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Reduced nitrate leaching from an Irish cropland soil under non-inversion tillage with cover cropping greatly outweighs increased dissolved organic nitrogen leaching

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ABSTRACT

Reduced tillage and cover cropping are common measures to minimize leaching losses of nutrients from cropland soils. While the efficiency of these measures for reducing inorganic N leaching has been studied intensively, their effect on dissolved, organically-bound nitrogen (DON) remains unclear. In this study, leaching of nitrate, ammonium and DON from spring barley-based cropping systems, subject to either conventional management (CT = inversion tillage with a winter fallow period), or non-inversion tillage with a winter mustard cover crop (NIT + CC), were assessed using suction cup sampling and modelled drainage volumes. Total dissolved nitrogen losses with drainage from the NIT + CC treatment (2.5 ± 0.2 g N m^{-2} yr^{-1}) were considerably smaller than those from the conventional treatment with fallow (13.9 ± 0.7 g N m^{-2} yr^{-1}). As drainage volumes were similar between treatments, differences in total N leaching were mainly associated with larger nitrate concentrations under CT (23.0 ± 1.1 mg N L^{-1}) than under the NIT + CC treatment (5.1 ± 0.3 mg N L^{-1}). The average contribution of DON to total dissolved nitrogen concentration was 3% within the CT treatment, but rose to 19% within the NIT + CC treatment, which was primarily due to the strong reduction in nitrate and to a lesser extent due to the higher concentrations of DON within the NIT + CC treatment (NIT + CC: 0.52 ± 0.04, CT: 0.33 ± 0.04 mg N L^{-1}). Averaged over the two-year study period, the CT system showed a net loss of 9.4 g N m^{-2} $yr^{-}1$ whilst an N surplus of 1.7 g N m^{-2} yr^{-1} was observed for the NIT + CC system. Here DON accounted for 11% of total N leaching, supporting the notion that it can be an important component of dissolved N losses in agroecosystems. By neglecting DON leaching the N-surplus under NIT + CC would have been overestimated by 18%. In conclusion, our results show that the capacity of winter cover cropping in combination with non-inversion tillage to reduce nitrate leaching far outweighed the higher leaching losses of DON observed. The quantification of DON losses, however, may be essential for a complete picture of the N balance of these and similar cropping systems.

1. Introduction

Management interventions are an important approach for reducing the environmental impacts of intensive agricultural production systems (Power, 2010) and are a key factor in achieving many of the sustainable development goals outlined by the United Nations (General Assembly, 2015). The objectives of the development goals include the mitigation of global climate change, whilst ensuring food security (Lal, 2010,

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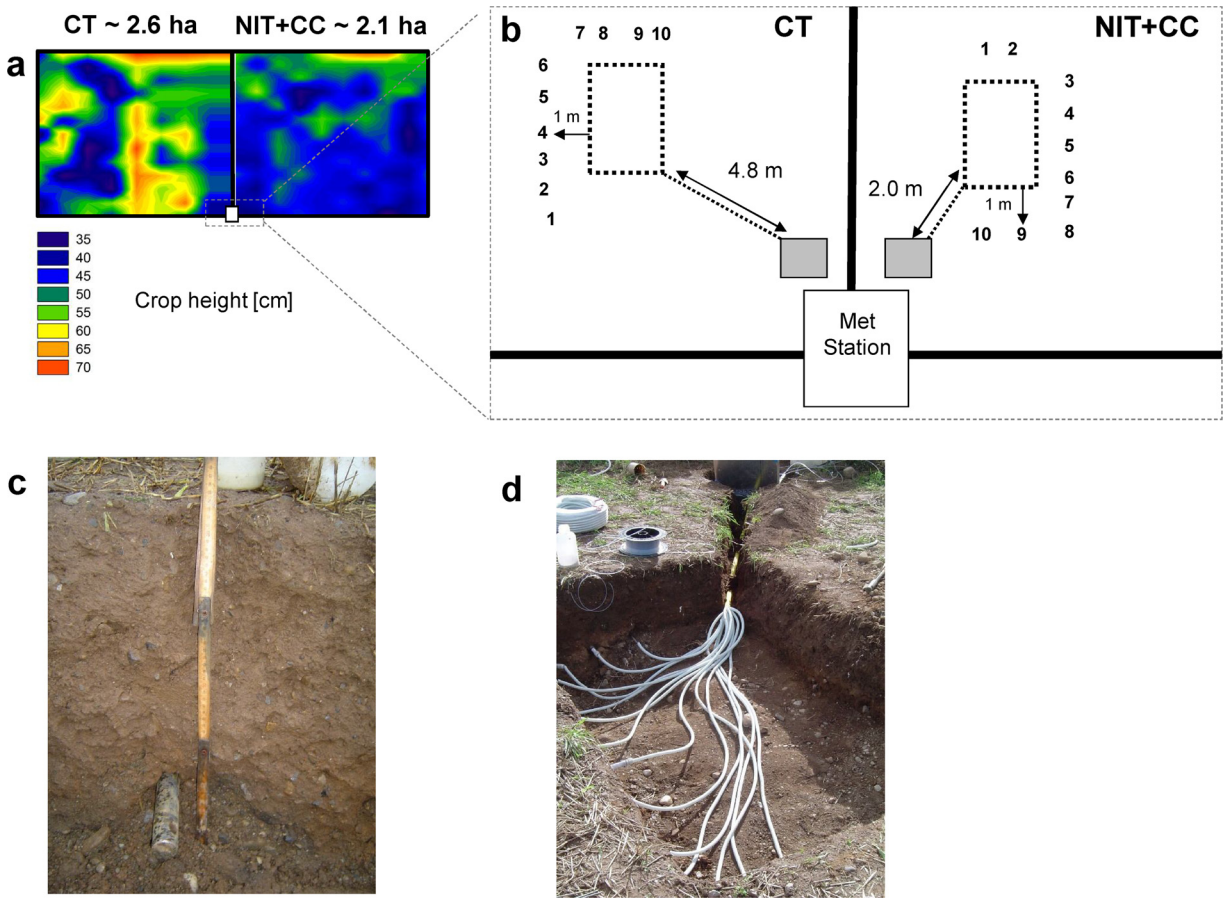

