Accumulations of N, P and K in Soil in Different Systems of Outdoor Keeping during Winter with Cattle

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N-, P- und K-Akkumulationen im Boden bei unterschiedlichen Verfahren der Winteraußenhaltung von Rindern

1 Introduction

Extensively managed grazing systems are typical in sites with less productive soils and can be characterized by a high labour productivity (ANDREAE, 1966; 1983). Such systems are superior to other management strategies in case of:

- relatively unfavourable natural conditions and
- extremely unfavourable economical conditions.

Successful keeping of suckler cows and beef cattle depends on the breed, concerning the meat quality performance in particular, and items of costs for stables, fodder and work (BALLIET, 1993; BUCHWALD, 1994; DEBLITZ, 1994). Year-

Zusammenfassung

Bei der Winteraußenhaltung kann es aufgrund der Freisetzung von in Exkrementen, namentlich Harn, enthaltenen Nährstoffen, des eingeschränkten Nährstoffentzuges und der Zerstörung der Vegetation zur Akkumulation von Nährstoffen kommen. Fütterungs- und ausnutzungsbedingt nehmen die Ammonium-, Nitrat- und Kalium-Mengen eine besondere Stellung ein. Ausgerichtet auf diese Zielgrößen wurden die Böden von Winterweiden, Acker- und Strohpferche beprobt und die N_{min}-Mengen sowie die Bodenreaktion und die pflanzenverfügbaren Phosphat- und Kalium-Mengen bestimmt. Die Ergebnisse lassen sich wie folgt zusammenfassen:

In der unmittelbaren Nähe der stationären Fütterungsplätze von Winterweiden wurden große Ammonium-N-Mengen in der Schicht 0–60 cm festgestellt (durchschnittlich 194 kg N ha^{-1}). Allerdings waren die entsprechenden Gehalte auf Sommerweiden vergleichbar hoch. Bereits in einer Entfernung von 25 m von den Futterplätzen ließ sich ein Rückgang der Ammonium-Mengen um 75 % feststellen. Mit Kalium verhielt es sich grundsätzlich ähnlich. Auch die K-Mengen waren mit >25 mg K 100 g^{-1} Boden in den Fütterungsbereichen deutlich höher als in 25 m Entfernung mit etwa 12 mg K 100 g^{-1} Boden. Die Nitrat-N-Mengen waren auf wesentlich niedrigerem Niveau (<20 kg N ha^{-1} in der Schicht 0–60 cm) als die Ammonium- N Mengen, wobei zwischen Fütterungsplätzen und weiter entfernten Messpunkten kaum Unterschiede bestanden. Unter Ackerpferchen konnte ein Zusammenhang zwischen Besatzdichte und Ammonium-N-, Nitrat-N- bzw. Kalium-Mengen festgestellt werden. Im Unterschied zu den Winterweiden war der Nitrat-Anteil am Gesamt-N deutlich höher. Eine Akkumulation von Phosphat war weder unter Winterweiden noch unter Ackerpferchen feststellbar. Im Durchschnitt lagen die Gehalte bei 3 mg P 100g^{-1} Boden unter Winterweiden und 5 mg P 100 g^{-1} Boden unter Ackerpferchen (Bodenschicht 0–30 cm). Dennoch sollte zur Vermeidung punktueller Konzentrationsspitzen von N und K eine dezentrale Fütterungspraxis vorgezogen werden, was durch den Einsatz mobiler Fütterungseinrichtungen erfolgen kann. Strohpferche können eine weitere Alternative zur Vermeidung von Nährstoffeinträgen darstellen. Sie erfordern allerdings viel Einstreu (> 20 kg GV^{-1} d^{-1}), ansonsten können sich im Boden aufgrund der hohen Besatzdichten und langen Pferchzeiten Akkumulationen von bis zu 700 kg N ergeben. Einsparungen an Einstreumaterialien sind über die Wahl der Strohart möglich, nicht aber über eine mechanische Strohaufbereitung.

Schlagworte: Ackerpferche, Strohpferche, Winterweide, Fleischrinder, N-Akkumulation, K-Akkumulation.

