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Summary of a Doctoral (Ph.D.) Thesis

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EFFECTS OF DIFFERENT PASTURE UTILIZATION INTENSITIES ON THE SOIL AND THE VEGETATION OF GRASSLANDS

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I. INTRODUCTION

12% of Hungary's total area is grassland, which means 1.1 million hectares. 70% of these grasslands have low productivity and only 5% are involved in the high productivity category. The main reason behind this is that grassland soils have low fertility, and semiarid conditions. Consequently, more than half of the Hungarian pasture lands are utilized by low input grassland management.

Several domestic animal species are grazed, but breeds bred and improved on grassland are of the greatest significance. Moreover, grassland, a place for living and nutrition, meets the requirements of native breeds. Recently, the role of indigenous breeds, such as the Hungarian Grey Cattle, has become increasingly important. Its significance is raising as the requirements for meat quality and "hungarikum" products is increasing. These breeds are the most appropriate for keeping the pasture in good condition and maintaining the landscape of countryside.

Grasslands of Hungary could supply grass for more animals than there are now, but we have to consider that one herd is grazing on one pasture, that means locally sites could be overgrazed, overutilized. When we plan the stocking rate for a certain land we have to take into account the grass production.

Grazing should be managed in such a way that deterioration will not occur neither on vegetation nor soil.

In an environmental point of view, the above mentioned are the most important on protected grasslands, that means 200,000 ha area in Hungary. Nature conservation requires such a grassland management that will not decrease the biological diversity and will not alter the characteristics of landscape or degrade the land.

We have to know the impacts of selective grazing of ungulates, treading, nutrient content of faeces and urine on grassland soil and vegetation for fulfilling all these requirements.

Our aim was to investigate the effects of different grazing intensities on grassland soil and vegetation. The experiment was conducted on natural grasslands of Hortobágy National Park with Hungarian Grey Cattle herd.

We measured the effects of cattle grazing/pressure on soil characteristics such as penetration resistance, some chemical parameters, the changes of chemical parameters in time, vegetation cover, biodiversity, nutritional value and botanical composition of pasture.

The determination of the macro- and microelement content of cow hair was also involved in our work.

Samples were collected not only from the grazed parts of grassland, but from the favoured places of animals such as watering place, animal camp and tracks.

II. MATERIALS AND METHODS

Two grasslands on Hortobágy National Park utilized by Hungarian Grey Cattle were chosen for the experiment. Both pasture lands were utilized by free range grazing with 200 cows and their offspring. Grazing was started in 1993 on Gyökérkút pasture land, and five decades ago on Sárkány pasture land. Both soil types were meadow solonetz. Soil and plant samples were collected at parts of the grassland which were exposed to different animal pressures, these were chosen after ethological survey (Table 1. and 2.).

Table 1.

Sampling places of Gyökérkút grassland

Name	**Intensity of pasture utilization**	**animalunit-day/m^2**
Pasture	low	0.01
Pasture	medium	0.05
Watering place	intensive	5.5
Animal track	intensive	3

Table 2.

Sampling places of Sárkánykút grassland

Name	Intensity of pasture utilization	animalunit-day/m^2
Pasture	low	0.01
Pasture	medium	0.08
Animal camp	intensive	7

Soil samples were taken from three vertical layers: 0-20 cm, 20-40 cm, 40-60 cm. Four replicates per treatment were analyzed, each analyzed sample were made of 5 soil cores. Soil cores and replicates created a diagonal line. Soil penetration resistance was measured in ten replicates per treatment in April 2002. Botanical measurements meant four replicates per treatment. Sampling dates were April 2001, November 2001, April 2002, November 2002, and April 2003.

The fresh faeces samples were collected from 4-4 cows in June and October 2002. Urine samples were derived from 3 cows of Sárkány herd. 6-6 cows' hairs from both herds were collected in December 2002.

