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Effect of an agri-environmental measure on nitrate leaching from a beef farming system in Ireland

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ABSTRACT

Agricultural nitrogen (N) management remains a key environmental challenge. Improving N management is a matter of urgency to reduce the serious ecological consequences of the reactive N. Nitrate (NO_3^-–N) leaching was measured under suckler beef production systems stocked at two intensities: (1) intensive, 210 kg organic N ha^{-1} with two cut silage harvests; and (2) rural environmental protection scheme (REPS), 170 kg organic N ha^{-1} with one cut silage harvest. Three replicate plots of each treatment were instrumented with ceramic cups (8 per plot), randomly placed within each plot at a depth of 1 m to collect soil solution for NO_3^-–N at 50 kPa suction to collecting vessels one week prior to sampling. Samples were taken on a total of 53 sampling dates over 3 winter drainage periods (2002/03, 2003/04 and 2004/05). Over the course of the experiment the mean annual soil solution NO_3^-–N concentration exceeded the MAC twice out of 15 means (5 treatments over 3 years). The REPS grazing and silage sub treatments had significantly lower mean annual soil solution total oxidized N (TON) concentrations than the respective intensive treatments in years 2 and 3. Annual total NO_3^-–N losses over the three years in intensive and REPS systems ranged from 55 to 71 and 15 to 20 kg N ha^{-1}, respectively. Mean N surpluses in intensive and REPS systems were 210 and 95 kg ha^{-1}, respectively with the corresponding mean N inputs of 272 and 124 kg N ha^{-1}. The reduction in N inputs under the REPS system results in lower N leaching losses and contributed to a significant reduction in pressures on water quality.

1. Introduction

Improving water quality in Ireland, in particular for the eutrophication in lakes, rivers and coasts, remains one of the key environmental challenges (Fenton et al., 2011; Toner et al., 2005). Among the substances responsible for eutrophication, nitrate (NO_3^-–N) leaching from agricultural soils is by far the most important contributor (Nguyen et al., 2010). There has been considerable legislation, at the European and national levels, which has lead to the introduction of the Nitrates Directive (1991/676/EC) and the Water Framework Directive (2000/60/EC). Both of these legislative instruments require mandatory actions and measures to be introduced to ensure good water quality (Stark and Richards, 2008). The 2007–2009 biological surveys (McGarrigle et al., 2010) has shown another slight improvement in overall surface water quality, with 69% of river channel length classified as unpolluted. On the other hand national groundwater quality is still under threat as 40% of the monitoring locations showed 10–25 mg NO_3^- L^{-1}, 16% of the monitoring locations exceeded 25 mg L^{-1} NO_3^- and 3% exceeded 50 mg L^{-1} NO_3^- (Craig et al., 2010).

In Europe, agri-environmental measures (AEMs) were established to reduce agricultural impacts on the environment and positively contribute to environmental protection and enhancement. They were introduced through a number of EU regulations such as 797/85 EC and 2078/92. The implementation of AEMs is compulsory at the national level and was optional for farmers within member states. The rural environmental protection scheme (REPS) was established in 1994 as Ireland's AEM. The scheme was designed to financially reward farmers for carrying out their farming practices in an environmentally friendly manner and to

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ensure good environmental practice on farms. REPS places compulsory limits on inorganic fertilizer N rates, application timing and the overall farm stocking rate must be below 170 kg organic N ha^{-1}. It also contains a large range of other compulsory and optional measures with a particular focus on enhancement of biodiversity. A comprehensive study of the environmental impacts of REPS has been absent in Ireland (Finn and hUallacháin, 2011).

The REPS scheme in Ireland was attractive to farmers, an estimated 31% of Irish farms received REPS payments in 2004 (Connolly et al., 2005). Almost 74% of farms which participate in REPS are in the three dry stock systems, namely cattle rearing, cattle Other and mainly sheep (Connolly et al., 2005). Reduced fertilizer N inputs to grazed permanent grassland should lead to decreased NO_3^- leaching rates. Over an 8 year period, NO_3^-–N leaching was 38 and 129 kg N ha^{-1} on a clay loam soil (Scholefield et al., 1993) receiving fertilizer inputs of 200 and 400 kg N ha^{-1}. Watson et al. (2000) reported a significant positive relationship between fertilizer N application rate (100–500 kg N ha^{-1}) and load of NO_3^-–N leached. Published schemes on NO_3^-–N leaching in Irish agricultural system is scarce and the studies highlighted the potential threat of NO_3^-–N to surface and groundwater pollution. There has been no evaluation of the efficacy of REPS in reducing nutrient loss to water. Ryan et al. (2006) estimated mean NO_3^- and NH_4^+ concentrations of 8.2 and 0.30 mg N L^{-1} leachate, respectively at 1 m bgl (free draining soil) under dairy systems where mean N input and stocking density were 319 kg ha^{-1} and 2.38 LU ha^{-1}. Similar to grass, cereal-growing on recently ploughed grassland on well drained soils receiving 75–100 kg N ha^{-1}, poses a significant risk to water quality from leaching of NO_3^- (Ryan et al., 2001). Farmers and regulators urge the need to improve N recovery in agricultural systems. For example EU directives impose pressure on agriculture to make more efficient use of N. The objective of this study was to examine the effect of reduced animal stocking rate and associated fertilizer N inputs on NO_3^- leaching under suckler beef production on a moderately well drained clay loam soil in Ireland.