Summary

In pasture systems with winter grazing, the release of urinary nitrogen, limited nitrogen removal by plants, and sward damage increase the risk of nutrient accumulation in soil. Depending on feeding practice and the nutrient utilization by plants, considerable accumulations may occur in form of ammonia, nitrate and potassium. With focus on these features, soils of winter pastures, arable land folds and straw bedding corrals were analysed regarding amounts of mineral N, soil pH, and plant available phosphate and potassium amounts. The results can be summarized as follows: High amounts of ammonia N were found in layer 0–60 cm at the center of stationary feeding places on winter grazed pastures (on average 194 kg N ha^{-1}). However, the amounts were similar on summer grazed pastures (= control). The ammonia concentration in soil decreases with an increasing distance from the center of the feeding places. A decrease by already >75 % was found in a distance of 25 m. The situation was similar for potassium, since the amounts decrease from >25 mg K 100 g^{-1} soil in the center to approximately 12 mg K 100 g^{-1} soil in a distance of 25 m. The amounts of nitrate N (<20 kg N ha^{-1} in layer 0–60 cm) were significantly lower than amounts of ammonia N. Nitrate concentrations at feeding places were similar to the concentrations in a distance. In arable land folds, amounts of ammonia N, nitrate N, and potassium were influenced by the stock density. The proportion of nitrate N is much higher than in pastures. Concerning phosphate the load into soils is negligible. Total P averages 3 mg P $100g^{-1}$ soil (layer 0–30 cm) on winter grazed pastures and 5 mg P $100g^{-1}$ soil in arable land folds. However, the feeding of supplemental preserves on winter pastures and arable land folds should be arranged decentralized by using mobile feeding equipment to avoid high peaks of N and K close to feeding places. Stock keeping in straw bedding corrals is an alternative to avoid nutrient loads into soils, but it requires high amounts of litter material (> 20 kg GV^{-1} day^{-1}). Otherwise the high stock densities and long folding periods within this system cause the highest nutrient accumulation in soil, reaching peak values up to 700 kg N ha^{-1}. Savings of litter material are possible by using the right kind of straw, but no reduction is possible by a mechanical straw treatment.

Key words: Arable land folds, straw bedding corrals, winter pastures, beef cattle, K accumulation, N accumulation.

round outdoor stock keeping enables saving high costs for stables. Provided that precautions against negative effects of wind are arranged and isolated lying places are offered (WALLBAUM, 1996; HEIKENS, 1999), outdoor keeping during winter is possible in almost all sites, no matter what kind of breed is used (SCHNEIDER, 1915; ALLEN et al., 1989; SCHALITZ and FISCHER, 1995; OPITZ V. BOBERFELD, 1997; WASSMUTH, 2002). The following types of winter outdoor keeping are favourable:

- Winter grazing or – when the bearing capacity of the soil is insufficient-
- arable land folds or
- straw bedding corrals.

Winter grazing means an extension of the grazing period over winter (= moderate or temporary high stock densities) using the remaining herbage as long as possible and feeding conserves on pastures in supplementation. Arable land folds are spaciously fenced areas (= usually moderate stock densities) with crop stubbles or intercrops. Straw bedding corrals are smaller fenced areas (= very high stock densities) using straw or hay of inferior quality as litter material. All types of outdoor keeping are not common practice in Central Europe yet, which might be the reason for a lack of legally binding directions. In terms of animal comfort, outdoor keeping can be practised absolutely animal friendly (WASSMUTH, 2002). However regarding the risk of nutrient losses, as well winter grazing as folds and corrals raise the question: What is the amount of nutrients from excrements and what is the extent of local accumulations? Different winter pastures, arable land folds and straw bedding corrals were examined to answer this question under consideration of the outlined aspects.

2 Material and Methods

The soils of the examined winter pastures and summer pastures as standard of comparison can be characterized as Stagnic Luvisols with pH 4.7 – pH 5.0 at an altitude of 500 m above sea level in the region Westerwald. Winter pastures were grazed with a stock density of 4.5 GV ha^{-1} and monthly rotation. After a preceding use for forage preservation, summer pastures were grazed without rotation for two months with a stock density of 4.2 GV ha^{-1}. The herd size was limited to a number of 35 – 45 suckler cows, using Limousin cross-breedings, and their calves.