Soil penetration resistance was measured of the physical characteristics (DARÓCZI – LELKES, 1990). The measured chemical parameters were the followings: pH (BUZÁS et al., 1988), water soluble total salt content (LUKÁCS – RÉDLY, 1988b), organic C% (HARGITAI, 1988a), total nitrogen (HARGITAI, 1988b), nitrate-nitrogen (FELFÖLDY, 1987), ammonium-nitrogen (FILEP, 1995), Lakanen-Erviö soluble (LE) (MSZ 21470-50:1998) and total element content (KOVÁCS et al., 2000) of phosphorus, sulphur, potassium, cobalt, copper, iron, manganese and zinc.

Vegetation cover and botanical composition were measured by the method: BALÁZS (1949). Results were evaluated by BARCSÁK et al. (1978), HARASZTI (1977), BARCSÁK (1988), SZODFRIT et al. (1993), NAGY (2003).

Element content of cow hair, faeces, urine were determined by KOVÁCS et al. (1996).

Data were evaluated by SAS software: mean and standard deviation (SAS, 1999a), one-way anova and t-test (SAS, 1999b). Descriptive statistics were used for the evaluation each investigated parameter. One-way anova and t-test were applied for soil, hair, faces and botanical composition.

III. RESULTS

The effects of grazing on soil penetration resistance

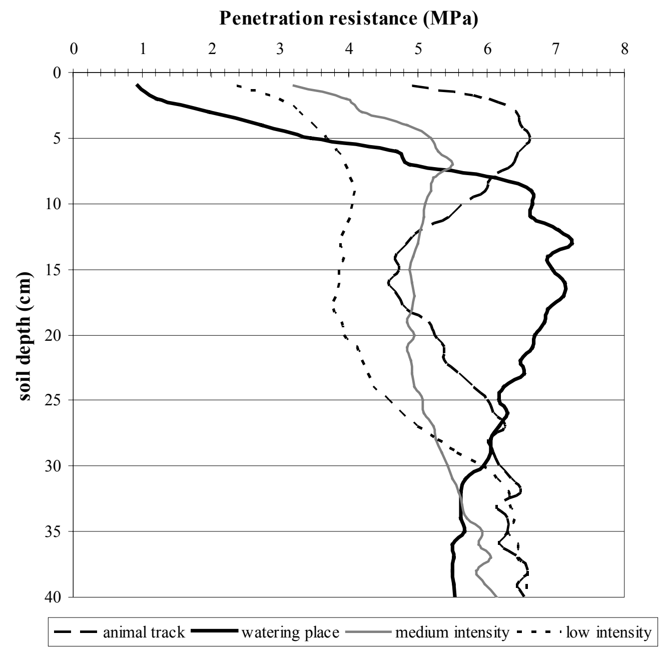
Higher grazing pressure induced higher soil penetration resistance (Diagram 1.). Penetration resistance of the upper some centimetres of soil at watering place (1-2.5 MPa) and animal camp (0.5 MPa) was higher than at the other sites of grassland (2-4 MPa). This loose soil structure derives from the continuous movement of cattle, as hooves do not compact this layer but loosen it. Penetration resistance increased with soil depth. Its value at animal camp did not differ from other parts of the grassland in deeper layers, however the values of 9-25 cm were significantly higher at watering place than at sites with least animal pressure. Penetration resistance of soil at animal camp was not higher than at the grassland, because, in contrast with the watering place, cattle lays here consequently the weight of animals makes contact to soil on a relatively large surface.

The soil of animal track is heavy and compacted in the upper layer, deeper in the soil penetration resistance did not differ from the value of grassland with less animal pressure. Deeper layers were not compacted as tracks are used for 1-2 years, so there are no long term effects.

The medium grazing pressure does not increase the soil penetration resistance comparing to the low grazing intensity.

Diagram 1.

Soil penetration resistance at Gyökérkút grassland (2002.)



The effects of grazing on soil pH

The pH of acid grassland soil has been shifted to the neutral zone by the high density of ungulates on Gyökérkút grassland. Grazing intensity did not influence significantly the pH of alkaline soil on Sárkány grassland, but a tendency can be seen that is converse of the one that has been established on Gyökérkút. Consequently we supposed that urine and faeces converge soil pH to the neutral value.

