ ], the daily precipitation sum [mm], the daily relative air humidity [%] and the average daily wind speed [ $\text{m s}^{-1}$ ] data are necessary as inputs.

The weather data of the examination area are the data recorded by the Debrecen Weather Station of the Hungarian Meteorological Service, for which I applied to the Climate Department of the Hungarian Meteorological Service with the interval of 01.01.2005 to 31.05.2006. From 01.06.2006 to the end of the examination period, until 31.12.2007, I collected the hourly data from the homepage of the Hungarian Meteorological Service<sup>1</sup> daily and recorded them with SPSS for Windows 11.0.

On the homepage however only the hourly temperature [ $^{\circ}\text{C}$ ], the wind speed [ $\text{km h}^{-1}$ ], and the air humidity data [%] can be found. I got the missing data from the leader of the Debrecen Weather Station of the Hungarian Meteorological Service.

In the units, format and time scale of the data from the three different sources there were big disparity what I had to eliminate. To create the final weather database I used Microsoft Office Excel programme. Into the database I only entered daily weather data.

I counted the values of potential evapotranspiration (PET) separately as PET is a very important weather data from a plant production view. I used the method of Szász (Szász, 1988) for calculating the potential evapotranspiration, what is

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<sup>1</sup> [www.met.hu](http://www.met.hu)

acknowledged and wide-spread in Hungary. This method takes the atmospheric elements and processes that determine the evaporation of water – the temperature and relative humidity of the air, wind speed and micro-advection effects (*so-called oasis-effect*) - into consideration.

To characterize weather data and to show how weather conditions changed during the examination years, further systematizing of the climatic data was needed. I summed up the global solar radiation data monthly and delineated it on a column graph in MJ m<sup>-2</sup> month<sup>-1</sup>. I got the monthly maximum, minimum and average temperature, air humidity and wind speed data by counting simple arithmetic means from the daily data. I summed up precipitation data monthly. I represented the potential evapotranspiration data on a daily basis and evaluated the change of the daily data.

### 2.2.2. Introduction of the examination area

I collected the supplementary botanical and grass production data that are necessary for the development of the grass model from an exact protected area. As an examination area I chose the great pasture of Hajdúbajos that lie in the eastern part of Hajdú-Bihar County southeast from Debrecen. I considered this grassland appropriate for my examinations as it is rather big in size, heterogeneous in its relief, according to what it bears various plant associations and has a nature protected status as well. The great pasture of Hajdúbajos is located geographically in the crossing point of three regions, the South-Nyírség, the Berettyó-Kálló Interfluve and the South-Hajdúság, right next to the territory of the Debreceni Erdőpuszták (*Baranyi, 2001*). As the area is the most important Hungarian habitat of the strictly protected lesser mole rat (*Spalax leucodon*) (*Gyarmathy, 1993*) it became the Lesser Mole Rat Reservation of Hajdúbajos Nature Conservation Area in 1976. Besides the lesser mole rat, the area is the habitat of other protected species as well. Among these species the most important is the strictly protected Pannon endemic Hungarian pasque flower (*Pulsatilla hungarica*).

The biggest part of the examined pasture is within grass cultivation branch, forests approximately occupy 10% of its total area. The last one century resulted in crucial changes at the pasture that had been grazed for a long time. The traditional form of land use ceased or at least had been thrust into the background, which process makes its negative effect felt. The non proper land use caused quick succession changes that besides the closing and growing of the grass is a harmful progression to the natural fauna also. The present

day animal stock is only able to graze an insignificant part of the green mass what leads to the accumulation of the organic substance. Therefore mowing against weeding is necessary at some parts of the pasture. Mowing is thus only a constraint, there is a need to replace it by increasing the number of grazing animals and the intensity of grazing (Mazsu, 2001).

### *2.2.3. Land historical examinations*

For the land historical examinations of the study area I performed cartography surveys by the investigation of geographical and historical descriptions and management plans, by the experiences of reports and personal interviews, as well as by a significant archival data collection.

