

Upscaling soil carbon and nutrient losses from dairy farms to regional level

Hanegraaf M.C.¹, Den Boer D.J.¹, Doppenberg G.J.¹ and Korevaar H.²

¹Nutrient Management Institute, Wageningen, the Netherlands; ²Wageningen UR – Agrosystems Research, Wageningen, the Netherlands; marjoleine.hanegraaf@nmi-agro.nl

Abstract

An important aspect of agro-ecology is adjusting farm management to the regional landscape. In intensive farming systems, the approach may target, among others, reduction of N- and P-losses along water borders and/or an increase biodiversity through cultivation of cereals. However, not much is known of the short- and long term impact of such measures on soil carbon contents (SOC). An ex-ante assessment was made of soil carbon change following implementation of measures to reduce nutrient losses in the region of Winterswijk (NL). The Roth-C model was used to assess carbon loss over time. Upscaling to farm and regional level was done on the base of potential area sizes. It was found that, although individual measures that reduce N- and P-losses may lead to either loss or gain in SOC-content at field level, implementation of all measures would at the regional level lead to zero change in SOC-stock. Thus in theory it is possible to improve water quality while maintaining SOC-contents at the regional level. However, this result depended largely on the area sizes where some high impact measures may be implemented, e.g. cultivation of cereals and raising pH. It was concluded that discussing farm and regional priorities for soil and water quality could be the next step in the regional stakeholder process.

Keywords: N and P losses, Roth-C model, dairy farms, regional level

Introduction

An important aspect of agro-ecology is adjusting farm management to the regional landscape. This may involve agricultural practices to realise production goals, e.g. drainage. It may also involve practices directed at several external targets, e.g. reducing N- and P-losses to improve water quality and/or increase biodiversity. Governing bodies focus primarily on the accumulated effect of measures for achieving the regional targets. Effects of these measures on soil carbon contents (SOC) in agricultural soils are seldom taken into account. A regional stakeholder process that includes both farm and landscape qualities is important if intensive dairy farms are to maintain nature values (Hanegraaf *et al.*, 2015). For the present study, we performed an ex-ante assessment of soil carbon change related to successful measures for reducing nutrient losses and increasing biodiversity. Results at field level were scaled up to the regional level to provide data and insights as possible input for the regional stakeholder process.

Materials and methods

The work was carried out in the Winterswijk region in the Netherlands. This region is characterised by a 'coulißen' landscape on sandy soils, consisting of a mosaic of agricultural lands, hedgerows and woodlots, dissected by brooks and rivers. Dairy farming is the dominant farming system. In previous studies, farmers have been testing measures to reduce N- and P- losses and improve biodiversity (Den Boer and De Haas, 2013). The applicability of successful measures throughout the region was assessed using technical data (groundwater level, pH) and farmers' evaluation. It was found that for the 5,000 ha area, nutrient losses could be reduced by 123 t N and 72 t P₂O₅, which equals 9 and 20% of the amounts used, respectively. Successful measures were taken as a starting point for modelling changes in SOC-contents at regional level. It concerned the following: (1) cultivation of grain cereals instead of maize or potato; (2) introduction of grass-clover mixtures; (3) cultivation of a good catch crop after maize; (4) no farmyard manure (FYM) if soil P is high (c. 7 P-PAE) within 10 m of water borders; and (5) liming

to raise pH to recommended level in acid maize soils. The change in SOC-content with each measure was assessed using the Roth-C model (Coleman and Jenkinson, 1999) and a time-scale of 20 years. The outcomes of the modelling at the field level were used for upscaling to the regional level, using the data of area sizes from the previous study.

Results and discussion

It was shown that the selected measures to reduce N- and P-losses may lead to either loss or gains in soil carbon content (Figure 1). As a starting point, a SOC-content of 65 Mg ha⁻¹ was assumed, which evolved widely over a period of twenty years, i.e. from 49 Mg C ha⁻¹ (potato without FYM to 74 Mg C ha⁻¹ (cereals, incorporating straw).

