Presumed yield benefit of grassland renewal is offset by loss of soil quality

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Abstract

An important motivation for farmers to renew grassland swards (by ploughing and reseeding) is to introduce the most recent grass cultivars that give high yields and high forage quality. However, grassland renewal may affect soil quality negatively due to ploughing. The aims of this study were (1) to compare grass productivity and soil chemical quality of young and old grasslands, and (2) to investigate the relation between soil chemical quality and grass productivity. On clay soil in the north of the Netherlands we measured grass productivity and soil parameters of 'young' (5-15 years without grassland renewal) and 'old' (>15 years without grassland renewal) grasslands, located as pairs at ten different dairy farms. We selected grasslands with at least 70% desirable grasses (i.e. *Lolium perenne* and *Phleum pratense*). We found a lower herbage nitrogen (N) yield in young grassland and no significant difference compared with old grassland in terms of herbage dry matter yield and fertilizer N response. The soil of young grassland contained less soil organic matter (SOM), carbon (C-total) and nitrogen (N-total) compared to the old grassland soil. Grass productivity was positively correlated with SOM, N-total and C-total. The current management practice of renewing grassland after 10 years without considering the botanical composition is counter-productive.

Keywords: grass productivity, nitrogen, permanent grassland, soil organic matter

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). An important motivation for grassland renewal is to introduce the most recently developed perennial ryegrass varieties (*Lolium perenne*) to increase feed production and quality. Plant breeding programmes have accomplished a yield increase of 3% per decade plus enhanced digestibility, and many studies have shown that, with this increase, reseeding is economically attractive for farmers (Chaves *et al.*, 2009; Sampoux *et al.*, 2011). However, these studies are based on comparison of older grass varieties with new varieties sown at the same time on the same field. Possible effects of loss of soil quality due to ploughing have not been taken into account. The main objective of this study was to compare grass productivity and soil chemical quality of young (5-15 years) with old (>15 years) permanent grassland on clay soil.

Materials and methods

The study was conducted in 2014 at ten conventional dairy farms on marine clay soil in the north of the Netherlands. At each farm a young and an old grassland were selected based on the following criteria: seeded with the most recently developed commercially available perennial ryegrass varieties at time of renewal, no clover seeded, with no visual soil compaction, and at the time of sampling containing at least 70% desirable grasses (i.e. *Lolium perenne* and *Phleum pratense*). On each grassland, an experimental plot of 15×9 m was laid out with three 10×3 m sub-plots fertilized with 0, 150 or 300 kg N ha^{-1} yr^{-1}. The remaining 5×9 m sub-plot was not fertilized and was used to measure SOM, N-total and C-total in April 2014. Grass was harvested four times in 2014, weighed and sampled for dry matter (DM) and total N analysis. See Iepema *et al.* (2020) for details on the experimental lay-out, measurements and statistical analyses.

Results and discussion

The N yield without N fertilization (NY_{N0}) was significantly lower in the young grasslands compared to the old grasslands. The other grassland productivity parameters, i.e. grassland dry matter yield without nitrogen fertilization (DMY_{N0}), grassland dry matter yield response to nitrogen fertilization (DMY-res) and grassland nitrogen response to nitrogen fertilization (NY-res) were not different between the young and old grasslands (Table 1).

The average age difference between young and old grasslands was 16 years. Assuming an increase of 0.3% per year in productivity by genetic improvement, the average increase in productivity in these 16 years should theoretically be 4.8%. However, we found a (non-significant) decrease in DMY_{N0} of 9% of the young compared to the old grasslands. This is the productivity without N fertilization. According to Dutch legislation, farmers on a clay soil were allowed to fertilize their grasslands with 345 kg available N ha^{-1} $year^{-1}$ in 2014. At the N application rate of 345 kg N ha^{-1} $year^{-1}$, we also did not find a difference in the DMY (based on the DMY_{N0} and DMY-res per field) of young (on average 16.2 Mg DM ha^{-1}) and old grasslands (on average 16.3 Mg DM ha^{-1}). This finding is in line with the study of Hopkins (1990) who found higher productivity of *Lolium perenne* reseeds only at fertilizer-N rates of 450 and 900 kg N ha^{-1} $year^{-1}$. Apparently, the genetic potential of the most recently developed varieties sown in the young grasslands in our study was offset by the loss of soil quality.

