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SUSTAINABLE NUTRIENT MANAGEMENT OF FEN GRASSLAND ON PEAT SOIL

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SUMMARY

In the past the northeast German lowlands drained peat soils are mainly used as pastures and meadows for milk, beef and energy production. Sustainable utilization of peat soil grassland is highly required, based on an appropriate management of the grass sward itself, water and nutrients. In order to fulfil the quality and quantity requirements of animal production systems, peat soil grasslands need an adequate fertilization with potassium (K) and phosphorus (P) and, in many situations, also with nitrogen (N). In this paper, results of grassland fertilization studies on peat soil are introduced. It is based on several long term field and lysimeter experiments, conducted for N, P and K at the peat soil research station Paulinenaue (northeast Germany) since 1960 and 1991 respectively. The results revealed, that the nutrient type, the fertilizer rate, their reduction, omission or increase, rapidly influenced the nutrient uptake and yield of the grassland sward as well as the nutrient leaching losses. In contrast to the common practice on mineral soils, the soil nutrient content was not helpful for the fertilizer rate determination whereas the optimum K and P content and the dry matter yield of the grass sward were a good indicator for calculating the fertilizer rate. For N, the findings resulted in on farm fertilizer rate recommendations minimizing the trade-off between production and leaching losses.

***Keywords**: nitrogen, potassium, phosphorus, nutrient balances, nutrient leaching*

INTRODUCTION

In the past the North German lowlands were dominated by large peat swamps. Particularly since the eighteenth century those areas have been drained and used for agricultural production. Currently, those drained peat soils are mainly used as pastures and meadows for milk and beef production and biomass production for energy plants. Grasslands provide a broad list of ecosystem services, mainly in the fields of production, biodiversity, climate, water and cultural issues (Isselstein and Kayser 2014). While the functions of grasslands for biodiversity and cultural issues are significantly influenced by the historical development and the actual situation within the regions, the task of simultaneously optimizing the production systems and minimizing negative effects on climate and water are globally very similar. Drainage is a precondition for the establishment and use of high yielding and high quality forage grass swards on peat soils, however, this also leads to peat mineralization, causing carbon (C) emissions and leaching of nutrients. The amounts of C emissions are mainly depending on groundwater level and thickness of the peat layer (Figure 1). In comparison to other grassland sites of northeast Germany in the peat soil the N store was higher and the K store was lower, but the leached N and K amounts were higher in peat soils than in mineral soils (Figure 2).

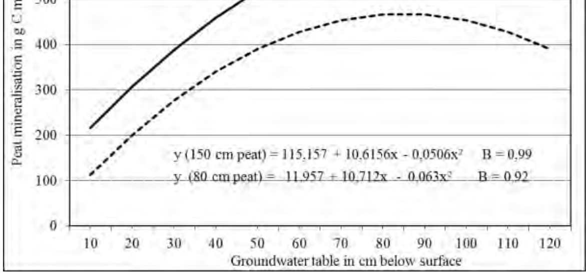

Figure 1: Peat mineralization of two Histosols depending on groundwater table (lysimeter, Mundel 1976)

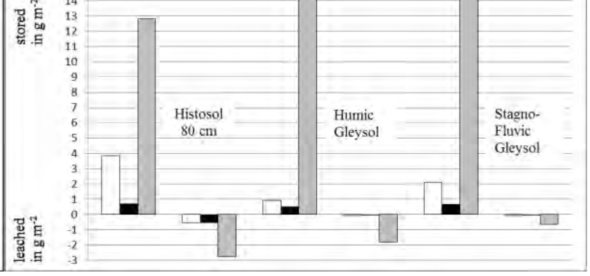

Figure 2: Nutrient stores and nutrient leaching of different European soils under grassland use (lysimeter, N 200, P 48, K 133 kg ha^{-1}, Mundel 1977)