Soil pH at medium grazing intensity did not differ from pH of grassland soil utilized by low intensity.

The effects of grazing on soil salt content

Medium grazing intensity did not increase soil salt content comparing to low animal pressure (Diagram 2. and 3.)

Soil salt% at 0-20 cm depth was higher at animal track, watering place and animal camp than at the other sites of pasture. The difference was tenfold between the lowest and highest animal density.

Salt concentration of soil at watering place and animal camp decreased as depth increased. The tendency of the changes in soil salt content at the other sample sites was contrary to the treatments mentioned before. Namely, the salt accumulation zone of solonetz soil is in the deep layers.

Diagram 2.

Soil salt content in different depth at areas of pasture utilized with different intensities. (Gyökérkút, %)

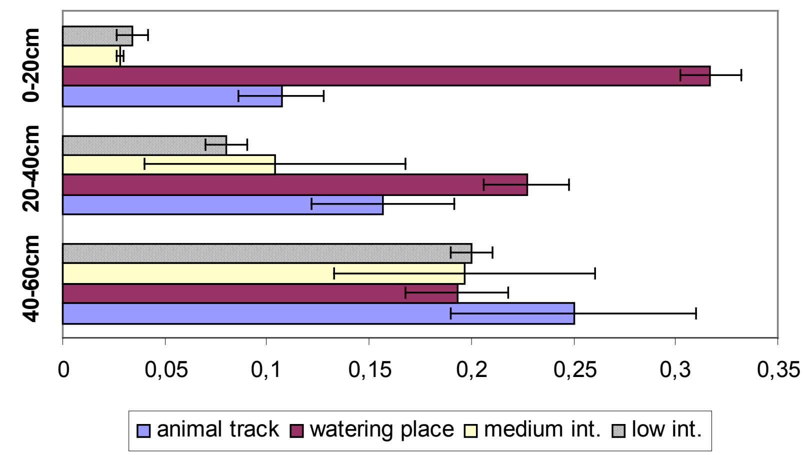
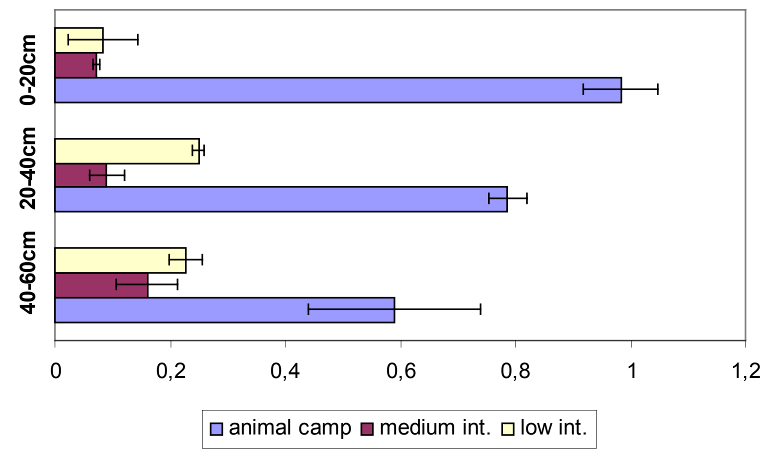


Diagram 3.

Soil salt content in different depth at areas of pasture utilized with different intensities. (Sárkánykút, %)



The effects of grazing on soil organic carbon

Higher grazing pressure has increased soil organic carbon on both experimental pastures. Soil organic carbon% of watering place (Gyökérkút), medium grazing intensity and animal camp (Sárkány) differed from sites of pasture where cattle spend time only for grazing. The reason for higher soil organic C content at medium than low grazing intensity on Sárkány pasture is the long grazing regime.

On Sárkány pasture grazing intensity had no significant effect on organic C content of soil deeper than 20 cm and less concentrations were determined at high animal pressure treatment than at the other sites of Gyökérkút grassland.