The soils underneath the arable land folds are classified as Cambisols and Stagnic Cambisols with pH 4.3 – pH 5.5 located at an altitude of 350 m above sea level in the region Hunsrück. The cattle were kept on barley or rape stubble or arable fallows. The stock density varied between 5.2 or 43.3 GV ha^{-1} and the folding period on each field was between nearly one month and almost three months. The herd consisted of 130 Limousin suckler cows.

The soil of the straw folds are characterized as Eutric Leptosol with pH 6.0 located at an altitude of 400 m above sea level in the region Hunsrück. Neighbouring unploughed areas next to straw bedding corrals were used as controls. The treatments in corrals are shown in Table 1. The size of the groups in each corral was 12 suckler cows, a Piemontese cross-breed, plus calves. Barley, triticale, and wheat straw in whole stalk was used as litter material. Table 2 shows the treatments in the experiment to assess the capacity of water uptake of straw, which implies three repetitions.

Soil samples were taken in layers 0–30, 30–60, and 60–90 by using a Pürkauer rod. The samples were taken at the stationary feeding places and in different distances from these attraction points (distances are illustrated in Figure 1, 3 and, 4 by rhombuses on the x-axis). Soil material from 15 bores were put together and homogenized to obtain representative samples. To avoid mineralization processes, samples were extracted immediately (= max. 2 hours after sampling) in 0.1 N H_2SO_4 for the potentiometric determination of NH4-N with an ammonia-specific electrode according to DANIEL et al. (2000) and were extracted in 0.025 N $CaCl_2$ solution for NO_3-N determination by means of the UV absorption method according to NAVONE (1964). The extracts were stored at –18 °C until the determination of mineral N. Amounts of mineral N were calculated by the determined concentrations considering the soil water content and the compactness of the packing of soil. Soil pH was determined potentiometrically in a 0.01 M $CaCl_2$ extraction. Phosphate and potassium were determined after an extraction in Ca-acetate-lactate (ANONYMOUS, 1991).

For the assessment of the water uptake capacity of straw, various kinds of straw with different pre-treatments, see Table 2, were stored in water for 48 h and exposed to atmosphere afterwards. The water uptake capacity was calculated by the difference of 1 kg wet straw and weight of straw after a period of approximately 4 h in which seeping water run of.

Table 1: Conditions in corrals
Tabelle 1: Pferchbedingungen

Criteria \ **Corral**	V	I	III	II	IV
Folding Period (Months)	5.0	4.0	4.5	6.5	5.0
Stocking Density (GV* 100 m^{-2})	3.6	3.6	3.4	3.4	5.6
Litter (kg GV^{*-1} day^{-1})	35.5	21.3	19.3	19.3	15.9
Final Height of Dung Layer (cm)	90	60	50	35	35

*GV = stock unit 500 kg lifeweight

Table 2: Treatments to assess the water uptake capacity of straw
Tabelle 2: Behandlung zur Abschätzung der Wasseraufnahme-Kapazität von Stroh

Factors	Levels
1. Straw Species	1.1 Barley 1.2 Oat 1.3 Triticale 1.4 Wheat
2. Preparation	2.1 Ground < 1 mm 2.2 Shredded Fine < 2.5 cm 2.3 Shredded Coarse > 7.0 cm 2.4 Long (= untreated) 2.5 Mixture (= similar portions)

Data were processed using analysis of regression and variance. Equations were generated considering the coefficient of determination (= r^2). Mean values were compared in multiple t-tests with · = 0.05. Significant differences in Figures are expressed by divergent letters.

3 Results and discussion

The amounts of mineral N per area and plant available potassium beneath winter pastures depending on the distance from feeding places (= for roughage only) are shown in Figure 1.

All feeding places are stationary in the longer term. In consequence, locally very high stocking pressure in these areas causes total sward damage and high nutrient input to the soil. It is evident, that ammonium and potassium accumulations in layer 0–60 cm increase significantly with decreasing distance to the fix feeding places. A decrease by already >75 % was found in a distance of 25 m from the manger. This effect is similar for winter and summer grazing. In contrast, this problem is not evident for nitrate and phosphate (data on P is not shown in Figure 1). Mean values of the winter pastures are only 25 kg NO_3-N ha^{-1} in 0–60 cm and 3 mg P 100 g^{-1} soil in layer 0–30 cm.

