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Simulated environmental and climatic effects of perennial ryegrass seed production

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INTRODUCTION

Environmental and climatic effects of agricultural practices are difficult to assess for various reasons: Both the temporal and spatial variation is large and effects develop over time scales from hours or days (e.g. nitrous oxide emmissions) to hundreds of years (e.g. soil carbon sequestering).

One approach to achieve estimates on such effects is computer simulations of the agroecosystem. In this study we used the model system 'Daisy' to simulate effects of implementing perennial ryegrass (PR) seed production in a conventional grain-based cropping system on the leaching of nitrate and on the soil organic carbon (C) content.

The simulated scenarios contained various cropping rotations as well as different strategies regarding crop residues.

METHODS

First, the 'Daisy' model description of PR was calibrated against measurements of biomass, nitrogen uptake and seed yield from a multi year field experiment in Flakkebjerg, Denmark.

Secondly, a number of scenarios were defined. The reference scenario was a typical Danish grain based crop rotation with nitrogen fertilization according to the Danish norm-regulation. In this rotation, PR replaced grain crops for either one or two years of the five-year rotation.

Table 1 – Overview of key management information in the simulated scnarios. Dates in parentheses indicate sowing dates. The N fertilizer rates follow the Danish norm-system for the season 2020/2021. In this regulation, all crops are assigned an allowed N-quota, which is adjusted according to soil type, irrigation, previous crop and catch crops. See notes below the table for explanations and further details.

Scenario		Year 1	Year 2	Year 3	Year 4	Year 5
Reference grain rotation	Main crop	OR (Aug 23rd)	SB (March 1st- Apr. 1st)	WW (Sep. 15th)	SB (March 1st- Apr. 1st)	WW (Sep. 15th)
	Fertilizer [kg N/ha]	210	109	208	144	208
	Catch crop	+ (Sep. 1st)	-	-	-	-
	Residue management	↓	↑	↓ or ↑	↑	↓ or ↑
1-year grass seed rotation	Main crop	OR (Aug 23rd)	SB (March 1st- Apr. 1st)	WW (Sep. 15th)	SB_pr (March 1st- Apr. 1st)	PR
	Fertilizer [kg N/ha]	192	109	208	144	170
	Catch crop	+ (Sep. 1st)	-	-	-	-
	Residue management	↓	↑	↓ or ↑	↑	↓
2-year grass seed rotation	Main crop	OR (Aug 23rd)	SB_pr (March 1st- Apr. 1st)	PR	PR	WW (Sep. 15th)
	Fertilizer [kg N/ha]	210	144	170	135	190
	Catch crop	+ (Sep. 1st)	-	+	-	-
	Residue management	↓	↑	↓	↓	↓ or ↑

Crop abbreviations: OR = Oilseed rape, WW = Winter wheat, SB = Spring barley, SB_pr = Spring barley with perennial ryegrass undersown, PR = Perennial ryegrass.

+/- = Catch crop following main crop in a given year. Overwintering ryegrass is considered a catch crop except in the first winter after being undersown in spring barley, where it is treated like a normal winter crop.

() = Sowing date for main or catch crop. Spring barley is sown as soon as the soil is considered trafficable after March 1st, but no later than April 1st. The condition for soil trafficability was defined by a soil water pressure below -50 H_2O and a temperature above 10°C in a 10cm soil depth.