Therefore, more sustainable management systems of drained peatlands are required, particularly including smooth, non-destructive treatments of the grass sward to ensure long-term usability and to avoid frequent ploughing and re-seeding, the limitation of drainage intensity and the adaption of fertilizer rates just to the swards requirements as well. Very often grassland use is characterized by an inappropriate management of nutrients. With particular respect to the soil nutrient storage grasslands on peat soil need an adequate fertilization with K and P and, in many situations, also with N, in order to fulfil requirements of animal production systems in terms of forage quality and quantity. In this paper results of ongoing long term field fertilization experiments and associated lysimeter experiments with N, P and K are reported and integrated into a sustainable nutrient management strategy on peat soils.

MATERIAL AND METHODS

The results presented here originate from the field experimental and lysimeter station Paulinenaue, located in the federal state of Brandenburg, Germany (52.687° N, 12.721° E, 9.2 °C mean annual air temperature, 534 mm mean annual precipitation 1982-2012). It was formed in the Warsaw-Berlin ice marginal valley of the central European last glaciation (Weichsel) and is part of a large, about 550 km² peatland zones. The sandy sediments were covered by 0.3 to 3 m thick peat layers, mainly formed from reed and sedge dominated vegetation. Actually, the soil is a Eutric Histosol of an up to 0.7m thick peat layer with a total C (Ct) content of 30 - 40%, covering about 12m of fluviatile sand. The first draining attempts were executed in the 14th century, followed by several further developments, especially by the construction of a channel and ditches, so from 1718 to 1724, extended in 1882 and between 1907 and 1925. Therefore the area could be used for cattle and sheep grazing and hay production. Between 1958 and 1961 and during the 1970ies and 1980ies, the ditches were again extended and water pumping stations were constructed in order to adjust the ground water table in the grassland site according to the actual demand of the plants (Behrendt 1988). Mean groundwater tables in summer were between 40 cm and 80 cm below and in winter close to the surface.

Two field trials have been conducted on the peat soil with graduated N fertilization from 0 to 480 kg N ha^{-1} (every cut got one third of the total yearly N rate) and constant PK fertilization since 1961 (Kreil 1965, Käding and Werner 1997) and with graduated P and K fertilization (applied in Spring) since 1991 (Schuppenies 1995, Pickert and Schuppenies 2002a). These constitute the experimental bases of our fertilizer studies, over the time periodically analyzed and evaluated with respect to different scientific questions. Both field trials as well as the additionally introduced joined grassland experiment on K and P fertilization on different soils together with other research stations since 1997 (Greiner *et al,.* 2014), are single-factor field plot trials of a complete randomized block design with four replications. They have been managed with three cuts and a harvesting area of at least 10m² per plot. Between 1977 and 2000 the influence of the N fertilization on the soil Ct and total N (Nt) contents in the upper soil layer was analyzed in order to check a potentially negative impact of the N fertilization on the peat soil (Käding *et al.,* 2003). Additionally, experiments at the Paulinenaue Lysimeter Station were conducted to study special questions in terms of peat mineralization and nutrient leaching (Mundel 1976 and 1977, Käding and Hölzel 1996). The lysimeters are consisting of peat and other soil types originating from Paulinenaue and other northeast German grassland sites and can be operated at adjusted groundwater levels with at least four replications. Each has a surface area of 1m² and a depth of 1.5m.

RESULTS AND DISCUSSION

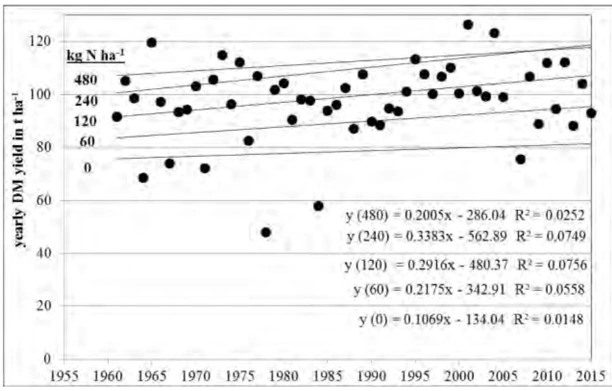

Figure 3: Grassland DM yield on peat soil depending on N rate. (single scores for the annual means over all N rates, 1961 – 2015)