The distribution of the nutrients in different depths beneath the fix feeding places is shown in Figure 2, considering 30 cm layers up to a depth of 90 cm. More than a half of measured nutrient amounts beneath winter pastures occur in 0–30 cm and the proportion in this layer increase with increasing distance from feeding places. In areas of high attraction for animals, nutrients may accumulate and cause harmful effects to the environment (KÖNIG, 2002). However, this effect is not only a specific problem of winter grazing (LANTINGA et al., 1987; AFZAL and ADAMS, 1992; HOMM, 1994; ANGER, 2001; MILIMONKA et al., 2001; LANDWEHR, 2002; EBEL et al., 2003). In conclusion, it is well possible to control the risk of N accumulations by orderly rotation and by changing the feeding places frequently.

In addition to the situation with winter grazing, amounts of mineral N in arable land folds with different stock densities are shown in Figure 3.

Figure 4 shows the amounts of potassium. The amounts of phosphate average 5 mg P 100 g^{-1} soil (level 0–30 cm) and even in folds with rape stubbles no correlation with the distance to the feeding place was evident. The feeding places are mobile and stay fixed for the duration of one week. Under these circumstances, a dependence of the amounts of mineral N and potassium on the distance to the feeding place is only detectable for the lowest stock density. Changing feeding places apparently avoids excessively high peak values even with stock densities between 10 and 40 GV ha^{-1}. However, the comparison of the amounts of mineral N with a stock density of 5,2 GV ha^{-1} and the amounts in the other treatments with stock densities >10 GV ha^{-1} suggests, that high stock densities cause higher overall nutrient accumulations assuming uniform periods of 80 days.

Nearly two thirds of the mineral N amounts occur in layer 0–30 cm. Relatively high amounts of potassium in the area with a stock density of 10.1 GV $ha^{-1}$are probably caused by the highest folding frequency and the shallowness of the soil – the saprolitic Cv horizon is in 45 cm depth. The area of the fold on fallow land (= 20,2 GV ha^{-1}) has been out of cultivation for 10 years and the year of investigation is the first folding period. Apparently, high amounts of potassium in the soil are influenced by this circumstance because nutrient exportation was limited.

According to Table 1, stock densities of straw bedding corrals are comparable to those of loose-box stables. In Figure 5 local mineral N amounts in layer 0–60 cm are shown for five different straw bedding corrals. Data on phosphate concentrations in layer 0–30 cm is not included, because no significant differences from control plots were detectable. Information on available potassium is only presented for treatments with significant differences compared with control plots. Depending on the amount of litter and the final height of the dung layer, see Table 2, immense accumula-