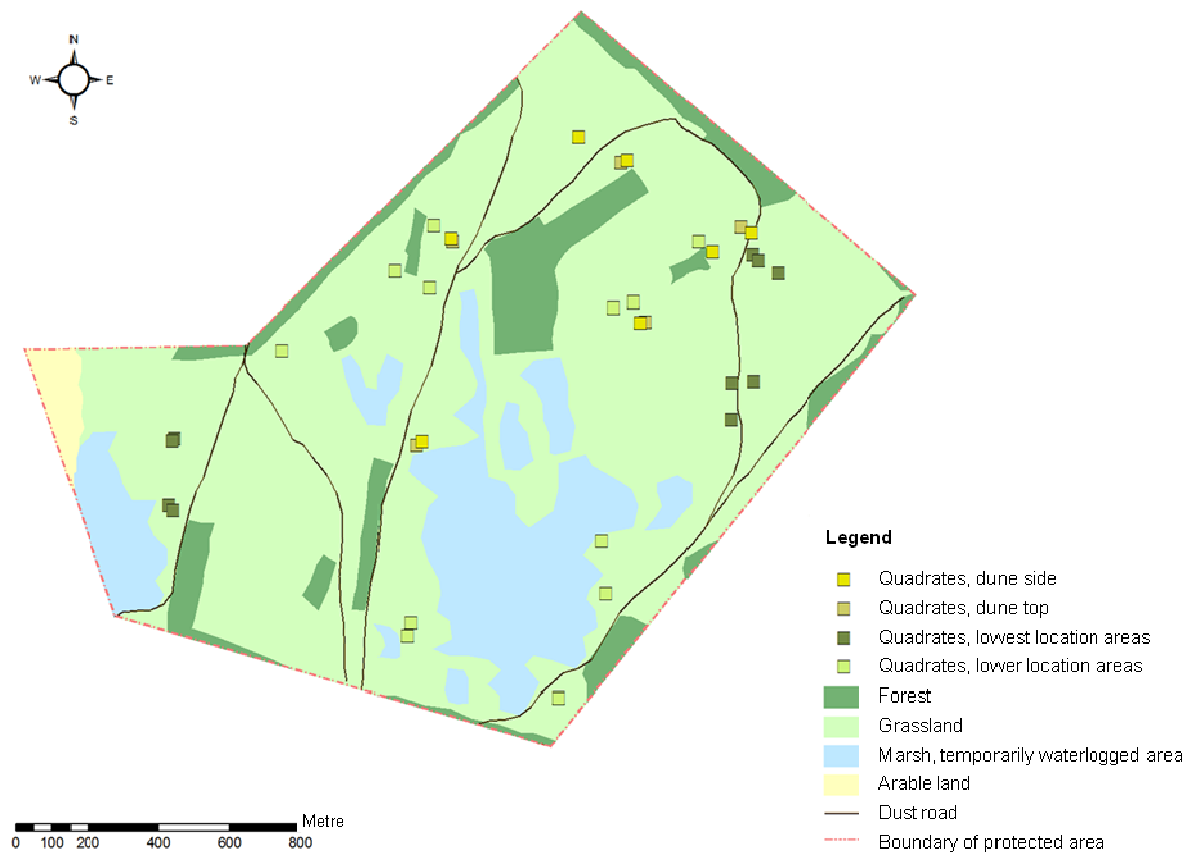
To the land use and land historical cartography examinations a database was needed that contains those more dimensional data that have information on the changes of the landscape and of land use, both in space and time. To this job I used the maps of the I. (1782-1785) and the II. (1819-1869) Military surveys, present topographical map sections, important elements of the Digital Base Map of Hungary (administrative units, linear and point map elements) and the present-day freshest remote sensed CORINE Land Cover CLC2000 European Land Cover Database. For cutting and graphical joining of the map sections I used Adobe Photoshop software. The georefereration of the raster database created in this manner was made by identifying reference points by using ESRI ArcGIS software package. After creating the digitalized sections (vector database), I created the geo-database of the land use examinations that contains the necessary data and map sections. With the attribute tables may aim was to quantify land history and land cover, and through this to determine the land use characteristics and the alteration of these features.

I pursued my archival examinations in the Hajdú-Bihar County Archives. I found and processed data from the beginning of the 1750s until the middle of the 1950s. I searched and evaluated data mainly on grazing animal husbandry. Among the archival sources there are censuses from the Sárrét than from the Derecske districts, feudal land tenancy census records, statistical reports and the final accounts of Hajdúbagos settlement as well.

### *2.2.4. Botanical data*

I carried out the botanical survey according to the *Balázs* quadrature method (Balázs, 1949). By considering the characteristics of the examination area I worked with 1x1 metre sized examination quadrates. Adjusting to the overall research aims all together 34, uniformly 1 square metre sized quadrates were

developed. I located the exact geographical situation of the quadrates by GPS device (*Figure 1*).



*Figure 1. Examination quadrates on the studied pasture*

During the establishment of the quadrates I endeavoured to take into consideration the local conditions at the pasture. I have divided the examination area into four different altitudinal levels, these are the dune top (BT), dune side (BO), lower location areas (M) and lowest location areas (LM). Accordingly to the proportion of the different altitudinal levels to each other and to the total area of the pasture, 5 quadrates at dune tops, 7 at dune sides, 12 at lower location areas and 10 at the lowest location areas were set. The method of the establishment was the so called guided random method, as the different altitudinal levels gave the estimated place of the quadrates but within these territories the correct place of each quadrate was the result of random choice.