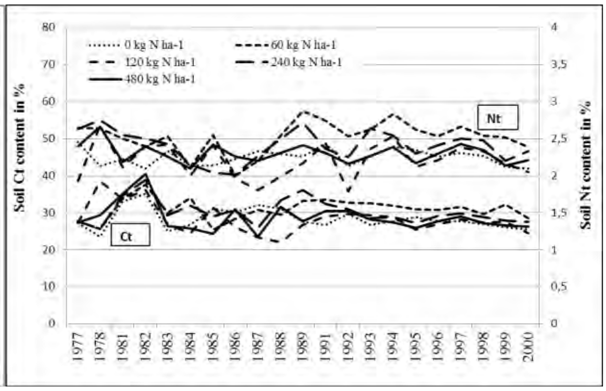

Figure 4: Ct and Nt content in the peat grassland soil depending on the N fertilizer rate from 0 to 480 kg N ha^{-1} (1977 – 2000)

In the grassland experiment with graduated **N fertilization** the dry matter (DM) yield increased with increasing N rates. The yields are characterized by a large variation among the years, but did not decrease over the trial period of 55 years. Without N an annual mean DM yield of almost 8 t ha^{-1} was gained, increasing to 10 t ha^{-1} with 120 kg N ha^{-1}. The effects of the higher N rates on DM yield were rather low but lead to a further increase of 10% up to about 11 t ha^{-1} with 240 kg N ha^{-1}. Any further N increase did not lead to a DM yield increase (Figure 3). The soil Ct and Nt contents were analyzed between year 16 and 39 of the trial. During this period of 23 years the Ct and Nt contents did not decrease. There was no difference between the different fertilizer levels (Figure 4).

At ‗normal' fertilizer levels, as shown in Figure 2, only small amounts of N were found in the leachate. When high N fertilizer rates of 750 and 1,500 kg ha^{-1}, corresponding to excreta spots on cattle pastures, were applied in lysimeters for three years, severe N leaching up to 81.9 g m^{-2} could be observed (Table 1).

Table 1 N discharge in the seeping water in depending on the N fertilization (lysimeter, fertilization 1992 – 1994, 1995 no fertilizer; fertilization and discharge data in g m^{-2})

N fertilizer rate*	1992*	1993*	1994*	*1995*	**1992-94***	***1992-95***
0	0,3	0,6	1,2	*1,4*	**0,7**	***0,9***
75	0,6	4,5	20,0	*11,2*	**8,4**	***9,1***
150	6,0	47,3	81,9	*37,7*	**45,1**	***43,2***

On peat soil almost 40% of the DM yield is generated by the 1st cut and 30% in each of the two following cuts. Without N fertilization the DM production per kg N is very high. It amounts to more than 160 kg DM kg N ha^{-1} for the 1st cut and to 130 kg for the 2nd and 3rd cuts and decreases rapidly with increasing N fertilizer rates (Figure 5). At a yearly N rate of 120 kg N ha^{-1} the scope of the lower DM production rates already starts. Due to increasing N contents in the crop the crude protein (XP) yield is also increasing with the N fertilizer rates (Figure 6). With 4 and 2 kg harvested N per kg fertilized N at a fertilizer rate of 60 and 120 kg N ha^{-1} there were high N recovery rates, rapidly approaching 1 kg with further increasing N fertilizer application.