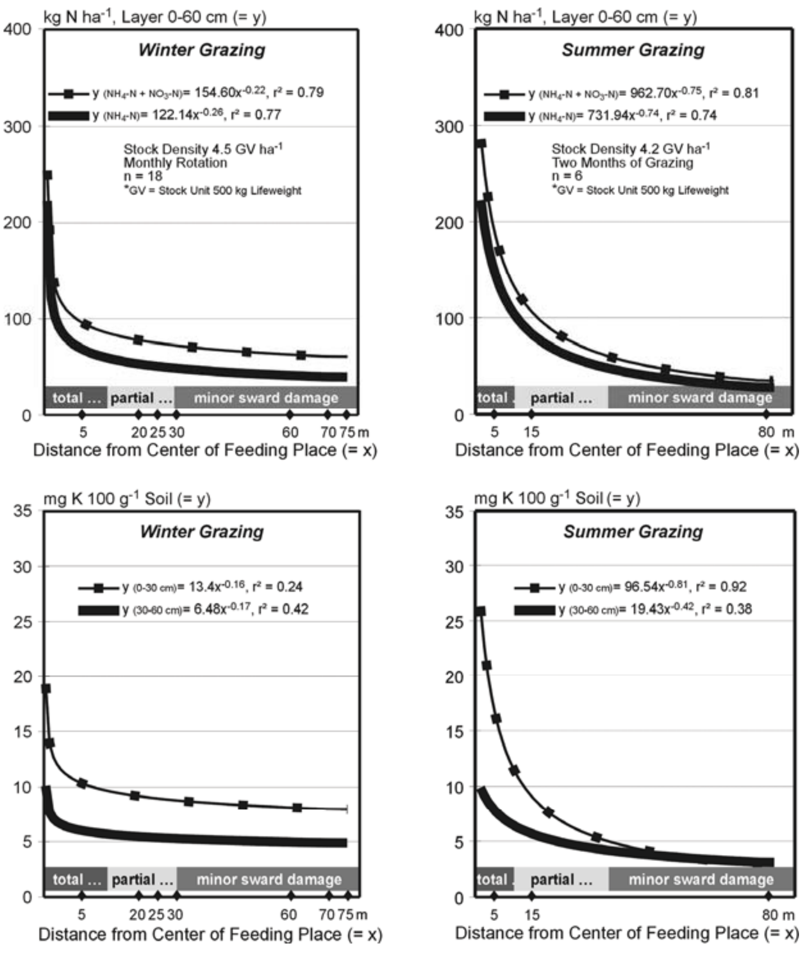

Figure 1: Amounts of NH_4-N, NO_3-N and K (= y) in soil of winter and summer pastures depending on the distance from feeding place (= x), sampling date mid of March

Abbildung 1: NH_4-N- und NO_3-N- sowie K_2O-Mengen (= y) von Winter- und Sommerweiden in Abhängigkeit der Entfernung zum Futterplatz (= x), Beprobung Mitte März

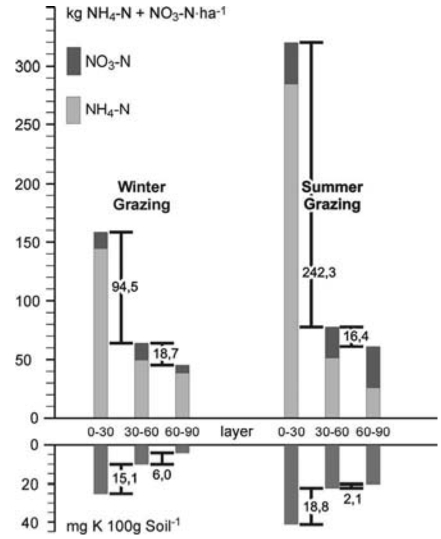

Figure 2: Amounts of NH_4-N, NO_3-N and K (= y) in winter and summer pastures at different soil depths (= x), sampling date mid of March

Abbildung 2: NH_4-N- und NO_3-N- sowie K_2O-Mengen der Futterplatzregionen (= y) von Winter- und Sommerweiden in Abhängigkeit der Bodentiefe (= x), Beprobung Mitte März