The topsoil (0-10 cm) of the young grassland contained significantly lower soil organic matter, C-total and N-total than the topsoil of old grassland (Table 1), indicating C and N losses in topsoil due to ploughing. SOM and related soil parameters were strongly correlated with grass productivity parameters (Table 2).

Conclusions

Our study confirms that when grassland contains at least 70% desirable grasses, grass productivity does not increase after renewal on the long-term, most likely because of loss of SOM as a result of ploughing. In the past, dairy farmers could compensate for this loss of soil quality through extra fertilization. However, due to current legislative prescriptions, fertilization is limited and this makes such compensation less feasible. Therefore, a strict recommendation to renew all grasslands after 10 years to improve productivity

Table 1. Grass productivity and soil parameters in the 0-10 cm depth of the young (n=10) and old (n=10) grasslands on marine clay soil.[1]

Parameter	Unit	Young grassland		Old grassland		
		mean	SD	mean	SD	*P*-value
Grass age	years without cultivation	9	4	25	4	<0.001
DMY_{N0}	Mg DM ha^{-1} $year^{-1}$	9.2	2	10.2	1	0.154
DMY-res	kg DM kg N^{-1}	20	6	18	4	0.250
NY_{N0}	kg N ha^{-1} $year^{-1}$	172	50	198	21	0.034
NY-res	kg N kg N^{-1}	0.68	0.06	0.64	0.09	0.198
Soil organic matter	g. 100 g dry $soil^{-1}$	10.7	3.3	13.3	2.2	0.031
C-total	g C kg dry $soil^{-1}$	45.2	18	61.0	12	0.002
N-total	g N kg dry $soil^{-1}$	4.82	1.7	6.28	1.2	<0.001

[1] Means, standard deviations and *P*-values are based on a paired T-test. DMY_{N0}: grassland dry matter yield without nitrogen fertilization, DMY-res = grassland dry matter yield response to nitrogen fertilization; NY_{N0} = nitrogen yield without nitrogen fertilization; NY-res = grassland nitrogen response to nitrogen fertilisation; SD = standard deviation.

Table 2. Pearson correlations between grass productivity parameters and topsoil parameters (measured in 0-10 cm soil layer).

Grass productivity parameter	SOM	N-total	NSC±	C-total
DMY_{N0}	0.65**	0.70**	0.71**	0.67**
DMY-res	-0.78 ***	-0.79***	-0.81***	-0.77***
NY_{N0}	0.75 ***	0.80***	0.81***	0.77***
NY-res	-0.29	-0.28	-0.27	-0.30

[1] NSC± = nitrogen supply capacity calculated from N-total, corrected for grassland age according to the formulas of the Dutch grassland fertilization guideline. ** $0.001<P<0.01$; *** $P<0.001$.

can be considered obsolete. When the introduction of high yielding grassland varieties is necessary, the focus should be on oversowing (i.e. non-destructively adding grass seeds to the existing sward) rather than renewing the grassland. Moreover, farm management should focus on minimizing the need for renewal by good grassland management, e.g. maintaining desirable grasses by grazing, adequate fertilization, irrigation and preventing soil compaction (De Boer *et al.*, 2018).

Acknowledgements

We thank Jan Boonstra, Jan-Paul Wagenaar and Jan Zonderland for assistance with grass sampling and the farmers for the use of their grasslands. The data collection for this research was part of the project 'Graslandbeheer en biodiversiteit Goud van oud grasland op de Noordelijke zeeklei' funded by the provinces Fryslân and Groningen, and LTO Noord funds.

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Grassland at the heart of circular and sustainable food systems

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Volume 27
Grassland Science in Europe