The effects of grazing on soil nitrogen content

Soil (0-20 cm) total nitrogen concentration of watering place and animal camp were higher than of areas covered by vegetation. Medium grazing intensity increased soil total nitrogen content on Sárkány grassland, but the same treatment on Gyökérkút, that means a lower animal pressure, did not influence the investigated soil property.

The concentration of soil total nitrogen has decreased as sample depth increased. Values at watering place (Gyökérkút) were significantly higher only in the upper soil layer comparing to other grassland areas, however differences were found in the whole sampled depth (0-60 cm) between high and low grazing intensity on Sárkány grassland.

Soil ammonia concentration at sites of low grazing intensity did not differ from sites of medium grazing intensity. Soil ammonia content was in some cases higher at animal tracks and in all cases at watering place than at other areas of Gyökérkút pasture.

The higher the animal pressure the higher the ammonium-nitrogen concentration was of the upper soil layer on Sárkány pasture. Ammonia derived form excreta did not exist deeper in the soil.

As it has been discussed above, grazing pressure influenced the concentration of ammonium-nitrogen and it had the same effect on the concentration of soil nitrate-nitrogen, except at overgrazed areas where higher nitrate concentration was measured also deep in the soil (Table 3. and 4.).

Soil ammonium-N and nitrate-N increased in the vegetation period then significantly decreased in winter at the overutilized watering place (Table 5.).

Table 3.

Soil nitrate-N content in different depth at areas of pasture utilized with different intensities. (Gyökérkút, mg/kg)

Depth (cm)	Low animal pressure		Medium animal pressure		Watering place		Animal track	
	mean	std	mean	std	mean	std	mean	std
0-20	2.70 a	1.31	2.77 a	2.12	20.83 b	6.32	14.73 b	4.36
20-40	1.83 a	0.929	1.50 a	0.173	14.63 b	3.40	11.87 b	5.37
40-60	2.07 a	0.252	1.67 a	0.404	17.00 b	3.46	10.17 b	3.38

Different abc letters mean the statistical significance at 0.05 level

Table 4.

Soil nitrate-N content in different depth at areas of pasture utilized with different intensities. (Sárkánykút, mg/kg)

Depth (cm)	Low animal pressure		Medium animal pressure		Animal camp	
	mean	std	mean	std	mean	std
0-20	1.27 a	0.764	8.23 b	2.42	11.20 b	1.48
20-40	0.900 a	0.361	3.80 b	0.781	4.66 b	0.115
40-60	1.87	0.929	2.00	0.529	1.23	0.404

Different abc letters mean the statistical significance at 0.05 level

Table 5.

Soil nitrate-N content in the 0-20 cm layer at areas of pasture utilized with different intensities. (Gyökérkút, mg/kg)

Sampling date	Low animal pressure		Medium animal pressure		Watering place		Animal track	
	mean	std	mean	std	mean	std	mean	std
04. 2001.	2.08 a	1.15	2.53 a	0.54	15.86 b	4.03	12.47 b	3.38
11. 2001.	2.98 a	0.348	2.69 a	0.594	29.99 c	4.72	18.63 b	4.55
04. 2002.	2.70 a	1.31	2.77 a	2.12	20.83 b	6.32	14.73 b	4.36
11. 2002.	3.27 a	0.874	8.33 ab	4.22	33.93 c	3.82	10.47 b	2.67
04. 2003.	3.53 a	2.10	4.17 a	0.74	16.77 b	8.20	11.56 ab	4.57

Different abc letters mean the statistical significance at 0.05 level

The effects of grazing on soil phosphorus, potassium and sulphur content

The Lakanen-Erviö soluble (LE) and total phosphorus, potassium and sulphur content of soil has increased as grazing pressure increased on both experimental grassland, but not all the differences between treatments were statistically confirmed.

P, S, K concentrations of soil at low grazing intensity did not differ from the ones at medium grazing intensity on Gyökérkút grassland. In Sárkány pasture, Lakanen-Erviö soluble P, K (Table 6.) and total P, S concentrations of soil differed between treatments.