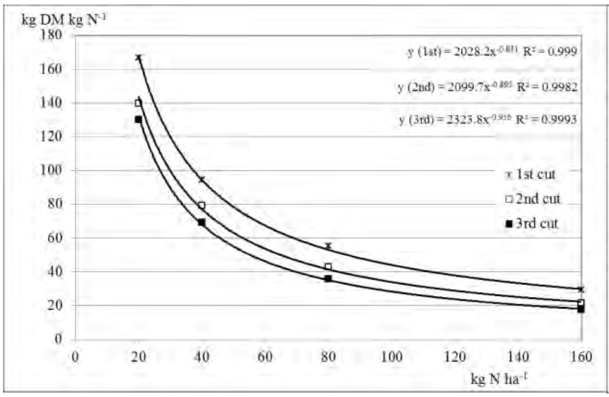

Figure 5: DM production of different cuts on grassland on peat soil depending on the N fertilizer rate (1961-2015)

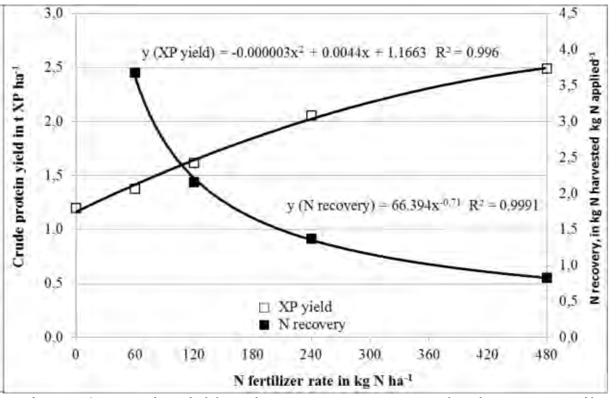

Figure 6: Protein yield and N recovery on grassland on peat soil depending on the N fertilizer rate (1961-2003)

Without **K fertilization** the grassland DM yield on the peat soil at Paulinenaue was declining very rapidly up to 30% within 5 years, independently from the level of N fertilization (Figure 7). On the other hand, in all three N levels the yield was increasing rapidly and reaching the level before the interruption of K fertilization within 2 years after K has been applied again. After 14 years without **P fertilization** almost no decline was observed on different grassland sites. Concerning K, this situation can differ among other typical non peat grassland sites and must be evaluated with respect to the specific soil and ground water conditions. Whereas without K the DM yield on the grassland on peat soil and on the silty loam in the mountains rapidly decreased, there was no yield impact on the silty river plain grassland (Figure 8).

During the trial period the K balance ($K_{applied}$ - K_{yield}) was negative for all N and K fertilizer levels. There was no correlation to the soil K content (Figure 9). The course of K contents in the harvested grass corresponded very well with course of DM yield (Figure 10 vs. Figure 7). If the K content in the first cut was in the range of 18 to 29 g kg DM^{-1} and in the second and third cut in the range of 14 to 21 g kg DM^{-1} the grass swards delivered high yields, if the K content in the first cut was below 10 to 18 g kg DM^{-1} and in the subsequent cuts in the range of 7 to 19 g kg DM^{-1} the grass sward suffered from potassium shortage and delivered only weak yields. In all cuts at P contents of 2.5 to 4 g kg DM^{-1} the grass swards delivered high yields, below the range of 2 to 2.8 g P kg DM^{-1} the grass sward suffered from P shortage and delivered only weak yields.

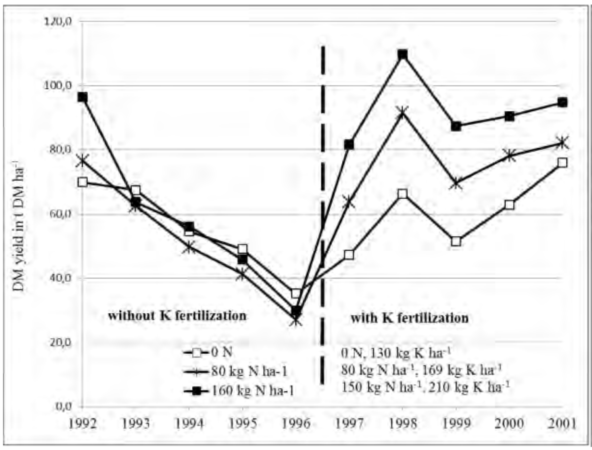

Figure 7: Course of DM yield with and without K fertilization (1992-2001) (Pickert and Schuppenies 2002b)

