RESTORATION OF FORMER CORNFIELDS ON ACID SANDY SOILS: SOD-CUTTING, GRAZING OR AFFORESTATION?

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Abstract: In the Netherlands, many agricultural lands are converted to nature. A main question in these attempts is how to reduce or use excess nutrients. We studied the effect of sod-cutting, grazing and afforestation after 18 years in former cornfields on sandy soils. Agricultural soils had lower microbial C, but higher net N-mineralization per unit microbe and especially higher P than undisturbed soils. In restoration treatments, quality of soil organic matter improved from organic slurry to more distinctive forms, and fungi increased as well. However, nutrient availability was only reduced by sod-cutting, with an additional biodiversity bonus that soils were now nutrient-poor, but still relatively base-rich. Under grazed conditions, availability of N and P did not decrease. Species number slightly increased compared to reference grasslands due to higher pH, but these were mainly common species. In new oak forests, availability of N and P did not decrease either, but here nutrients could be used for rapid growth.

Keywords: 4030 (European dry heaths); Semi-natural dry grasslands and scrubland facies; 9190 (Old acidophilous oak woods with Quercus robur on sandy plains); identifying appropriate conservation and restoration objectives; nutrient removal; reclamation of former agricultural land.

Introduction

In the Netherlands, many agricultural fields are converted to nature (e.g., Kemmers et al. 2005). A main question in these attempts is how to reduce or use excess nutrients. On sandy soil, vegetation previously consisted of nutrient-poor oak forests, heathlands and dry grasslands, but agricultural use has increased nutrient loads enormously. Nature managers basically opt for three ways: sod-cutting, conversion of agricultural fields to grasslands maintained by cattle or horses, and afforestation. Sod-cutting may be a fast way to reduce nutrient-availability and restore plant biodiversity (Niemeyer et al. 2006), but is expensive. Grazing may be cost-effective, but species diversity may remain low until nutrient availability and plant productivity become reduced (Pegtel et al. 1996). The cultural landscape of the Netherlands has been relatively open for centuries, and large forested areas may not be appreciated. However, afforestation may actually profit from high nutrient-availability, via high growth rates of young trees. In order to improve management decisions, this study evaluated changes in nutrient availability and plant species composition after 18 years of sod-cutting, grazing or afforestation in National Park De Maashorst. We concentrated on restoration of organic matter and nitrogen cyling, potential reduction of phosphate availability and changes in plant biodiversity. The research questions were: (1) how much has nutrient availability increased in agricultural fields compared to the more natural oak forest, heathland and dry grassland, and (2) how large is the improvement in nutrient-availability and vegetation when restored by sod-cutting, grazing and afforestation?

Materials and methods

The study was conducted in De Maashorst, a sandy area in southern NL, with humid temperate climate and rainfall in all months. For reference vegetation, four plots were randomly selected in heathland (H0), and five in dry grassland (G0) and older oak forest (F0), undisturbed by agricultural use, and considered to be end-stages of succesion within a specific restoration series. For the agricultural situation, five plots were selected in heavily fertilized corn fields (AF). Restoration series were sampled in former corn fields, 18 years after restoration. For sod-cutting, five plots were selected with the organic topsoil partly intact (H1), and five plots with the organic topsoil removed completely (H2). For grazing, scven plots were selected in high-productive grasslands (G1), and five plots in smaller areas where productivity seemed lower (G2). For forest development, five plots were selected in oak plantations (F1). For each situation, intact soil samples were collected for microscopic analysis of organic matter characteristics in thin sections. In each plot, plant species composition was recorded within quadrats of 2x2 m (open vegetation) of 5x5 m (forest), and vegetation samples collected for analysis of N:P ratios. In each plot, two soil cores were sampled from 0-20 cm depth, one for a six week laboratory incubation experiment in which (a.o.) microbial C and net N-mineralization were measured, and the other for (a.o.) chemical analyses of pH and different P-fractions. Microbial C was measured via chloroform fumigation-extraction, and net N-mineralization with 0.5 M K_2SO_4-extraction in fresh and incubated samples. P-fractionation included total, organic and inorganic P via 0.5 M H_2SO_4 extracts of heated and nonheated samples, plant-available Olsen-P and amorphous P, Fe and Al in ammonium oxalate extracts (van der Zee and van Riemsdijk 1988).

Results and discussion

In undisturbed reference plots, soil organic matter showed a well-organized structure, with frequent organic aggregates and fungi. In agricultural soil, however, organic matter had turned into slurry due to ploughing and manure application, and fungi had strongly decreased, which is in accord with de Vries et al. (2007). Microbial C decreased accordingly from undisturbed to agricultural soil (Figure 1).

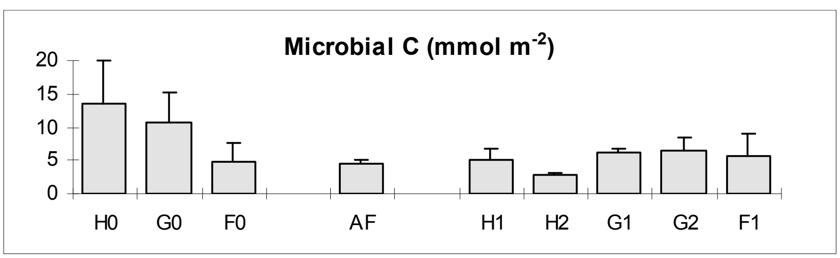

Figure 1. Microbial C in undisturbed reference vegetation (H0, G0 and F0), agricultural fields (AF) and different restoration stages with sod-cutting (H1 and H2), grazing (G1 and G2) and afforestation (F1).

