Effects of cattle grazing on selected soil chemical and soil physical properties

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Abstract

At present, in Austria there is an attempt to propagate intensive cattle grazing. Therefore, the effects of trampling and cattle grazing on selected soil chemical and physical properties at the scale of a representative paddock in a mountainous region in Austria were investigated. Excessive trampling and cattle grazing lead to a distinct soil compaction especially in the 5-10 cm soil layer, resulting in stagnant water conditions, and to an accumulation of nutrients in topsoil (mainly potassium, phosphorus, boron). Furthermore, there is a permanent transfer of soil nutrients (mainly potassium and nitrogen) and organic matter by grazing cattle within a paddock. Fertilizer recommendations for a sustainable pasture management will be given.

Keywords: soil chemical properties, soil physical properties.

Introduction

Grazing management practices need to be both ecologically and economically sustainable. Therefore, an efficient utilization of fertilizers and a grazing intensity adapted to the site are necessary. The aim of this study was to examine the effects of trampling and cattle grazing on selected soil chemical and physical properties at the scale of a representative paddock in a mountainous region in Austria in order (1) to maintain or increase soil quality, (2) to decrease nutrient losses from pasture soils, and (3) to formulate fertilizer recommendations for a sustainable pasture management.

Materials and methods

This investigation was conducted in the Styrian Enns valley (Austria) at an altitude of 675 m. The climate is relatively cool and humid, with a mean annual air temperature of 6.7 °C and annual precipitation of 1023 mm, of which 60 % falls during the growing season (April-September). The mean monthly temperature varies from –4.5 °C in January to 17.0 °C in July. The soil is a deep, base-rich Cambisol with a loamy sand texture. The paddock investigated has a total area of about 2 ha and had been grazed by dairy cattle (Brown Swiss) five times per grazing season for more than 10 years. The stocking density was approximately 4 cows ha^{-1} during 180 days from early May to the end of October with an average grazing time of about 8 hours per day. The strip grazed permanent pasture was fertilized regularly with farmyard manure, mostly cattle slurry. Within the paddock investigated, three different vegetation types, representing different levels of disturbance were identified. The *Matricario-Polygonetum arenastri* has been developed near the entry to the paddock where trampling intensity is greatest. This vegetation type is characterized by the 'trampled plot' (3x8 m). The 'grazed plots' (5x10 m, three replicates) were distributed in the middle of the paddock and their vegetation belongs to the *Alchemillo monticolae-Cynosuretum cristati*. The 'boundary plot' (0.5x20 m) was located under the fence and the plant species composition can only be referred to the order *Arrhenatheretalia*. The untrampled plot below the fence was grazed during the five grazing periods and had not received farmyard manure or excreta from grazing cattle. During the grazing season soil samples from the 0-10 cm soil layer (A horizon) for chemical analyses were collected before each grazing period (5 analyses of composite samples per plot). At the beginning and the end of the grazing season also soil samples for physical analyses were taken from topsoil. Soil analyses were carried out according to the ÖNORM methods (Austrian Standards Institute). Yield and mineral element content in the harvestable above-ground plant biomass were determined by using standard methods. For each plot, the arithmetic mean and coefficient of variability were calculated.

Results and discussion

Intensive trampling and cattle grazing lead to a soil compaction mainly in the 5-10 cm soil layer (Table 1) and to a degradation of soil structure. The porous crumb structure in the freely drained topsoil of the 'boundary plot' was replaced by a compact platy structure in the imperfectly drained topsoils of the 'grazed plots' and 'trampled plot'. Plant species such as *Ranunculus repens* L, *Agrostis stolonifera* L., and *Poa annua* L. are bioindicators of such compacted, periodically wet topsoils. When comparing the three different plots, the topsoil of the 'trampled plot' had a lower C_{org} content and consequently also a lower N_{tot} content than the topsoils of the 'grazed plots' and the previous two had a higher C_{org} and N_{tot} content than the topsoil of the 'boundary plot' (Table 2). The comparatively lower C_{org} content in topsoil of the 'boundary plot' despite a 5-fold to 8-fold higher below-ground phytomass (data not shown) can be explained by a permanent removal of organic matter due to cattle grazing without a compensatory return by farmyard manure and cattle excreta. The lower annual input of carbon from below-ground phytomass (data not shown) and a higher mean soil temperature seem to be the main reasons for the lower C_{org} content in topsoil of the 'trampled plot' compared to those of the 'grazed plots'. Primarily the topsoil of the 'trampled plot' was enriched with nutrients due to enhanced external inputs with farmyard manure and cattle excreta (Table 2, 3). Especially potassium, phosphorus, and boron are accumulating in topsoil. In the untrampled and unfertilized but grazed 'boundary plot' the nutritional status of the topsoil was very low due to the continuous removal of nutrients by grazing cattle. The long-term effect of this redistribution of nutrients within a paddock is that small areas below the fence become depleted of nutrients, while areas especially near the entry to the paddock accumulate high amounts of nutrients in topsoil, primarily those which are returned in a high degree with cattle excreta (e.g. potassium, phosphorus, boron). On the other side, potassium and nitrogen are depleted from topsoil more easily than phosphorus and sulphur due to a comparatively higher transfer from soil to the harvestable plant biomass (Table 3).