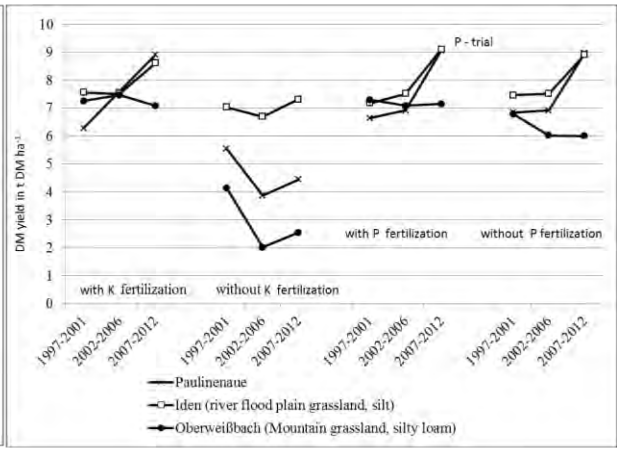

Figure 8: DM yield with and without K and P fertilization on different grassland sites in northeast Germany (1997-2012) (Greiner *et al.*, 2014)

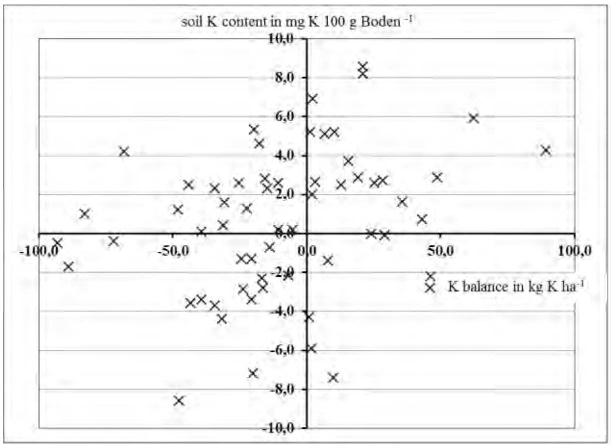

Figure 9: Soil K content depending on the K balance (three N levels, 1992-2001)

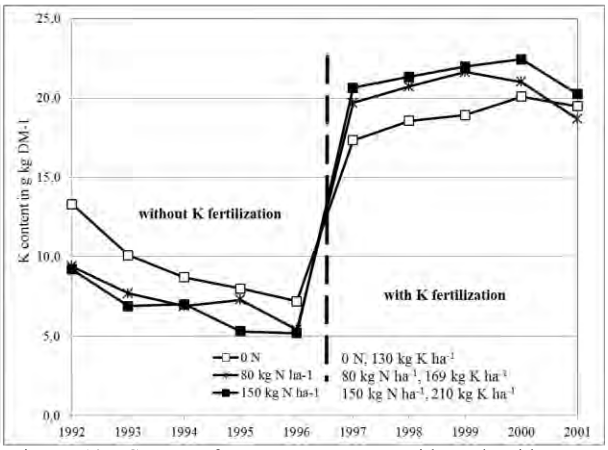

Figure 10: Course of grass K content with and without K fertilization on different grassland sites in northeast Germany (1997-2002)

By supporting a higher uptake with the grass yield a balanced K fertilization helped to minimize N leaching (Figure 5). The N balance is strictly negative, even if fertilized with 160 kg N ha^{-1}. In the opposite, the sole application of N fertilizers dramatically increased the N balances and the risks for N leaching (Figure 12).