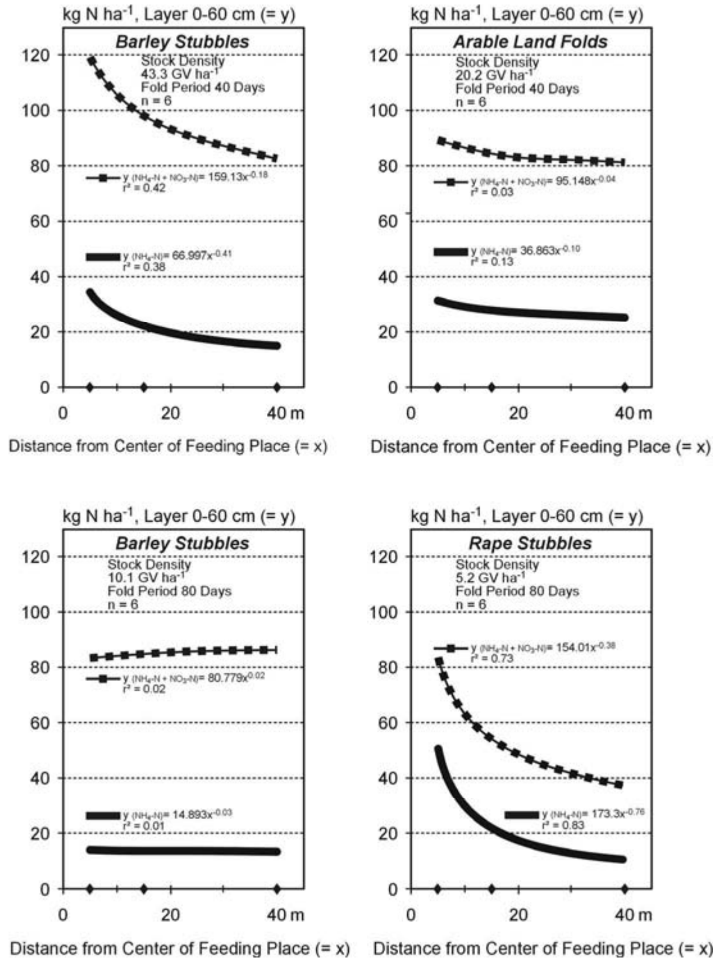

Figure 3: Amounts of NH_4-N and NO_3-N (= y) of various arable land folds depending on the distance from feeding place (= x), sampling date February

Abbildung 3: NH_4-N- und NO_3-N-Mengen (= y) verschiedener Ackerpferche in Abhängigkeit von der Entfernung zum Futterplatz (= x), Beprobung Februar

tions of ammonia and potassium are found. No excessive nitrate, ammonia or potassium values were found in treatments with > 20 kg litter material per GV and day, but a maximum of 80 kg K 100 g^{-1} soil (corral III) and a maximum of 700 kg N ha^{-1} as ammonia-N plus nitrate-N (corral IV) was found beneath the corrals with reduced litter input. It is hardly possible to remedy such extreme situations by agronomic measures in the following growth period. In opposite to the controls, two thirds of the nutrient amounts in the folds are located in layer 0–30 cm. To avoid excessive nutrient accumulations in straw bedding corrals, the amount of litter should be twice as high as for deep straw bedding in stables. However, it must be taken into account, that considerable portions of the applied straw amounts, indicated in Table 1, were consumed by the animals.

Information on the water sorption capacity of different treated straw sources is presented in Figure 6. Regardless of the pre-treatment, barley straw is the favourable litter material, whereas wheat straw is the least suitable material. No significant differences between practicable methods of mechanical straw treatment are evident. Apparently, the choice of the right kind of straw represents a possibility to save several amounts of litter material.

4 Conclusion

All presented systems of outdoor stock keeping are practicable. Providing a proper practise, high nutrient accumulations in top soil are not a necessary consequences of keeping animals outside during winter. However, management aspects are determinants for a sustainable use. In winter pastures and arable land folds, limited stock densities and frequently changing feeding places can be used as measures to avoid local areas with continual high concentrations of animals and to achieve a more homogenous distribution. In areas of temporary high animal densities, for example in places of rest with protection from the wind, the use of sufficient amounts of lit-

