Extending grassland age for climate change mitigation and adaptation on clay soils

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Abstract

Permanent grassland soils can act as a sink for carbon and may therefore positively contribute to climate change mitigation and adaptation. We compared young (5-15 years since latest grassland renewal) with old (>15 years since latest grassland renewal) permanent grassland soils in terms of carbon stock, carbon sequestration, drought tolerance and flood resistance. In old grassland soils we found a higher carbon stock (62 Mg C ha^{-1}) than in young grassland soils (51 Mg C ha^{-1}). The carbon sequestration rate tended to be higher (not statistically significant) in young (average 3.0 Mg C ha^{-1} $year^{-1}$) than old (1.6 Mg C ha^{-1} $year^{-1}$) grassland soils. Regarding potential drought tolerance, we found larger soil moisture and lower soil bulk density in old than in young grassland soils. Old grassland soils were also more resistant to heavy rainfall. We conclude that by extending grassland age on clay soil, farmers can contribute to climate change mitigation and adaptation ecosystem services.

Keywords: carbon sequestration, ecosystem services, permanent grassland, soil carbon stock, water infiltration

Introduction

On clay soils in the Netherlands, permanent grasslands are renewed (i.e. destroyed by herbicides, ploughed and reseeded) on average once every 10 years (Russchen, 2005). Ploughing of grassland for renewal significantly reduces soil carbon stocks (Linsler *et al.*, 2013; Necpálová *et al.*, 2014). In addition to climate change mitigation by preventing loss of carbon due to ploughing, permanent grassland can potentially play a role in climate change adaptation by increased drought tolerance and flood resistance. We tested the effect of permanent grassland age (young versus old grassland) on carbon stock and carbon sequestration rate in the topsoil (0-10 cm soil layer) as this can contribute to climate change mitigation. Additionally, we investigated the effect of permanent grassland age on soil parameters that can influence the resistance to periods of drought and the resistance to excess rainfall. Resistance to excess rainfall and periods of drought are both aspects of climate change adaptation.

Materials and methods

The study was conducted in 2014, at 10 dairy farms on marine clay soil in the north of the Netherlands. At each farm, a young (5-15 years since grassland renewal) and an old (> 15 years since grassland renewal) grassland were selected. On each grassland, a non-fertilized plot of 5×9 m was used to determine soil quality parameters in April 2014 and in December 2018 (only C-total). See Iepema *et al.* (2021) for details on the experimental lay-out, the measurements and the statistical analyses.

Results and discussion

By combining the observations from 2014 and 2018, we found a significant positive curvilinear relationship between age of the sward and carbon stock in the 0-10 cm soil layer. In the first years after grassland renewal, carbon stock increased relatively fast and after approximately ten years the line curved to a flatter response (Figure 1).

Potential drought resistance as indicated by soil moisture content, soil bulk density and soil structure, was significantly higher for old than for young grassland topsoils (Table 1). Rooting, the fourth parameter indicating potential drought resistance, was not significantly different between young and old grassland. However, we measured in old grassland a greater percentage of root tips from the total number of root tips at 10 cm (64%) in comparison with young grassland (57%). It might be that in old grassland, moisture and nutrients are more concentrated in the 0-10 cm soil layer, causing a larger proportion of root tips at 10 cm, which also contributes to a better soil structure in this soil layer. The old grassland soils showed the potential for greater resistance to heavy rainfall in comparison with the young grassland soils, as indicated by the larger water infiltration rate and a higher number of macropores (statistically significant only at 20 cm soil depth; Table 1). Macropores at this soil layer increase infiltration capacity under the subsoil (Jarvis *et al.*, 2017).

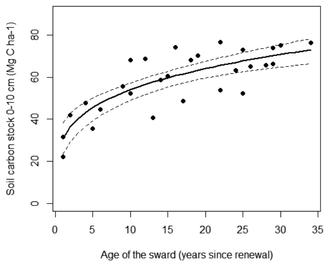

Figure 1. Carbon stock in the 0-10 cm soil layer (measured in 2014 and 2018) as a function of grassland age (years since renewal) with 95% confidence interval (dotted lines). The black line shows the model $y = 30.7 * x^{0.27}$; $R^2 = 0.67$.

Table 1. Characteristics of the topsoil (0-10 cm depth) related to climate change mitigation and adaptation of the young (n=10) and old (n=10) grasslands on marine clay soil.[1]

Parameter	**Unit**	**Young grassland**		**Old grassland**		***P*-value**
		mean	**SD**	**mean**	**SD**	
Grass age	Yrs without cult.	9	4	25	4	<0.001
Soil carbon stock	Mg C ha^{-1}	51	16	62	9	0.013
Carbon sequestration rate[2]	Mg C ha^{-1} $year^{-1}$	3.0	2	1.6	1	0.145
Parameters indicating potential drought resistance						
Soil moisture content	volume %	28.6	3.2	31.7	2.8	0.007
Soil bulk density	g cm^{-3}	1.16	0.1	1.03	0.1	<0.001
Crumbs	% of total weight	67.3	20	80.3	15	0.011
Angular blocky elements	% of total weight	12.2	14	4.6	8	0.052
Root tip density at 10 cm	Number dm^{-2}	109	16	118	40	0.524
Root tip density at 20 cm	Number dm^{-2}	81	17	65	23	0.185
Proportion of root tips at 10 cm (from the total number of root tips)	%	57	7	64	4	0.002
Parameters indicating potential excess rainfall resistance						
Water infiltration rate	mm min^{-1}	3.7	6	11.1	13	0.033
Macropores at 10 cm	number dm^{-2}	3.5	2	5.3	3	0.175
Macropores at 20 cm	number dm^{-2}	1.5	1	3.4	2	0.013

[1] Means, standard deviations, *P*-values based on a paired T-test. SD = standard deviation; Yrs without cult. = years without cultivation.

[2] Carbon sequestration rate was only measured on 6 young and 6 old grasslands.

Conclusions

The carbon sequestration rate of young grassland topsoil was larger than that of old grasslands, yet carbon is also still sequestered in the topsoil of grassland older than 30 years. Extending grassland age on clay soils can positively contribute to climate change mitigation and adaptation, but by how much warrants further study.

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