On the developed quadrates I carried out two coenological surveys, the first was in 2006 representing the late spring – early summer aspect, while the second showed the late summer – early autumn aspect and was made in 2007. To determine the species found at the studied pasture and to create a coenological table I used the work of *Simon (2000)*. In the coenological table I registered the

scientific names and families of all species. I noted the life forms, the TWR namely the temperature and water management and the soil reaction values of the species. I determined the nature conservation values categories and the coverage values ( $D_B$ ) of each species, and the total coverage (b%) (Balázs, 1949) of the quadrates as well. In naming the species I used Priszter's nomenclature (Priszter, 1998).

#### 2.2.5. Grass production data

To measure the realized grass production at the great pasture of Hajdúbagos, I performed a test mowing series. I used the same quadrates than in the botanical survey. I started the test cuttings in April 2006 and timed them according to the general sheep grazing period during which a pasture is grazed 6 times a year and grazing on a certain territory is repeated in 35 days (Kertész, 1993).

Before cutting the grass I always registered the average grass height – in the quadrates I measured the grass height at three points by the side of a fictitious diagonal and from the data I calculated a simple arithmetic mean – and left a three cm high stubble. In those quadrates where the average grass height was exactly three cm or lower than that I did not remove the grass. In 2006 I walked over the pasture 6 times for mowing, from the end of April to the beginning of November, but in October and in November I could not cut the grass due to the low average grass height. I also walked over the examination area 6 times in 2007, however because of the low grass height I could remove the grass only once in July, in merely two quadrates. After removing the grass I measured the green and after drying the dry volume of the samples.

Considering that at some parts of the great pasture of Hajdúbagos grazing was in progress throughout the research period and also on nowadays, during grass production examinations I only evaluated the grass yields of those quadrates that were established at non grazed area sections. This solution was necessary as defending the quadrates against grazing animals was not realizable. In the grass production evaluations I did not reckon with the yield of those three quadrates either that were developed at a unique part of the pasture, at the closer habitat of the strictly protected Hungarian pasque flower (*Pulsatilla hungarica*). During since the blooming and ripening of this species I had to leave out these quadrates from the examination and therefore the yield of these quadrates could distort the grass production results.

### 2.3. Estimating the animal carrying capacity of the examined pasture

When estimating the animal carrying capacity of the examined pasture I took the yield of the certain increments as a basis. I planned the utilization of the pasture 6 times, namely in 6 rotations during the 210 days grazing period. In calculating the fodder demand of the animals I followed that general rule according to which the green grass consumption of a ruminant animal is approximately 10% of its body weight per one day. *Kertész* (1993) determined this value in 7 kg green grass (1.7 kg *d.m.*) for a ewe daily, and *Béri* (1993) in 60 kg green grass (13-14 kg *d.m.*) for a milking cattle also per one day. *Szemán* (2008) contributes to this with that statement that to the grass consumption of 10% of the total animal weight approximately 20% of the consumed grass should be added as trampling loss.

### 3. IMPORTANT STATEMENTS OF THE DISSERTATION

#### 3.1. Weather data

By evaluating the weather data that are important for the grass production model (monthly global solar radiation sum, monthly minimum, maximum and average temperature, monthly precipitation sum, monthly average relative air humidity, monthly average wind speed and daily values of potential evapotranspiration) it can be stated that the examination year 2007 differed greatly from the other two examination years with its unfavourable, often extreme weather conditions.

The monthly sum of the global radiation data ran similarly in 2005 and in 2006 and the yearly sums are also close to each other, while in 2007 the annual sum of the global radiation data considerably exceeded the data counted for the previous two years.

The average temperature of the examined years increased constantly, however grass production should not be connected only with the run of the average temperature data, it is important to evaluate the change of the monthly minimum and maximum temperature values as well. In the summer period of 2007 rather high temperatures occurred and the monthly minimum temperatures also exceeded the values of preceding two examination years.

The quantity of precipitation was notably less in 2007 according to the first two years of examination and besides this slight amount, the distribution of precipitation was especially rhapsodic.