Phosphorus, potassium and sulphur content of soil were higher at overgrazed areas of grassland, such as animal camp and watering place than at certain areas of pasture used only as grass source for cattle on both pastures.

Rotation of summer and winter made some changes only in LE K concentration of 0-20 cm soil. Plant available potassium content of soil increased from spring to autumn and then decreased to spring because of the vertical movement at the overutilized sites of pasture.

The differences in soil P content between treatments were significant only in the upper layer (0-20 cm). Soil sulphur and potassium content were higher at overgrazed areas than at low grazing intensity on Gyökérkút pasture in the 0-40 cm layer and on Sárkány in the 0-60 cm layer. However, plant available sulphur content of soil did not give a definite tendency in the 20-60 cm layer.

Table 6.

Soil potassium content in different depth at areas of pasture utilized with different intensities. (Sárkánykút, mg/kg)

Depth (cm)	Low animal pressure		Medium animal pressure		Animal camp	
	mean	std	mean	std	mean	std
	Lakanen-Erviö soluble K					
0-20	126.0 a	31.00	532.7 b	13.01	3485 c	314.7
20-40	71.13 a	31.66	155.3 a	30.99	696.3 b	78.83
40-60	87.70 a	8.20	67.07 a	26.95	168.7 b	30.24
	Összes K					
0-20	3804 a	390.6	4158 a	92.71	6742 b	603.0
20-40	3801 a	368.2	4238 a	421.6	5938 b	86.38
40-60	3324 a	138.2	3656 b	72.23	5247 c	21.70

Different abc letters mean the statistical significance at 0.05 level

The effects of grazing on soil micronutrient status

The cobalt, zinc and copper content of soil at different treatments showed no animal pressure effect on none of the experimental grasslands.

Equipments, devices connected to grazing management can be found at certain areas of pasture such as watering place and animal camp. It is supposed that higher iron content of soil was not caused by animal activity but grazing iron devices.

Soil total manganese concentration of investigated microelements was least at overgrazed areas of pasture.

The effects of grazing on grassland vegetation

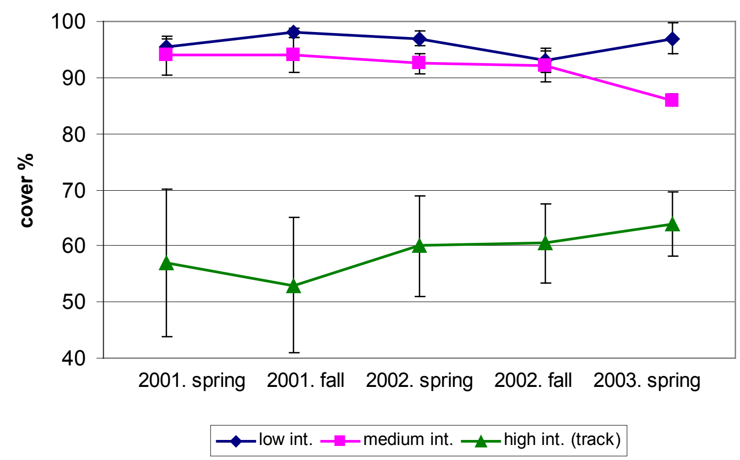
Plant species richness at grassland area utilized by medium grazing intensity did not differ from the one at low grazing pressure on Gyökérkút pasture. Less plant species were found in animal tracks, as only some plants tolerated high trampling pressure. There were no possibilities for germination of plants at the watering place of herd, because of the physical effects of cattle, on more than

1000 m^2. Grazing intensity influenced the number of plant species, as higher animal pressure resulted in more grass, and dicotyledon other than legume species on Sárkány pasture. This grassland had less plant species comparing to Gyökérkút, where twice more species were observed.

Medium, comparing to low grazing intensity, decreased the vegetation cover by some percent, that still remained above the 90 percent, but the changes were not significant in all cases (Diagram 4.). Animal trampling significantly suppressed the vegetation on animal tracks, the rate of the bare soil was approximately 40%. Grazing intensity did not change the vegetation cover at Sárkány pasture, due to the low vegetation cover characteristic to the whole pasture.