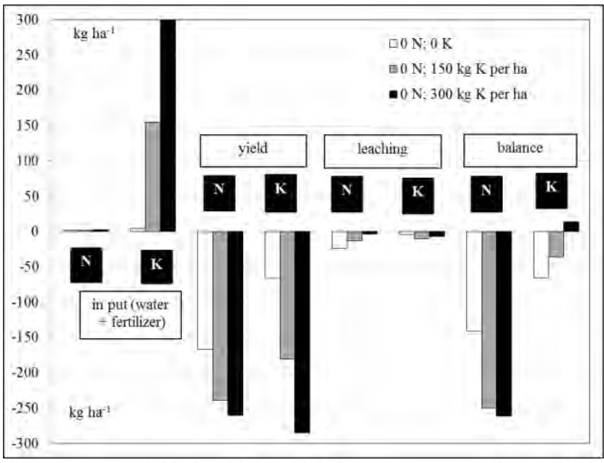

Figure 11: N yield, leaching and balance on peat soil grassland depending on the K fertilizer rate (lysimeter 2003-2008)

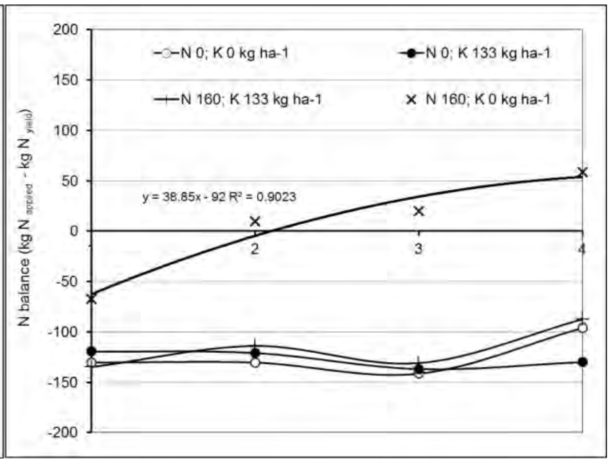

Figure 12: N balance on peat soil grassland depending on the N and K fertilization (mean 2 trials, 4 years each (Pickert and Schuppenies 2002a)

CONCLUSIONS

The results of the long term fertilizer experiments in the field trials and in the lysimeters allow the establishment of a resource efficient nutrient management system for grassland on peat soil under the climatic conditions of northeast Germany, that minimises the trade-offs within the ecosystem services in the fields of production and climate and water protection.

Despite a much greater N uptake by the grass sward, a fertilizer rate of 120 kg N ha^{-1} is sufficient in terms of high yields and efficient nutrient use on peat soil grassland. If there is a particular need, i.e. in years with yield depressions an increase up to 160 kg N ha^{-1} is possible. In that N fertilizer range the soil Ct and Nt content are not affected and there is no risk of N leaching. The difference between the grass sward N uptake of about 300 kg N with a normal yield of 10 t DM ha^{-1} and the N fertilizer rate of 120 to 160 kg N ha^{-1} amounts to 140 to 180 kg N ha^{-1}, that is delivered by the peat soil. Compared to grassland on mineral soils only the half amount of N is needed for the same DM yield. In the new fertilizer regulation in Germany the contribution of the peat soil nutrient store to the nutrient supply of grassland and therefore the reduction of the fertilizer rate is set to 80 kg N ha^{-1} (BMEL 2015). The results show, that this value could be corrected remarkably for the northeast German peat soil grassland.

For K and P on peat soil only the yearly grass uptake in the range of 20 and 3 kg t DM^{-1} (200 and 30 kg ha^{-1} for a grassland yield of 10 t ha^{-1}) should be yearly replaced by fertilization. It does not seem necessary to keep the soil P and K content at a certain level as recommended for mineral soils. By checking the content of P and K in the grass, i.e. together with the laboratory analysis of the nutritive value of the grass silage, it is possible to supervise and optimize the nutrient management system of a farm.

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