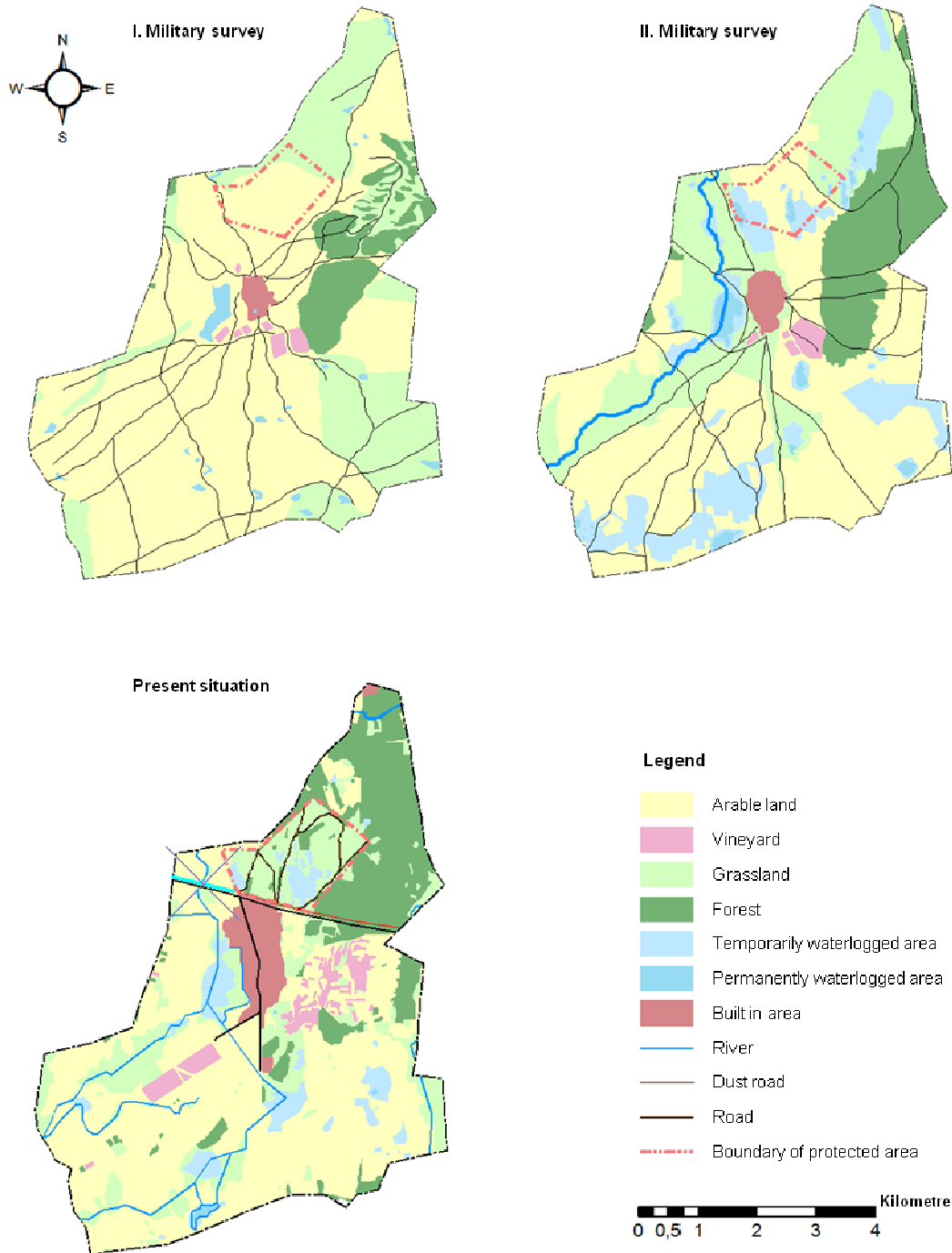
The first two examined years were similar also in the run of the monthly average relative air humidity values, while in 2007 the air humidity data were below the values measured in the previous two years almost in every calendar month.

There is no big difference between the average monthly wind speed figures of the examined three years. However in the unfavourable year of 2007, the slightly higher monthly average wind speed values could have a considerable effect on the production of grass plants as this relatively high volume of wind could contribute to the poor water management of the grass plants in the dry and warm year of 2007 with low air humidity values what leads to the decrease of production.

The values of potential evapotranspiration were rather equal in the first two examination years, and were not similar in the biggest part of the years to the PET data of 2007. In this last year, water utilization was adverse too, what could be followed throughout the run of realized grass production.

### 3.2. Land historical examinations

The historical and present maps representing the examined area are telling a lot about land use changes (*Figure 2*).



*Figure 2. Maps created for the examination area by the I. and II. Military surveys and present maps*

According to the GIS examinations, the area of the examined pasture once was arable land thus the protected area cannot be regarded as primeval grassland,

what is necessary to be considered in its management. The changes in the façade of the area that can be followed on the maps indicate that the present pasture was not always waterlogged, thus certain opinions according to which the water supplementation of the area and the alteration of its water management characteristics are very important are not necessarily consistent.