Diagram 4.

Vegetation cover at pasture areas utilized with different intensities on Gyökérkút pasture (2001 – 2003.)



The long term grazing regime has changed the botanical composition on both pastures. The ratio of grass species was higher at medium than at low grazing intensities at Gyökérkút and Sárkány as well. However legume and other dicotyledon species covered less percent of the surface at medium than at low animal pressure sites, but none of these differences were significant in each experimental year. Legumes did not exist at Sárkány pasture, but the soil cover of other dicotyledons was similar to the one at Gyökérkút, and the differences were significant.

Lower cover percent of legumes and grass species and higher of other dicotyledons, comparing to sites utilized by lower intensities, were characteristics of the vegetation in animal tracks. Grass and also other dicotyledon species were found around the watering place, but legumes did not prefer these conditions.

Based on the nutritional value of species, we consider that the ratio of potential weeds is higher in case of low utilization intensity than at a medium one on Gyökérkút pasture, but the difference was not evident on Sárkány. Medium animal pressure areas were richer in high nutritional value plants than moderate utilized sites on Gyökérkút, but it was not confirmed statistically. This assumption is strengthened by the significant differences found on Sárkány pasture. Weed cover was not affected by medium grazing pressure on Gyökérkút. The existence of Artemisia santonicum in high percentage at low grazing pressure areas on Sárkány caused a high value of potential weed cover.

The highest potential weed and forage plant cover and the lowest weed cover were found in animal tracks. The latter statement is less solid, because of the relatively rare existence.

Macro- and microelement supply of cows

According to the results of hair analyses cows of both herds have adequate supply of P, S, K, Co, Cu, Fe, Mn and Zn elements. Differences were found between herds in iron and manganese supply. The differences in roughage is supposed to be the reason for this.

IV. NEW SCIENTIFIC RESULTS

The consequences of cattle grazing lasting for one and several decades long were investigated on pastures of Hortobágy. Our new results about the effects of different grazing intensities are the followings:

- Moderate grazing intensity does not increase significantly the soil penetration resistance comparing to low grazing intensity. In the case of high grazing pressure the changes of soil penetration resistance depend on the type of site utilization. Soil penetration resistance is high at animal tracks, however it is lower in the upper soil horizon at animal camps and watering places comparing to those parts of the pasture that serve as grass source. Changes are expected to the soil depth of 20-25 cm.

- Grazing intensity influences soil chemical properties.
  Excreta of grazing animals drift the pH of acid soil to the neutral zone.
  High grazing intensity resulted in higher soil water soluble total salt content, organic carbon, total nitrogen, nitrate-nitrogen, ammonium-nitrogen, Lakanen-Erviö soluble and total element content of phosphorus, sulphur, potassium than low and moderate grazing intensity.
  Water soluble total salt content, organic carbon, total nitrogen, nitrate-nitrogen, ammonium-nitrogen, Lakanen-Erviö soluble and total element content of phosphorus, sulphur, potassium of soil at pasture sites utilized by moderate grazing do not differ or in the case of certain circumstances (longer grazing history, more intensive utilization, soil type) these values are higher than at sites of low grazing intensity.

- Water soluble total salt, nitrate-nitrogen, ammonium-nitrogen content of the upper soil layer increase during the grazing period and decrease in winter (no grazing season).

- Moderate grazing intensity decreases plant cover on a pasture with total vegetation cover, but does not change it on a pasture with originally lower plant cover.

- Number of plant species does not differ between sites utilized by moderate and low grazing intensities on pasture of high plant diversity.

- Grazing intensity affects the botanical composition of a pasture. The grass cover is higher, but the cover of legumes and other dicotyledons is less at moderately grazed sites than at sites utilized by low grazing intensity. Pioneer plant species which tolerate high grazing and trampling pressure are Lolium perenne and Polygonum aviculare.

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