2. Materials and methods

2.1. Study site description

The study was carried out at Teagasc, Grange research center which is located in Dunsany, Co. Meath, Ireland (53°32′N, 6°31′E) at 60 m above sea level. The research farm focuses on beef and suckler production and is mainly comprised of permanent grassland. The soils on the farm were mapped in detail by Gardiner (1962). The area is underlain by gravely, limestone boulder clay with occasional sorted sands and gravels. The soils are derived from the boulder drift cover and vary between clay loam and clays. The plots investigated comprised of moderately well drained, brown earth, clay loam soils of high base status. The FAO classification of the soil underlying the site is an Orthic Luvisols (Kurz et al., 2006).

2.2. Farming systems

Nitrate leaching was quantified under two suckler beef production systems in the final 3 years of an 8 year agronomic systems experiment. The agronomic systems experiment was conducted from 1997 to 2005. Drennan and McGee (2009) described the agronomic design of the experiment in detail. Spring-calving beef suckler cows were introduced in 2001 and 2002 which consisted of Limousin × (Limousin × Holstein-Friesian), purebred Limousin and purebred Charolais. The suckler beef systems were stocked at two intensities: (1) intensive: 211 kg organic N ha^{-1}; stocking rate (SR) 1.8 and 1.4 for bull and steer production, respectively and (2) REPS: 170 kg organic N ha^{-1}; SR 1.4 and 1.1 for bull and steer production, respectively. Number of silage harvests was 2 and 1 for intensive and REPS, respectively. Both treatments were managed as systems and grazing/silage plots were allocated in a randomized block design. A summary of the treatments, system intensity, grassland management and nutrient source applied to treatments are outlined in Table 1.

Animals were grazed on permanent grassland plots from April to October/November depending on weather and soil conditions. The grazing events during the whole grazing period in every year took place for 7, 5 and 4 times at every 4 week interval for grazing only, one cut silage and 2 cut silage, respectively. During the winter period animals were housed in slatted floor sheds and offered grass silage conserved from within their respective systems. Silage was harvested in both systems for feeding during the winter housing period. In the intensive system there were two silage harvests, May and August each year. Silage was harvested in once in the REPS system in late May/early June. The total annual fertilizer and manure N application rates for each system during the 3 years of the study are outlined in Table 1. Manure was applied (33 m^3 ha^{-1}) to the silage plots in spring and summer before or after first cut and after second cut silage and the manure N application rates are shown in Table 1. All plots received recommended rates of P and K fertilizer each year based on annual soil test results.

2.3. Soil solution sampling

Three replicate plots of each treatment were instrumented with ceramic cups (Soil Moisture Inc., California, USA); there were 8 cups per plot inserted at a depth of 1 m having a bentonite seal, 150 mm below ground surface, around the connecting tube. Ceramic cups were randomly placed within each plot as described by Ryan et al. (2006). Soil solution was sampled by applying 50 kPa suction to collecting vessels one week prior to sampling. Samples were taken on a total of 53 sampling dates over 3 winter drainage periods 2002/03 (year 1), 2003/04 (year 2) and 2004/05 (year 3). The samples were stored and transported at 4 °C to the analytical laboratories in Teagasc, Johnstown Castle. Soil solution samples were analyzed within 48 h of sampling for NO_3^-–N

Table 1
Summary of the treatments, stocking rate (no. animal ha^{-1}), system intensity, grassland management, grazing events (no. grazing time per year), nutrient source and rates applied (kg ha^{-1}) to each treatment.

Treatment	Intensity	Stocking rate	Grassland management	Grazing events	Nutrient applications					
					Fertilizer			Manure		
					Y1	Y2	Y3	Y1	Y2	Y3
T1	Intensive	1.8 (bull); 1.4 (steer)	Grazed only	7	269	188	212	–	–	–
T2	Intensive		Cut once for silage, grazed	5	247	222	273	129	86	102
T3	Intensive		Cut twice for silage, grazed	4	220	245	245	129	86	102
T4	REPS	1.4 (bull); 1.1 (steer)	Grazed only	7	57	57	57	–	–	–
T5	REPS		cut once for silage, grazed	5	114	114	114	98	70	102