Table 1. Selected soil physical properties (means of 8 analyses and coefficient of variability).

cm	Bulk density (g cm^{-3})			Pore space (%)		
Soil depth	Trampled plot	Grazed plot	Boundary plot	Trampled plot	Grazed plot	Boundary plot
0-5	1.21 (9)	1.06 (14)	0.99 (19)	52 (7)	59 (9)	62 (11)
5-10	1.52 (5)	1.17 (10)	0.95 (4)	43 (5)	55 (8)	64 (2)
10-15	1.56 (2)	1.37 (0.1)	1.08 (16)	42 (4)	48 (0.1)	59 (11)

Table 2. Selected soil chemical properties (A horizon, 0-10 cm).

		g kg^{-1}						mg kg^{-1} 7d^{-1}	meq 100 g^{-1}	%
	n	C_{org}	N_{tot}	S_{tot}	C_{org}/N_{tot}	C_{org}/S_{tot}	N_{tot}/S_{tot}	p.m.N.	CEC_{eff}	K
Trampled plot	5	39.8	4.2	1.0	9.5	40	4	246*	26.5	7.3
Grazed plot	15	45.0	4.7	1.0	9.6	45	5	253*	19.7	2.1*
Boundary plot	5	32.3	3.1	1.0	10.4	32	3	120*	16.7	1.1*

n = number of analyses; p.m.N. = potentially mineralizable nitrogen; CEC_{eff} = effective cation exchange capacity ($BaCl_2$-extract); K % = percentage potassium saturation ($BaCl_2$-extract); * = coefficient of variability > 30 %.

Table 3. Selected soil chemical properties (A horizon, 0-10 cm) and nutrient transfer from topsoil (0-10 cm) to harvestable plant biomass.

		$CaCl_2$	µS cm^{-1}	mg kg^{-1}			% Plant removal				
	n	pH	EC	P_{CAL}	K_{CAL}	B	C	N	P	S	K
Trampled plot	5	7.2	214	235	761	2.9	3.3	2.9	0.5	0.8	4.0
Grazed plot	15	6.4	97	110	165*	1.3	6.7	6.1	1.4	1.3	15.2
Boundary plot	5	6.4	84	15*	45*	0.6*	1.8	1.0	0.2	0.3	1.3

n = number of analyses; EC = electrical conductivity; P_{CAL}, K_{CAL} = lactate-soluble phosphorus and potassium content; B = acetate-soluble boron content according to BARON; % plant removal = element content in harvestable annual plant biomass in % of soil storage (C_{org}, N_{tot}, S_{tot}, aqua regia extractable P and K); * = coefficient of variability > 30 %.

Conclusions

Although the soil chemical and physical properties prior to cattle grazing are not known, it seems reasonable to assume that the observed differences are attributable to long-term excessive grazing and trampling. The different grazing and trampling intensity as well as the uneven return of cattle excreta in grazed pastures not only creates a mosaic of vegetation structures (Mendarte *et al.*, 2005), but also results in a spatial heterogeneity in soil nutrient content and soil compaction. A sustainable pasture management takes into consideration this large-scale heterogeneity in pasture soils. Both from an ecological and economical point of view, there is a need to control trampling and grazing intensity at certain parts of a permanent pasture such as areas near the entry to the paddock, because there is a risk of overgrazing and poaching, leading to a distinct soil compaction, nutrient accumulation in topsoil (mainly potassium, phosphorus, boron), bare patches, and weed infestation. Furthermore, these intensively trampled areas need no or only small amounts of fertilizer (especially K-rich fertilizer such as cattle slurry). Therefore, within intensively grazed paddocks differential fertilizer practices and variations in grazing management are necessary.

References

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