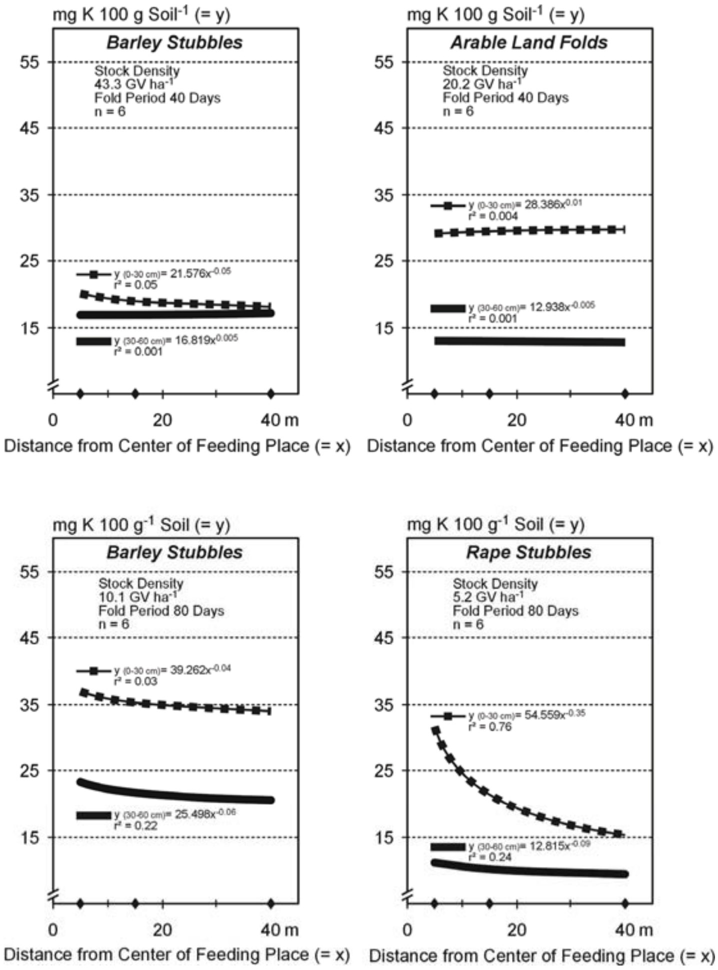

Figure 4: Amounts of K (= y) of various arable land folds depending on the distance from feeding place (= x), sampling date February

Abbildung 4: K_2O-Mengen (= y) verschiedener Ackerpferche in Abhängigkeit von der Entfernung zum Futterplatz (= x), Beprobung Februar

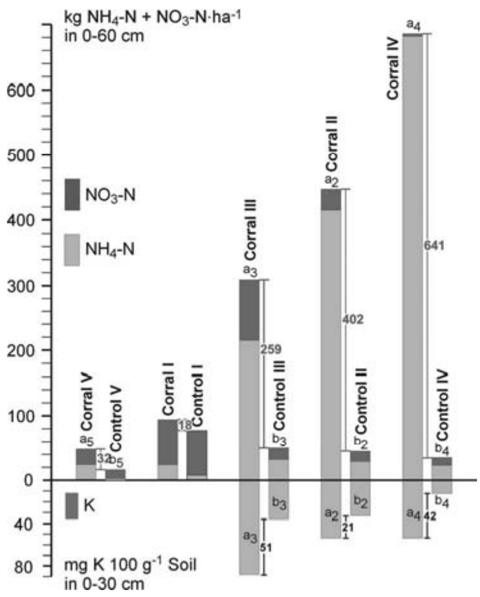

Figure 5: Amounts of NH_4-N and NO_3-N plus K and P beneath straw bedding corrals under different conditions compared with neighbouring areas (= controls)

Abbildung 5: NH_4-N- und NO_3-N- sowie K_2O-Mengen von Strohpferchen unter variierenden Bedingungen sowie angrenzender Bereiche (= Kontrollen)

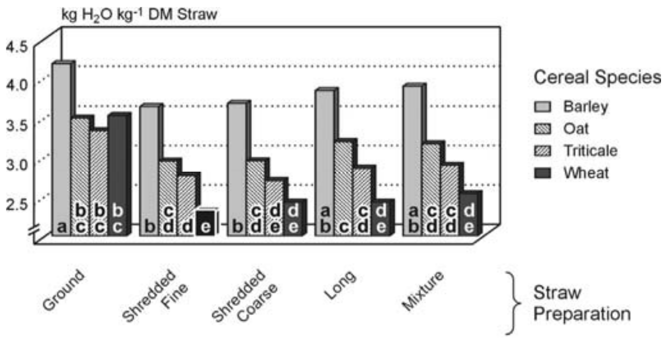

Figure 6: Water uptake by various kinds of straw depending on the preparation-method

Abbildung 6: Wasseraufnahme verschiedener Stroharten in Abhängigkeit von der Aufbereitung

ter material helps to protect against nutrient accumulations in the top soil (DEWES et al., 1991; DEWES and KOCH, 1993; ARNDT, 1995; OPITZ V. BOBERFELD and STERZENBACH, 1999). This measure is also consistent with demands concerning animal comfort and health (WALLBAUM, 1996; WASSMUTH, 2002). Straw bedding corrals require high amounts of litter material, which can be cheaply produced only in regions with high proportions of arable land. In peripheral sites hay of inferior quality (e.g. from nature conservation) might be an alternative. On account of cost saving, arable land folds are the favourable alternatives for winter grazing (JACOB, 2003). Prerequisites for a sustainable management of these systems are moderate stock densities and folding periods and changing feeding places.

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