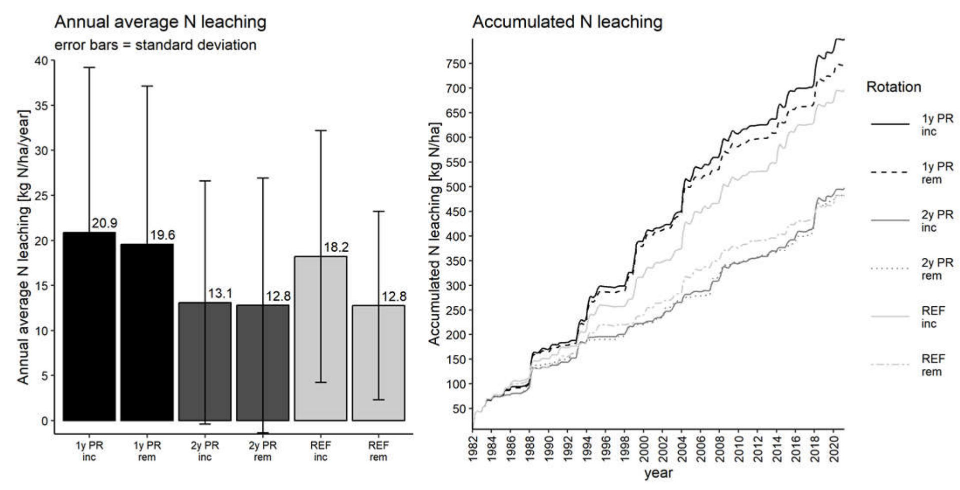
↑ = Crop residues (straw and leaves except the stubble) of the main crop are removed at harvest. In spring barley with undersown grass, both barley straw and any cut grass are removed during harvest.

↓ = All crop residues are left in the field and incorporated before establishment of the subsequent crop. When the subsequent crop is a spring sown crop, the residues (incl. catch crops) are incorporated by conventional inversion tillage on November 10th and the field overwinters with black soil. In the rotation with two years of subsequent ryegrass, the residues after harvest in the first year are left in the field on the soil surface, while they are incorporated by tillage after the second harvest prior to the sowing of winter wheat.

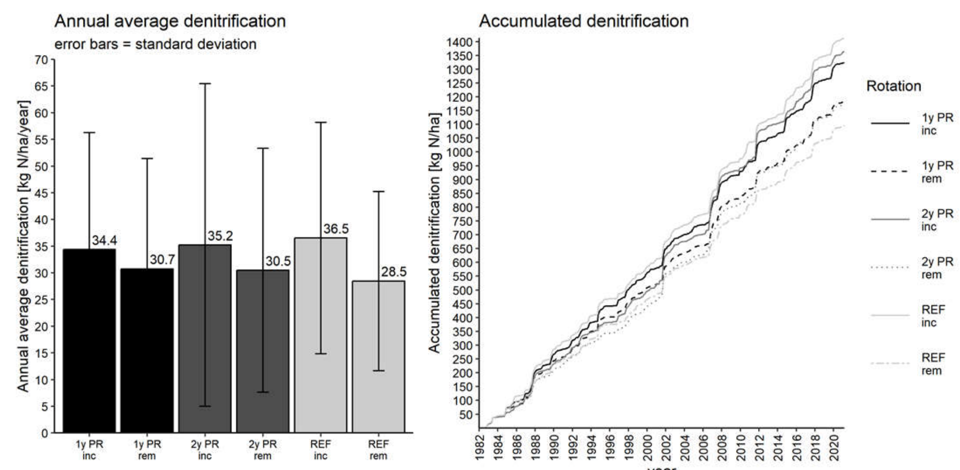
In each of the three cropping sequences, two strategies were simulated for management of the wheat straw – it was either removed for use as bio energy or bedding, or it was incorporated to the soil when plowing. In total six different scenarios were simulated.

Each simulation ran for 40 years (i.e. eight full rotations) using actual weather data from Flakkebjerg for the period 1981-2021.