Results showed a gain in C for both grassland and grass-clover; however without FYM, SOC-contents remain stable. The assessment was based on calculations with a standardised C-input of a 3-year old grassland which reflects actual agricultural practice in the region. As the new CAP stimulates permanent grasslands, gains in C may be even higher. The measure 'liming' illustrates that not all measures that reduce N- and P-losses turned out positive for SOC-contents. Over a period of 20 years, C-loss would be c. 8 Mg ha⁻¹, corresponding to a change on soil organic matter content from 3.3 to 2.8%. A possible consequence of this measure could be that SOC contents decrease to the extent that other related soil properties may become limiting, e.g. soil moisture. During the research period, farmers experienced a positive effect of this measure on crop yield, which was concomitant with higher N- and P-uptake. It could be argued from an agronomic viewpoint that this measure should be applied at all relevant fields, in combination with application of extra organic matter. Other measures were found to increase SOC-contents, e.g. the cultivation of cereals to provide concentrates at dairy farms. It was calculated that this measure would increase soil organic matter content from 3.3 to 3.8% over the 20-year period. This measure performed well for three aspects, i.e. reduction of nutrient losses, increase of biodiversity, and increase of SOC. However, chances that this measure will be implemented throughout the region are small, since it has not been included in the new CAP. Dairy farmers with min. 75% grassland and max. 30 ha arable land are exempt from the diversification requirement. We therefore expect that dairy farmers with derogation (80% grassland) will resume to grass and maize cultivation.

At the regional level, it was found that maximum implementation of all measures concerned would lead to almost zero change in SOC (Hanegraaf *et al.*, 2016). Thus for the region of Winterswijk it was found that water quality may be improved without deteriorating soil quality. This result was largely dependent

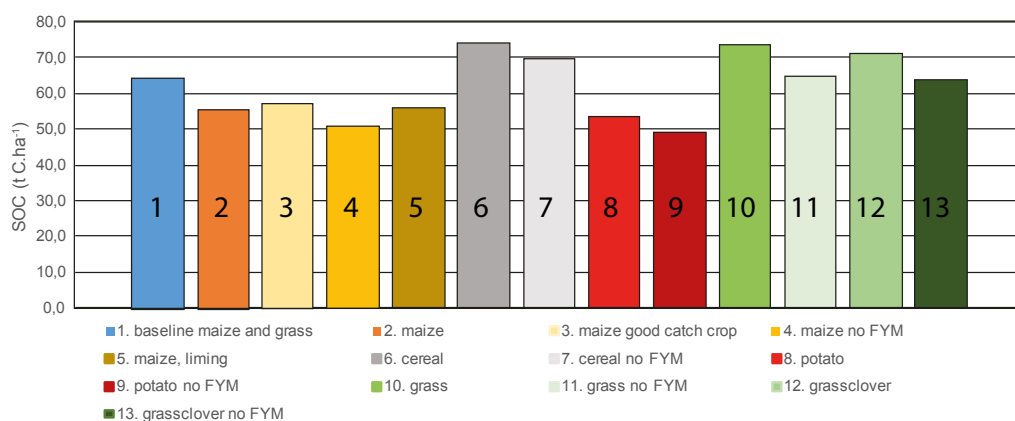


Figure 1. Changes in soil carbon-content (SOC) after 20 years.

on the area sizes where high impact measures could be implemented, e.g. cultivation of cereals and raising pH. Other selections of measures and area sizes may lead to different results concerning losses or gains in SOC-content at regional scale level. Discussing targets at the regional level may help in selecting priorities for adjusting farm management with respect to a reduction of nutrient losses while maintaining soil fertility.

Conclusions

This work focused on improved adjustment of farm management on critical levels of the regional landscape, e.g. soil type, groundwater level, and hedges. The approach showed that, at the regional level, it is possible to reduce N and P losses while maintaining SOC levels. Several combinations of measures are feasible, depending on farm characteristics as required roughage production, economics, and effect of individual measures on SOC. Next steps in the regional stakeholder process could be setting farm and regional priorities and agreement on measures to implement with or without a rewarding scheme.

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