Net N-mineralization was low in undisturbed heathland, but grassland and old forest did not differ from agricultural soil. However, net N-mineralization per unit microbe strongly increased in agricultural soil, probably due to manure application. Also, total P (and other P-fractions) were much higher in agricultural soil than for undisturbed vegetation (Figure 2). P-saturation increased from values below 0.05 in reference soil to 0.28 in corn fields, which suggest almost complete saturation (van der Zee and van

Riemsdijk 1988). Also, plant N:P ratios decreased from 15 to 7, which points to excess P (Koerselman and Meuleman 1996). Naturally, plant species number decreased in agricultural fields (Figure 3) and pH of the mineral topsoil increased (Figure 4).

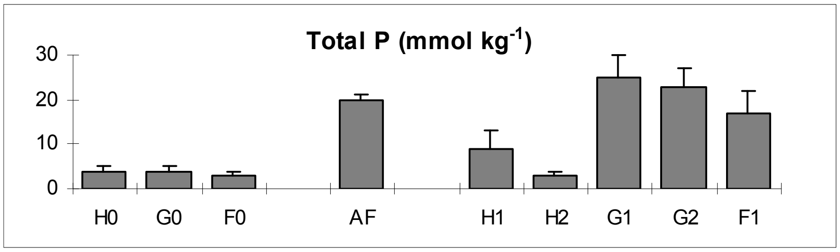

Figure 2. Total P in undisturbed reference vegetation (H0, G0 and F0), agricultural fields (AF) and different restoration stages with sod-cutting (H1 and H2), grazing (G1 and G2) and afforestation (F1).

In former agricultural fields, organic matter characteristics and soil fungi had been restored to some extent after 18 years. Earthworms, absent from undisturbed grassland, even appeared in restored grassland, possibly due to higher pH. However, microbial C only showed partial restoration, and was still low compared to reference soils. Also, net N-mineralization per unit microbe was still high, except for sod-cutting, where soil organic matter had been removed. Total P was still high after 18 years as well, except for sod-cutting. Also, P-saturation index remained above 0.20, still close to saturation, and plant N:P ratios indicated of 7 instead of 15 still indicated excess P (Koerselman and Meuleman 1996). This seems less optimistic than Kemmers et al. (2005) who suggested a clear decrease in P-saturation within 30 years.

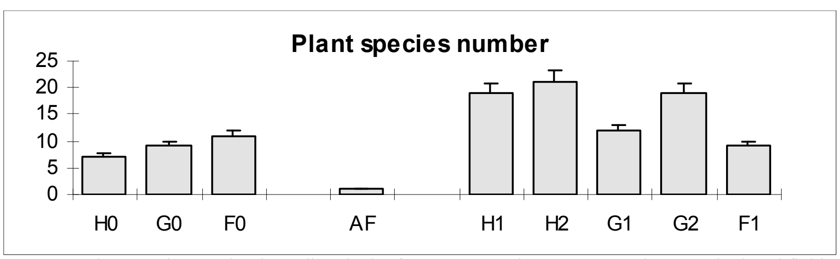

Figure 3. Plant species number in undisturbed reference vegetation (H0, G0 and F0), agricultural fields (AF) and different restoration stages with sod-cutting (H1 and H2), grazing (G1 and G2) and afforestation (F1).

Plant species number was high especially in sod-cutting treatments, due to lower nutrient availability. However, species richness had increased even above levels of reference vegetation, due to higher pH, and contained species characteristic of weakly buffered soil such as *Jasione montana* L., *Ornithopus perpusillus* L. and the red-list species *Filago minima* (Sm.) Pers. In grazed restoration stages, species number was higher than reference vegetation as well, but these were mainly common species such as *Agrostis capillaris* L. and *Jacobea vulgaris* Gaertn. The lower productive G2 grasslands contained more species than high productive G1, but it is not clear why. Lower productivity could at least not be attributed to lower nutrient availability, and may be due to local disturbances.

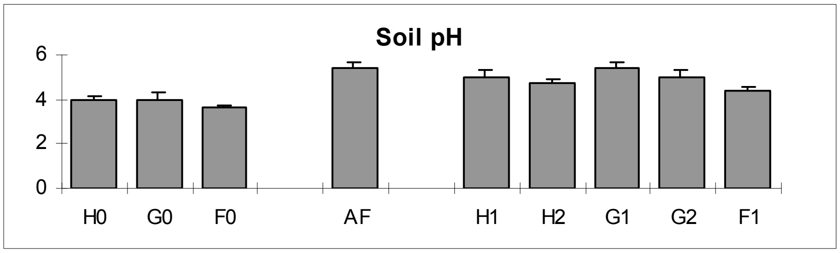

Figure 4. Soil pH in undisturbed reference vegetation (H0, G0 and F0), agricultural fields (AF) and different restoration stages with sod-cutting (H1 and H2), grazing (G1 and G2) and afforestation (F1).

Conclusions

Agricultural fields have lower microbial C, but higher net N-mineralization per unit microbe and much higher P-content than undisturbed reference soils, due to manure applications. Restoration leads to decrease in nutrient availability in sod-cutting treatments only. In grazed fields and forests, net N-mineralization per unit microbe and P-availability remain high even after 18 years. Plant species number may increase even above reference levels in the cost-effective grazing treatments, because pH has slightly increased. However, rarer species appeared mainly after sod-cutting. Afforestation does not seem to lead to decreased nutrient availability or higher biodiversity, but in this case nutrients can be used for rapid growth.

Acknowledgements

We wish to thank SBB and especially Klaas van der Laan for entrance and information, and Leo Hoitinga, Leen de Lange, Koos Verstraten, Piet Wartenbergh, Joke Westerveld and Ton van Wijk for discussions and assistence with laboratory procedures.

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