Rooting of permanent grassland in relation to build-up of soil organic matter for climate mitigation

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Abstract

Improved grassland rooting can have a positive effect on carbon sequestration. In our study we measured the root biomass and soil organic matter (SOM) of ten 'young' (<13 years) and ten 'old' (>18 years) grasslands on ten dairy farms on marine clay (fluvisol) in the north of the Netherlands. The aim of the study was to investigate the range of rooting in existing permanent grasslands in relation to grassland age and SOM build-up. The root biomass of the twenty permanent grasslands varied between 4.3 and 15.7 ton ash-free dry matter ha^{-1}. There was no significant difference in root biomass between old and young grasslands. SOM in the soil layer 0-10 cm was significantly higher in old grasslands and correlated positively with root biomass in 0-10 cm in old grasslands. By a theoretical calculation, we confirmed the possible long-term causality of measured differences in root biomass and SOM in old grasslands.

Keywords: permanent grassland, grass rooting, root biomass, soil organic matter, climate mitigation

Introduction

Higher grassland root biomass can result in a higher supply of organic matter to the soil (Abberton *et al.*, 2008). This increases carbon sequestration and can therefore be regarded as a tool for climate mitigation. There is a wide range in grassland root biomass which is related to e.g. grass species, cultivar and grassland management (Deru *et al.,* 2014). The aim of this study was to investigate the range of root biomass in existing young and old permanent grasslands on marine clay soils, the effect of grassland age ('young' vs 'old') and the relation between rooting and soil organic matter (SOM) build-up.

Materials and methods

On each of ten dairy farms on marine clay soil (fluvisol) in north of the Netherlands, two permanent grasslands were selected; a 'young' (<13 years) and an 'old' (>18 years) grassland. On each of these grasslands the root biomass was sampled in April 2014 at three soil depths (0-10; 11-20 and 21-30 cm) by taking three soil cores per plot per depth with a root auger (Ø 8.2 cm). The samples were thoroughly washed out with water over a sieve with a mesh size of 2 mm. All roots were collected (other non-root particles were removed by hand) and oven dried at 105 °C for dry matter measurement. After incineration at 600 °C, root biomass was corrected for percentage of ashes and expressed as ash-free dry matter (AFDM kg ha^{-1}).

SOM was measured in the soil layer 0-10 cm by taking a field-moist bulk sample of 70 cores (Ø 2.3 cm). A part of the bulk sample was oven-dried at 40 °C and SOM was determined by loss-on-ignition. An ANOVA procedure (Genstat 13.3, VSN international) to test for treatment effect ('young' versus 'old') on SOM and root biomass was used. Each of the 10 farms in which both treatments were compared was statistically regarded as a block. Pearson correlations between root biomass and SOM were calculated.

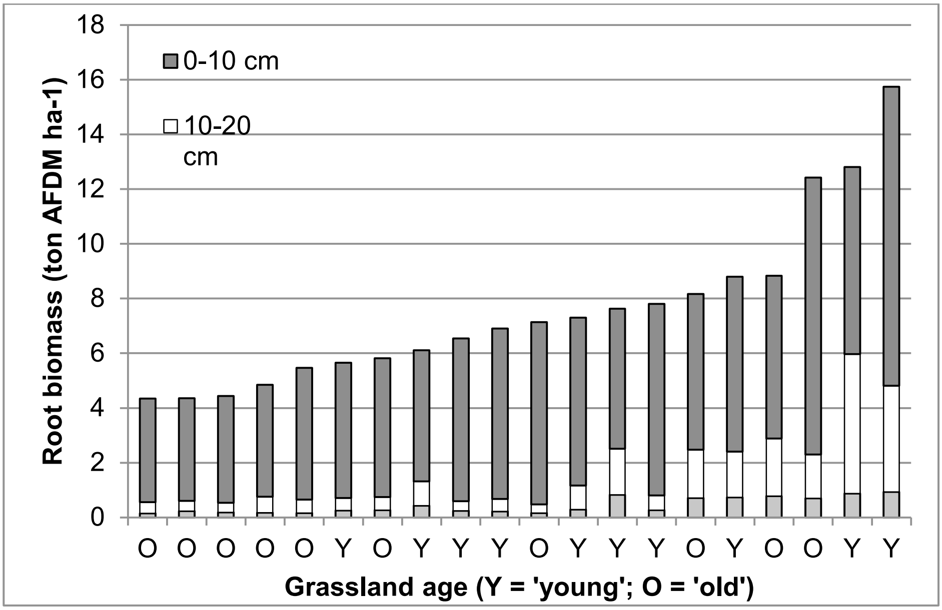

Figure 1. Range in root biomass ash-free dry matter (AFDM) in soil layer 0-30 cm (ton ha^{-1}) across the 10 'young' (<13 years) and 10 'old' (>18 years) grasslands.

