**Project number:** 6707
**Funding source:** Teagasc
**Date:** Nov 04, 2019
**Project dates:** Jan 2016-Dec 2019

# Toolkit to better understand nitrogen flowing in drainage water


## Key external stakeholders:

Policy makers
Regulators
Advisors
Farmers

## Practical implications for stakeholders:

This project provides a toolkit to a) identify the nitrogen source in a water sample b) identify the forms of nitrogen in a water sample and c) divide a dairy farm into safe and unsafe areas for N application

Main points
A drainage system collects water from large areas
The water flowing from the pipes can be sampled easily and tested in many ways
This information tells us about the concentration of nitrogen in the sample, where this nitrogen comes from (e.g. organic or inorganic fertilizer source)
This information splits a farm up into safe and unsafe areas with respect to nitrogen losses to the environment.
This toolkit could avoid losses if used appropriately.

## Main results:

Nitrogen in water samples from ditch networks, drainage pipes and groundwater all originated from an organic N source.
Nitrate was lost along well drained pathways
Ammonium was lost along poorly drained pathways
Using the drainage system was an efficient monitoring device to divide a farm up into safe/unsafe nitrogen loss to the environment areas.
Dairy farms have different levels of natural protection due to the soils on site.
Deep drainage systems in mineral soils did not negatively affect the N attenuation capacity of the soils.
Shallow drainage systems negatively affected this natural nitrogen attenuation capacity.

## Opportunity / Benefit:

Nitrogen losses to water can be avoided or minimized using this toolkit.
This work advocates deep groundwater drainage in terms of maintaining the natural attenuation capacity of soils and facilitating infiltration of water.

## Collaborating Institutions:

University of Sheffield and Marie Curie ITN Inspiration Network



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## 1. Project background:

Contamination and deterioration of natural water quality by nitrogen (N) from agricultural sources is a major threat to the environment. Globally, there is a societal expectation that sustainable food production should be achievable. The concept of sustainable intensification is based on to the equality between production and environmental targets. For this to become a reality, increased productivity must be accompanied by provision of clean water, air, habitats for biodiversity, recycling of nutrients and mitigation against climate change. Agriculture and food production rely heavily on external N inputs (e.g. fertilisers) and as agronomic systems generally have low use efficiency there is the risk of high N losses i.e. the leak of N excess to the environment. Agricultural landscapes contain many different soil/subsoil/bedrock typologies having heterogeneous N water attenuation capacities (intrinsic ability of soils to reduce contamination). Dairy farms represent complex environments, necessitating many techniques (isotopes, biogeochemical parameters, dissolved gases, bacterial gene abundances) used in combination, to provide a thorough characterisation of, examination of N source, transformation and fate along different subsurface pathways. These multiple techniques are currently seldom used in combination.

In Ireland, 30% of milk production occurs in high rainfall conditions and heavy textured soil areas. For better grass growth, artificial drainage systems (shallow and groundwater systems) are installed. The role of land drainage in N transfer, transformation and fate is however relatively unexplored. These systems may reduce N transformation potential by, for example, creating unsuitable conditions for denitrification leading to greater nitrate (NO3--N) losses or by-passing zones of high soil N attenuation capacity further compromising sustainability targets. Indeed, the potential to use drainage systems as a monitoring tool, which covers large areas of contribution, has been neglected in terms of multiple techniques that could explore N transfer, transformation and fate. The concept of “sustainable intensification” includes all the aspects of agricultural productivity and environmental protection. The primary aim of this thesis was to examine this concept in terms of impacts and relationships of drainage systems installed at intensive sites on and with soil drainage classes, N transfer, transformation and fate and water quality to develop advises and a range of multiple techniques to improve and guide future management. Herein, this concept has been tested within a range of different contexts in terms of scale (farm, plot and laboratory), soil characteristics (from heterogeneous soils to heavy homogeneous types), drainage designs (from random to parallel and from single to multiple, from moles to piped systems) and techniques (gaseous emissions, biogeochemical parameters, isotopic signatures, gene abundances) in order to produce a more refined interpretation of artificial drainage systems and the role they play within the sustainable intensification framework. As agricultural landscapes contain many different soil types with heterogeneous nitrogen (N) attenuation capacity, a zone of contribution (ZOC) surrounding a borehole and an installed drainage system was used to interpret subsurface hydro-biogeochemical functional capacity within four hydrologically isolated plots. By using the drainage system as a monitoring tool in combination with multiple techniques, a disconnectivity and complexity of the system was highlighted in terms of contamination sources uncovered and separate water attenuation functionalities.