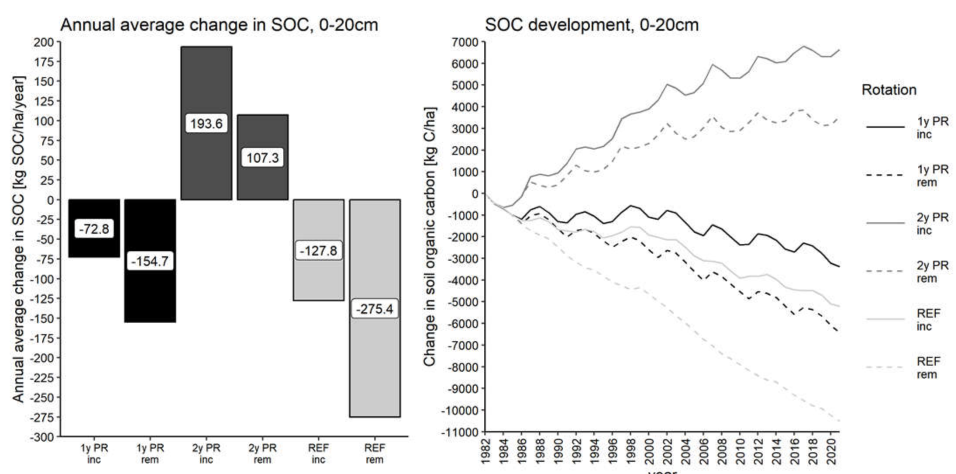
RESULTS



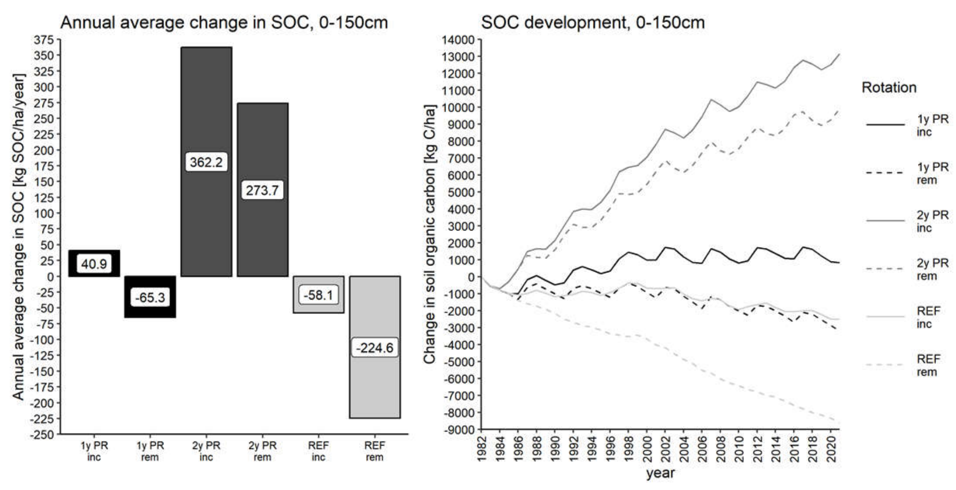
Introduction of PR to the grain based cropping system increased the N leaching when only cultivated for one season, but had the potential to reduce N leaching when grown for two consequtive seasons. The effect depended on how the wheat straw was handled.



Denitrification was mainly affected by how the wheat straw was managed, and there was no substantial effect of crop choice. In the reference scenario, wheat was grown 2/5 year, while it was only grown 1/5 years in the PR scenarios.



Topsoil organic C declined in both the reference scenario and when PR was grown as an annual crop. When grown for two consequtive seasons, the introduction of PR improved the SOC stock. This effect flattens towards a new equillibrium during the 40 year simulation.



The SOC stock in the soil down to 150 cm generally declined or was just maintained except when PR was grown for two consequtive seasons. Most of the effect of wheat straw management was seen in the topsoil, while crop choice also affected deeper soil layers.

CONCLUSION & DISCUSSION

We simulated environmental and climatic effects of incorporating PR to a grain based cropping system. The reference system lost C from the soil to the atmosphere, even when wheat straw was incorporated. Substituting a wheat with a PR in the cropping system improved this situation, but the soil C stock was only maintained if wheat straw was incorporated to the soil, and this system caused increased N leaching. Only in scenarios, where the grass grown for two consequtive seasons, PR cultivation had the potential to increase soil C stock in both the top- and subsoil without causing additional N leaching.

The study shows that when considering climatic and environmental effects, it makes a big difference to keep the soil cover (the PR sward) for a longer period and plan to harvest this crop for at least two year in a row. As an alternative approach, the grass could be harvested for seed in the first year and cut for biomass (e.g. for bioenergy, protein extraction, roughage etc.) in the second season. This strategy could replace some of the fodder production, which is lost when grass replace grain crops in the reference system.