During my archival examinations I aimed to survey the characteristics and changes of livestock of the examined area and found that between 1750 and 1955 there were properly a lot of sheep in the property of the farmers Of Hajdúbagos village. Beside sheep, the number of cattle and horse that were grazed on the grasslands around the settlement was always considerable. From the archival examinations it can be also stated that the livestock of the territory decreased significantly during the last century.

### 3.3. Botanical data

According to the botanical survey accomplished at the great pasture of Hajdúbagos I found all together 104 plant species from which I could precisely identify 102 species. I recorded the data of these species, which could be useful for developing the management suggestions for the examined pasture, in a coenological database. The coenological table contains the Hungarian and scientific names, families, nature conservation value categories, life form types, temperature and water management and soil reaction values, as well as the cover of the plant species per quadrates.

By the results of the botanical examinations it can be stated that the botanical character of the great pasture of Hajdúbagos is determined by plant species in four families. The great mass of the species found at the examination area are from the *Asteraceae* and *Poaceae* families, while *Fabaceae* and *Labiatae* families are also numerous in species. According to the coverage vales the most multitudinous species is bermudagrass (*Cynodon dactylon*), however pseudovina (*Festuca pseudovina*) and narrow-leaved meadow-grass (*Poa angustifolia*) can be considered mass species as well. During grass typing the dominancy of grass plants was proved, and it was also stated that the occurrence of legumes is rather rare. These plants could be found mainly at the lower and lowest location areas, particularly in spring time. The mean coverage of the potential weeds in the examination quadrates is around 10-12%, while the proportion of the harmful absolute weeds is relatively low. By the analysis of the nature conservation value categories of the examined plant species I stated that however the area preserves its natural status strong degradation effects endanger this state (*Table 1*).

Table 1. Grouping of the plant species found at the great pasture of Hajdúbajos according to the nature conservation value categories

Nature conservation value categories	Pc.	%
<i>Referring to natural conditions</i>	<b>39</b>	<b>43.33</b>
association forming species	6	6.67
accompanying species	28	31.11
pioneer species	5	5.55
<i>Referring to degradation</i>	<b>51</b>	<b>56.66</b>
disturbance tolerant species	25	27.77
weed species	26	28.89
<b>Total species</b>	<b>90</b>	<b>100</b>

### 3.4. Grass production data – the grass model

With the help of the hypothetical grass model elaborated to the examined pasture by using its weather, soil and botanical features, calculations that would be difficult and expensive in practice could be completed. Among others, the potential grass production, namely that theoretically possible yield can be determined, that depends on the photosynthetic active radiation, on the age of the plant, on the temperature, as well as on the value of water and nitrogen stress (Table 2).

The data of the table show markedly the differences caused by the cropyear effect. The most significant difference is between the annual total yields of the three examined years. While the simulated annual yield was some 270 g m<sup>-2</sup> (2.7 t ha<sup>-1</sup>) dry matter in 2005, in the more favourable year of 2006 it was 346 g m<sup>-2</sup> (3.46 t ha<sup>-1</sup>) *d.m.* The annual yield of 2007 was extremely less than the previous years', that time only 52 g m<sup>-2</sup> (0.52 t ha<sup>-1</sup>) *d.m.* was the quantity of the total yield.

As one of the main aims of my research is to determine the animal carrying capacity of the examined pasture, it is important to take the grass yield into consideration by increments. By the data of Table 2 it could be observed that in the first examination year the simulated cut of the grass was possible three times, while in the year of 2006 with more favourable cropyear effect four cut could have been simulated. The data also shows that the grass production of the first increment was the highest in both years, and that after the summer scorch period, the wet weather still resulted in higher grass production. In the year of 2007 with very low grass production, the average grass height was above the level that is needed for cutting only once during the whole year.

Table 2. Simulated grass productions in the examined years

Date of mowing	Grass yield d.m. [g m <sup>-2</sup> ]	Hay [g m <sup>-2</sup> ]	Green mass [g m <sup>-2</sup> ]
11.05.2005	188.08	218.70	626.93
15.06.2005	30.20	35.11	100.66
20.07.2005	52.05	60.52	173.49
24.08.2005	0.00	0.00	0.00
28.09.2005	0.00	0.00	0.00
02.11.2005	0.00	0.00	0.00
<b>Σ 2005</b>	<b>270.33</b>	<b>314.33</b>	<b>901.07</b>
11.05.2006	257.72	299.67	859.06
15.06.2006	49.88	58.00	166.27
20.07.2006	8.68	10.10	28.94
24.08.2006	30.12	35.02	100.39
28.09.2006	0.00	0.00	0.00
02.11.2006	0.00	0.00	0.00
<b>Σ 2006</b>	<b>346.40</b>	<b>402.79</b>	<b>1154.66</b>
11.05.2007	0.00	0.00	0.00
15.06.2007	52.19	60.68	173.95
20.07.2007	0.00	0.00	0.00
24.08.2007	0.00	0.00	0.00
28.09.2007	0.00	0.00	0.00
02.11.2007	0.00	0.00	0.00
<b>Σ 2007</b>	<b>52.19</b>	<b>60.68</b>	<b>173.95</b>
<b>ΣΣ</b>	<b>668.91</b>	<b>777.80</b>	<b>2229.69</b>