## 2. Questions addressed by the project:

What is the source of nitrogen in a water sample?
What losses of nitrogen occur in our drainage systems and dairy farms?
Does the attenuation capacity of dairy farms differ or is it all the same?
Can we use our drainage systems to investigate net denitrification?

## 3. The experimental studies:

The present study used the hydrologically isolated field facility at Johnstown Castle, the Dairy Farm at Johnstown Castle, the glasshouse facility at Johnstown Castle and five of the Heavy Soil Programme farms in the west of Ireland.

## 4. Main results:

Techniques such as natural isotopic abundances, biogeochemical parameters, isotopomers, gaseous emissions, dissolved gasses, can be combined to elucidate sustainability of intensive dairy systems.

Drainage systems can be used, when analysed with the above techniques, to elucidate water quality but more interestingly can be used as a monitoring tool, in combination with groundwater monitoring networks, to



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interpret net N source, transformation and fate, over large areas, on agricultural landscapes.

Although surpluses of N were found to be uniform across intensive dairy sites on the present study, the soil water attenuation function and "net denitrification" varied considerably across sites. This means that there was considerable variation within dairy farms in terms of N sustainability, which will have consequences for sustainable intensification.

Drainage systems affect this water attenuation function differently depending on their design. This means that the presence of a drainage system on agricultural landscapes does not infer poor water quality, more importantly than absence/presence is the depth and type of drainage system present.

During this assessment the techniques used in combination with the present study worked well to characterise and rank sustainability.

## 5. Opportunity/Benefit:

Drainage systems should be used as large monitoring networks to characterise agricultural landscapes.
The toolkit developed in the present study could be used to inform management change to prevent or minimise nitrogen losses to water.
The present study shows that deep groundwater drains maintain a soils natural attenuation capacity where shallow drainage techniques such as mole and gravel mole drainage take this function away completely. This should inform drainage design and decisions into the future.

## 6. Dissemination:

Beyond nitrate: developing multi-isotopic approaches to quantify the fate and transport of nitrogen within catchments. N.S. Wells, K. Knöller, E. Clagnan, O. Fenton, S.F. Thornton, S.A. Rolfe, M. Brauns. International Symposium on Isotope Hydrology: Revisiting Foundations and Exploring Frontiers – IAEA (International Atomic Energy Agency).Vienna, Austria, 11 – 15 May 2015.

Nitrogen loss, source, transformation and attenuation within an intensive dairy farm in SE Ireland. O. Fenton, E. Clagnan, S.F. Thornton, S.A. Rolfe, P. Tuohy, J. Murphy, N.S. Wells, K. Knoeller. 19th Nitrogen Workshop - Sveriges Lantbruks Universitet, Skara, Sweden, 27-29 June 2016

Nitrogen loss, source, transformation and attenuation on dairy farms in Ireland. O. Fenton, E. Clagnan, S.F. Thornton, S.A. Rolfe, P. Tuohy, J. Murphy, N. Wells, K. Knöller. International Drainage Symposium, University of Minnesota, Minneapolis, Minnesota, 6-9 September 2016

### Main publications:

1. Clagnan, E., Thornton, S.F., Rolfe, S.A., Wells, N.S., Knoeller, K., Fenton, O., 2018. Investigating "Net" provenance, nitrogen source, transformation and fate within hydrologically isolated grassland plots. Agricultural Water Management, 203, 1-8.

2. Clagnan, E., Thornton, S.F., Rolfe, S.A., Tuohy, P., Peyton, D., Wells, N.S., Fenton, O., 2018. Influence of artificial drainage system design on the nitrogen attenuation potential of gley soils: Evidence from hydrochemical and isotope studies under field-scale conditions.. Environmental Management, 206, 1028-1038.

3. Clagnan E, Thornton SF, Rolfe SA, Wells NS, Knoeller K, Murphy J, et al. (2019) An integrated assessment of nitrogen source, transformation and fate within an intensive dairy system to inform management change. PLoS ONE 14(7): e0219479. https://doi.org/10.1371/journal.

## 7. Compiled by: Owen Fenton



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