Results and discussion

Mean root biomass in the soil layer 0-30 cm of the twenty grasslands was 7.6 t AFDM ha^{-1} and ranged from 4.3 to 15.7 t AFDM ha^{-1} (Figure 1). This is much higher than the 2.1 to 4.1 t dry matter ha^{-1} found by Deru *et al.* (2014) on sandy soil in the soil layer 0-24 cm. There was no significant difference between old and young grasslands in root biomass. In general root biomass increases with increasing grassland age up to 15 years (Whitehead *et al.*, 1990), however, van Eekeren *et al.* (2008) showed that root counts at 10 cm soil depth were 77% lower for 38 year-old grassland compared to three-year-old grassland.

SOM in the soil layer 0-10 cm was significantly (P<0.001) higher in old grasslands (13.3 g 100 g^{-1}) compared to young grasslands (10.7 g 100 g^{-1}). For old grasslands there was a significant (R^2 = 0.6; P<0.01) correlation between root biomass at 0-10 cm soil depth and SOM at 0-10 cm soil depth. The equation showed that a 1 ton increase in root biomass (AFDM) was associated with a SOM increase of 0.88% at 0-10 cm soil depth. We verified this observation by a theoretical calculation of long-term effects of a high versus low root biomass on SOM, using our experimental data. We assumed a fixed root turnover of 76% per year (Scott *et al,* 2012), a contribution of dead root material to build-up of SOM of 50%, a SOM decomposition of 2% per year, a soil bulk density of 1.03 g cm^{-3} and no difference in organic matter contribution from stubbles and leaves. With these assumptions, a difference in root biomass of 1 t ha^{-1} contributes in the long run to a difference in SOM of 1.8% at 0-10 cm soil depth. This calculated theoretical effect is larger than our observed effect, which may be partly due to the fact that the equilibrium state has not yet been reached in our grasslands.

In contrast to the old grasslands, we found no correlation between root biomass (AFDM) and SOM in the young grasslands (Figure 2). SOM in permanent grassland soils is the resultant of many years of organic matter accumulation from dying roots and other unharvested plant parts and input of organic manures. In young grasslands this process has recently been disturbed by soil tillage, resulting in mixing

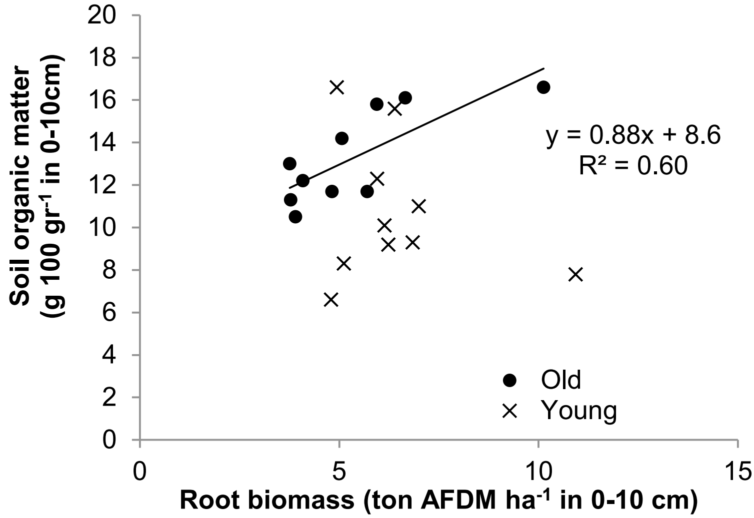

Figure 2. Relation between root biomass ash-free dry matter (AFDM) and soil organic matter in 'old'(>18 years) and 'young' (<13 years) grasslands, with linear regression line for 'old' grassland ($R^2 = 0.60$, P=0.009).

of organic matter into deeper soil layers and increased mineralisation in combination with a different cropping (arable) history.

Conclusions

There is a high variation of root biomass (AFDM) of permanent grasslands on marine clay soil. We did not find a significant difference between old and young grasslands in root biomass. In old (>18 years) grasslands a correlation between SOM and root biomass suggests that every ton root biomass (AFDM) results in an increase of 0.9% SOM at 0-10 cm soil depth. This can be theoretically justified by a calculation of long-term effects of a high versus a low root biomass on SOM.

References

Abberton M.T., Marshall A.H., Humphreys M.W., Macduff J.H., Collins R.P., Marley C.L. (2008) Genetic improvement of forage species to reduce the environmental impact of temperate livestock grazing systems. *Advances in Agronomy* 98, 311-355.

Deru J., Schilder H, van der Schoot J.R. and Van Eekeren N. (2014) Genetic differences in root mass of *Lolium perenne* varieties under field conditions. *Euphytica* (2014) 199, 223-232.

Scott J.T., Stewart D.P.C. and Metherell A.K. (2012) Alteration of pasture root carbon turnover in response to superphosphate and irrigation at Winchmore New Zealand. *New Zealand Journal of Agricultural Research*, 55 (2), 147-159.

Van Eekeren N., Bommelé L., Bloem J, Schouten A.J, Rutgers M, De Goede R, Reheul D and Brussaard L. (2008) Soil biological quality after 36 years of ley-arable cropping, permanent grassland and permanent arable cropping. *Applied Soil Ecology* 40, 432-446.

Whitehead, D.C., Bristow, A.W., and Lockyer, D.R. (1990). Organic matter and nitrogen in the unharvested fractions of grass swards in relation to the potential for nitrate leaching after ploughing. *Plant Soil* 123, 39-49.

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