I carried out the model validation with the comparison of the simulated and measured grass production data (Table 3), as the results of the model are more precise if they are close to reality.

The grass production data are included in the table in two different ways and in two different units. In the first block there are the grass production data calculated by the model. In the second block I indicated the grass production data that I collected at the examination area through the series of test mowing in the average of those 15 quadrates what were not grazed during the examination period. The two different production data are given either in g m<sup>-2</sup> or in t ha<sup>-1</sup> units.

In the table there are no production data from test cutting in 2005, because in this year I did not perform test mowing at the examination area. However from the data of the other two examination years it is apparent that the potential grass production data are close to the realized production data and to other research results. The difference between the simulated and realized production data fulfils the requirements of plant production models.

Table 3. Run of the grass production data estimated by model simulation and collected through the series of test mowing during the examination period

Date of mowing	Simulated grass production		Realized grass production (15 not grazed quadrat)	
	Yield d.m. [g m <sup>-2</sup> ]	Yield d.m. [t ha <sup>-1</sup> ]	Yield d.m. [g m <sup>-2</sup> ]	Yield d.m. [t ha <sup>-1</sup> ]
11.05.2005	188.08	1.88	-	-
15.06.2005	30.20	0.30	-	-
20.07.2005	52.05	0.52	-	-
24.08.2005	0.00	0.00	-	-
28.09.2005	0.00	0.00	-	-
02.11.2005	0.00	0.00	-	-
<b>∑ 2005</b>	<b>270.33</b>	<b>2.70</b>	-	-
11.05.2006	257.72	2.58	277.77	2.78
15.06.2006	49.88	0.50	28.65	0.29
20.07.2006	8.68	0.09	21.13	0.21
24.08.2006	30.12	0.30	32.00	0.32
28.09.2006	0.00	0.00	0.00	0.00
02.11.2006	0.00	0.00	0.00	0.00
<b>∑ 2006</b>	<b>346.40</b>	<b>3.46</b>	<b>359.55</b>	<b>3.60</b>
11.05.2007	0.00	0.00	0.00	0.00
15.06.2007	52.19	0.52	41.50	0.42
20.07.2007	0.00	0.00	0.00	0.00
24.08.2007	0.00	0.00	0.00	0.00
28.09.2007	0.00	0.00	0.00	0.00
02.11.2007	0.00	0.00	0.00	0.00
<b>∑ 2007</b>	<b>52.19</b>	<b>0.52</b>	<b>41.50</b>	<b>0.42</b>
<b>∑∑</b>	<b>668.92</b>	<b>6.69</b>	<b>401.05</b>	<b>4.01</b>

After the validation of the grass production model by the comparison of the model results with the realized grass production data, it can be considered consistent. By using the data of the grass model the animal carrying capacity of the pasture can be determined even by increments.

As I explained in the chapter on the method for calculating animal carrying capacity (see 2.3. *Estimating the animal carrying capacity of the examined pasture*), I estimated the grass production of the pasture by increments by taking the utilization periods of the 210 days sheep grazing term divided into 6 rotations as a basis. Table 4 contains the green grass production of the increments simulated by the grass model and the calculation of the animal carrying capacity which is among 0.99-6.55 ewe ha<sup>-1</sup> and 0.12-0.76 cow ha<sup>-1</sup> in the average of the examined three years.

