Extended Abstract

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Paper	Estimation of nitrous oxide (N_2O) emissions from agricultural soil management at higher resolution and implications for defining the cost of carbon at farm level

Abstract prepared for presentation at the 97th Annual Conference of the Agricultural Economics Society, The University of Warwick, United Kingdom

27th – 29th March 2023

Abstract	***200 words max***

This paper aims to define a high-resolution model to estimate nitrous oxide (N_2O) emissions from the application of fertilisers to agricultural soils across the Republic of Ireland and to assess the implications for this approach on the assessment and mitigation of greenhouse gases (GHG) emissions. N_2O emissions from the management of agricultural soils represented 10% of the total national GHG emissions in 2020. The high-resolution model proposed here modifies the current methodology based on the Guidelines for National Greenhouse Gas Inventories (IPCC, 2006) by adding soil characteristics and climate (environmental factors). To apply the high-resolution model, we use farm level microdata from the Teagasc National Farm Survey (NFS) and high-resolution spatial climate based data over the 2014 to 2020 period. Results from the high-resolution model indicates a reduction of 3% in N_2O emissions compared to the baseline model (IPCC methodology). However, the difference in estimated N_2O emissions on individual farms can range from -40% to +45%. Farms with a reduction in the quantification of N_2O emissions have poorer-quality soils, lower soil moisture and less variability in temperature and precipitation over the year. The design of a high-resolution emissions estimation process allows analysis of different agricultural practices and can assist in targeting appropriate GHG based mitigation measures based on cost-effectiveness criteria.

Keywords	Nitrous oxide, environmental factors, carbon cost.
JEL Code	Q000 see: www.aeaweb.org/jel/guide/jel.php?class=Q)

Introduction	***100 – 250 words***

N_2O emissions from the management of agricultural soils represented 10% of the total national GHG emissions in 2020 (Duffy et al., 2022). The current methodology for quantifying N_2O emissions uses a methodology based on the Guidelines for National Greenhouse Gas Inventories (IPCC, 2006) and national emissions factors differentiated by fertilizer type (Tier 2). Although this method approximates the sector's emissions, it does not consider two crucial environmental factors, namely soil characteristics (pH, texture, drainage) and climate (precipitation and temperature). By taking into account these factors, N_2O emissions can be quantified with increased granularity, and as a consequence that economic measures at farm level can be estimated more accurately. In this paper, we estimated the carbon cost from N_2O emissions. Carbon pricing is an instrument that captures the external costs of greenhouse gas (GHG) emissions and can help to reduce emissions from the agricultural sector in a cost effective way.

Methodology	***100 – 250 words***

The high-resolution model modifies the emissions factor of the direct N_2O emissions equations by adding environmental factors by using indices. The soil characteristics indices are soil pH, texture, drainage, soil type and soil moisture. Regarding climate, there are two indices, one for the annual precipitation and the other for air temperature. The assumptions of the indices are defined considering the results obtained in previous research in Ireland and the EU, and the information registered from 2014 to 2020 by the Irish Meteorological Service. Additionally, we estimate a baseline model for comparison that follows the current methodology used in Ireland. This model was proposed in the Teagasc Sustainability Report to show the GHG emissions at farm level in Ireland. Finally, the cost of carbon was included in the analysis to illustrate the potential financial implications for individual farms if the high-resolution model was adopted. The cost of carbon was assumed to be €41 per tonne of CO_2, which is the current price for the transport sector in the country (GI, 2022). In using the Teagasc National Farm Survey (NFS) we can compare the carbon cost by farm type and per hectare.

Results	***100 – 250 words***

The results indicate that the high-resolution model indicates an average reduction of 3% in N_2O emissions compared to the baseline model (IPCC methodology). However, the difference in estimated N_2O emissions on individual farms can range from -40% to +45%. Farms with a reduction in the quantification of N_2O emissions have poorer-quality soils, lower soil moisture and less variability in temperature and precipitation over the study period. Additionally, we estimated that the local climate generates a variation in N_2O emissions which goes from 10% to 27%, while the effect of differing soil characteristics was responsible for a range from 5% to 15% in N_2O emissions variability. This means that the application of one kilo of N input in different parts of the country generates different levels of N_2O emissions, which depends on the local environmental and biophysical conditions. For instance, a farm with a low soil moisture and air temperature of 10 ºC could release an emissions level per hectare of 543 kg N yr^{-1}, and the carbon cost would be €74.7, while a farm with a high soil moisture and air temperature of 12 ºC could release emissions per hectare of 895 kg N yr^{-1}, and the carbon cost would be €123.1. Adopting this approach has the potential to provide policymakers with more efficient estimates of the impact of targeted mitigation measures based on the shadow price of carbon.

Discussion and Conclusion	***100 – 250 words***

The findings of this study suggest that local environmental factors are essential in quantifying N_2O emissions, mainly soil pH, type and moisture. Furthermore, soil moisture is related to precipitation and temperature levels. The high-resolution model allows the more granular assessment of different mitigation strategies based on cost-efficacy criteria. Thereby allowing policymakers to target mitigation measures in a more efficient way by taking account of spatial heterogeneity and cost-efficacy criteria ensuring more efficient policy design. Implementing measures to reduce N_2O emissions from agriculture needs to fully consider regionally specific changes in management practice that take account of local soil and climatic conditions.