Fig. 1. Schematic Overview of the Experimental Design within the Study Site (a) The study site consists of two fields, one of which was conventionally tilled (CT) with the other subject to non-inversion tillage and the presence of a winter cover crop (NIT + CC). The coloured contours within the plots show the crop height as measured on the 6th August 2006. (b) Within each field 10 suction cups were installed horizontally from a trench (dotted rectangle) and the tubing extended along a further trench (dotted line) to an insulated aluminium sample collection box (grey rectangle) next to the meteorological station (Met Station) where the soil was undisturbed by management practices. The photographs in the bottom half of the figure show (c) the auger that was inserted horizontally just above the coarse sandy C horizon to create the 1 m long borehole into which the suction cups were inserted and (d) the final set-up prior to backfilling of the trenches. In the top half of the picture the aluminium collection box can be seen which was placed into the soil in order to keep the samples cool in the summer.

2004), as well as the sustainable management of nutrients (Drinkwater and Snapp, 2007) and soils (White et al., 2012).

Two common management practices utilised to enhance carbon sequestration, whilst also improving soil quality and nutrient, particularly nitrogen retention, are reduced tillage and cover cropping during fallow periods (Paustian et al., 2016). Whilst the effect of such management practices on dissolved inorganic nitrogen (DIN) leaching has been intensively studied in the past, less is known about dissolved organic nitrogen (DON) losses despite evidence that the contribution of DON to total N leaching is larger than that of dissolved ammonium which is generally considered in analyses addressing potential N leaching (Jiao et al., 2004; McKenzie et al., 2016; Perakis and Hedin, 2002).

In a review on DON in agroecosystems, van Kessel et al. (2009) cited 16 publications that have assessed DON as well as nitrate losses. However, only six of these referred to croplands (Lawes et al., 1881; Murphy et al., 2000; Saarijärvi et al., 2007; Shuster et al., 2003; Siemens et al., 2003; Vinther et al., 2006), with the contribution of DON to total N-leaching varying widely from 1 to 65%. Since then only a limited number cropland studies have reported both inorganic N and DON losses, mostly from contrasting rotation systems and/or in response to soil and fertiliser management practices with the contribution of DON to total N-leaching again varying widely from 1 to 74% (Böhm et al., 2009; Huang et al., 2011; Undurraga et al., 2009). Consequently, for the development and assessment of more sustainable management practices, information on DON concentrations and fluxes is needed for the improved assessment of agro-ecosystem N cycling and associated budgets.

In this study, we quantified the effects of non-inversion tillage in combination with a cover crop on N leaching from an Irish arable soil under spring barley cultivation with a particular focus on DON. We hypothesized that when compared to a conventionally tilled system without a cover crop this combination would result in i) a reduction in inorganic N leaching due to the enhanced uptake of residual mineral N during the winter by the cover crop and ii) an increase in organic N leaching due to the additional inputs of organic matter by the cover crop in combination with reduced soil aeration and thus lower mineralisation. Finally, we hypothesized that both these effects lead to an increase in the contribution of DON to total dissolved N in the soil solution, justifying the need to include DON leaching in field-scale N budgets.

2. Materials and methods

2.1. Study site and agricultural management

The study site ("Pump Field") was located at the Teagasc, Oak Park Crop Research Centre, Ireland (52°51′N and 6°55′W; 56 m asl), which has been the location of numerous field studies in the past. The region is characterised by a temperate Atlantic climate (MAP 823 mm, MAT