Table 4. Calculation of the sheep and cattle carrying capacity of the examined pasture by using the simulated grass production data

Simulated grass production			Sheep carrying capacity [ewe ha <sup>-1</sup> ]	Cattle carrying capacity [cow ha <sup>-1</sup> ]
Date of mowing	Green grass yield [g m <sup>-2</sup> ]	Green grass yield [kg ha <sup>-1</sup> ]		
11.05.2005	626.93	6269.31	21.32	2.49
15.06.2005	100.66	1006.58	3.42	0.40
20.07.2005	173.49	1734.86	5.90	0.69
24.08.2005	0.00	0.00	0.00	0.00
28.09.2005	0.00	0.00	0.00	0.00
02.11.2005	0.00	0.00	0.00	0.00
<b>Σ 2005</b>	<b>901.07</b>	<b>9010.75</b>		
11.05.2006	859.06	8590.64	29.22	3.41
15.06.2006	166.27	1662.71	5.66	0.66
20.07.2006	28.94	289.41	0.98	0.11
24.08.2006	100.39	1003.86	3.41	0.40
28.09.2006	0.00	0.00	0.00	0.00
02.11.2006	0.00	0.00	0.00	0.00
<b>Σ 2006</b>	<b>1154.66</b>	<b>11546.62</b>		
11.05.2007	0.00	0.00	0.00	0.00
15.06.2007	173.95	1739.52	5.92	0.69
20.07.2007	0.00	0.00	0.00	0.00
24.08.2007	0.00	0.00	0.00	0.00
28.09.2007	0.00	0.00	0.00	0.00
02.11.2007	0.00	0.00	0.00	0.00
<b>Σ 2007</b>	<b>173.95</b>	<b>1739.52</b>		
<b>ΣΣ</b>	<b>2229.69</b>	<b>22296.89</b>		

As it can be seen from the data of the table there are significant differences between the animal carrying capacity of the increments of the certain years. It is certified that the carrying capacity calculated by increments gives more accurate results, as the carrying capacity based on the annual grass yield assumes the balanced distribution of the yield among the grass increments.

With the help of the grass production model the optimal utilization of the pasture can be determined easily (Table 5). In case I simulated less or more utilization than 6 rotations throughout the 210 days sheep grazing period, I got different grass production data. In the displayed table the first 6 versions should be taken into account seriously as only these versions have practical significance. The other solutions are interesting from a model technology view. I ran the modelling of the effect of the altered number of simulated grass mowing on grass production with Jdate = 131, namely the 10<sup>th</sup> of May as a starting date, according to the basic settings. However if we plan the harvest later during the year, the simulated production of the grass will be higher.

Table 5. Run of the potential grass production with changing the grass utilization intervals (if the date of the first mowing is  $Jdate=131$ )

Simulated mowing by the piece/year	2005		2006		2007		$\Sigma\Sigma$	
	Yield d.m. [g m <sup>-2</sup> ]	Yield d.m. [t ha <sup>-1</sup> ]	Yield d.m. [g m <sup>-2</sup> ]	Yield d.m. [t ha <sup>-1</sup> ]	Yield d.m. [g m <sup>-2</sup> ]	Yield d.m. [t ha <sup>-1</sup> ]	Yield d.m. [g m <sup>-2</sup> ]	Yield d.m. [t ha <sup>-1</sup> ]
1	188.08	1.88	316.97	3.17	0.00	0.00	<b>505.05</b>	<b>5.05</b>
2	230.89	2.31	312.08	3.12	57.34	0.57	<b>600.31</b>	<b>6.00</b>
3	267.25	2.67	322.18	3.22	110.16	1.10	<b>699.59</b>	<b>7.00</b>
4	252.46	2.53	358.94	3.59	89.77	0.90	<b>701.17</b>	<b>7.01</b>
5	305.83	3.06	337.48	3.38	57.06	0.57	<b>700.37</b>	<b>7.00</b>
6	270.32	2.70	346.40	3.46	52.19	0.52	<b>668.91</b>	<b>6.69</b>
7	257.82	2.58	310.42	3.10	35.47	0.36	<b>603.71</b>	<b>6.04</b>
8	213.73	2.14	296.65	2.97	40.18	0.40	<b>550.56</b>	<b>5.51</b>
9	214.24	2.14	286.88	2.87	32.62	0.33	<b>533.74</b>	<b>5.34</b>
10	214.61	2.15	287.18	2.87	52.43	0.52	<b>554.22</b>	<b>5.54</b>

By examining the simulated grass production of the studied pasture with changing the grass utilization intervals, I stated that however the 6 rotations by 35 days within the general 210 days sheep grazing period is favourable for the grass plants as rather high grass yield can be ensured with this schedule, but higher yield could be reached with less utilization at the examined pasture.

These results should be taken into consideration during planning the management of the protected pasture even if the management objective here is not to reach the possibly highest economic benefit but to preserve the favourable natural status of the area.

#### 4. NEW AND NEWLY DETERMINED RESULTS OF THE DISSERTATION

The new and newly considered results of my examinations, that I carried out to establish suggestions to the management strategy of protected grasslands that serve predominantly nature conservation objectives but do not neglect rural and regional development aspects, could be summarized as the followings:

##### 4.1. New results of the dissertation

- The geo-database compiled to the studied area became suitable for running land calculation algorithms according to land use categories. By these results, to create land cover timelines in case of the certain land use categories became possible. By the map and table data of the GIS database it is apparent that in the land use of the examined area significant changes happened throughout the past two and a half centuries.
- With the help of the hypothetical grass model elaborated to the examined pasture after collecting weather, soil and botanical data that are characteristic to the area of the great pasture of Hajdúbagos, grass yield estimations became possible.
- The grass yield estimated by the grass production model was altogether  $6.69 \text{ t ha}^{-1}$  during the examined three years, expressed in dry matter. The simulated grass production of the certain examination years were  $2.7 \text{ t ha}^{-1}$  (2005),  $3.46 \text{ t ha}^{-1}$  (2006) and  $0.52 \text{ t ha}^{-1}$  (2007). These values are close to the realized production data.
- By changing the grass mowing intervals I proved that the utilization of the grass production in 6 rotations during the 210 days sheep grazing period is not the most appropriate management method at the examined pasture, as in all the three examination years the less, usually the three-four utilization resulted in the greatest quantity of grass yield.

#### 4.2. Newly determined results of the dissertation

- By the results of the botanical examinations it can be stated that the botanical character of the great pasture of Hajdúbagos is determined by plant species in four families. The great mass of the species found at the examination area are from the *Asteraceae* and *Poaceae* families, while *Fabaceae* and *Labiatae* families are also numerous in species. According to the coverage vales the most multitudinous species is bermudagrass (*Cynodon dactylon*), however pseudovina (*Festuca pseudovina*) and narrow-leaved meadow-grass (*Poa angustifolia*) can be considered mass species as well. During grass typing the dominancy of grass plants was proved, and it was also stated that the occurrence of legumes is rather rare. These plants could be found mainly at the lower and lowest location areas, particularly in spring time. The mean coverage of the potential weeds in the examination quadrates is around 10-12%, while the proportion of the harmful absolute weeds is relatively low. By the analysis of the nature conservation value categories of the examined plant species I stated that however the area preserves its natural status strong degradation effects endanger this state.
- According to the GIS examinations, the area of the examined pasture once was arable land thus the protected area cannot be regarded as primeval grassland, what is necessary to be considered in its management. The changes in the façade of the area that can be followed on the maps indicate that the present pasture was not always waterlogged.
- The annual run of the grass yield calculated by the grass production model reflects the significant effect of the cropyear on the quantity of the yield.
- By the simulated grass production data, the animal carrying capacity of the studied pasture is among 0.99-6.55 ewe ha<sup>-1</sup> and 0.12-0.76 cow ha<sup>-1</sup> in the average of the examined three years, however there are significant differences between the animal carrying capacities of the certain increments. Basing on this result I stated that at the examined pasture it is advisable to make the calculation by increments instead of estimating the animal carrying capacity of the annual grazing period which assumes the evenly division of the yearly total grass yield.

## 5. PRACTICAL USEFULNESS OF THE RESULTS

From my examinations the grass production model that was developed with full knowledge of the weather, soil and botanical characteristics of the studied protected pasture is of overriding importance. With the help of the hypothetic grass model calculations, which would be difficult and expensive in practice could be completed. By using the grass production model I determined the potential grass production, namely that theoretically possible yield that depends on the photosynthetic active radiation, on the age of the plant, on the temperature, as well as on the value of water and nitrogen stress. The potential grass production data are close to the realized production data and to other research results. To develop the compiled model one possibility is to validate it with realized grass production data collected through a longer period and even from more different examination areas. The developed model could be suitable to simulate the grass production of areas with different position, characteristics and dissimilar management.

With comparing the run of the weather data and the realized grass yield I stated that the effect of the cropyear significantly influence the quantity of the yield, what should be taken into consideration in case of a protected pasture where besides grazing and the occasional mowing no other grass management methods (e.g. artificial fertilizing, irrigation) are permitted. By examining the effect of the weather data I also stated that water stress has a considerable effect on grass yield as well.

In practice it is of very high importance that by the grass model the production of the certain increments could be determined rather easily and fast, what could be used for calculating the animal carrying capacity and through this to elaborate the optimal management strategy for the examination area.

My land historical examinations also own practical importance by supporting the planning and carrying out of nature conservation management and restoration activities.

My suggestions to the management of the studied protected pasture serve predominantly nature conservation objectives but do not neglect rural and regional development aspects, thus could promote the improvement of the possibilities for the local population in agricultural production and in income increase, the management strategies for the protection of nature conservation values as well as the planning of habitat reconstruction activities. Therefore nature conservation and the social-economic interests could be harmonized what is an essential element of the future nature conservation activity.

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