Long-term trajectories of the carbon footprint of nitrogen use in Mediterranean agriculture (Spain, 1860-2016)

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Abstract

Synthetic nitrogen (N) fertilization has been key in agricultural industrialization by removing N constrains to crop growth, but causes environmental impacts, including GHG emissions. We estimated the carbon (C) footprint of N use in Spanish agriculture from 1860 to 2016, including emissions from industrial fertilizer production, direct soil N_2O emissions using Mediterranean-specific factors, and indirect N_2O emissions. Overall, the yield-scaled C footprint of N use in Spanish agriculture increased 3-fold, as increased productivity and industrial energy efficiency could not offset the growth in synthetic N use and in N_2O emission factors.

Keywords: Nitrous oxide, Synthetic fertilizers, Irrigation, Environmental history

1. Introduction

The industrialization of agriculture, particularly N fertilizer use, boosted agricultural yields but also N surplus and associated impacts (such as N_2O emissions), the dependence on non-renewable resources, and the outsourcing of emissions to other sectors. Spanish agriculture represents a paradigmatic case of agriculture modernization under semi-arid conditions with high environmental impacts.

2. Methods

We estimated the C footprint of N use in Spanish agriculture from 1860 to 2016. We included "upstream" emissions from industrial fertilizer production (considering industrial efficiency changes), on-farm direct soil N_2O emissions, and downstream indirect N_2O emissions. The estimation of soil N_2O emissions was performed at the NUTS 3 level based on Mediterranean-specific emission factors adjusted to the type of water management and N input (Cayuela et al., 2017).

3. Results and discussion

The average direct N_2O emission factor of N fertilizers quadrupled (from 0.1% to 0.4%) due to irrigation expansion and the intensification of synthetic fertilizers and liquid manure applications. The large efficiency gains in fertilizers' industrial production were buffered by the changes in the fertilizer mix. Overall, N-related GHG emissions increased 8-fold, and were lately dominated by synthetic N production. The yield-scaled C footprint of N use in Spanish agriculture increased from 5.1 to 17.8 kg CO_2e kg N^{-1}.

4. Conclusions

Our results indicate a very large historical increase in GHG emissions related to N fertilzation in Spain, suggesting that mitigation efforts under Mediterranean climate should not only aim to increase nitrogen use efficiency (NUE) but also consider water management, fertilizer manufacture and fertilization strategies as key drivers of emissions.

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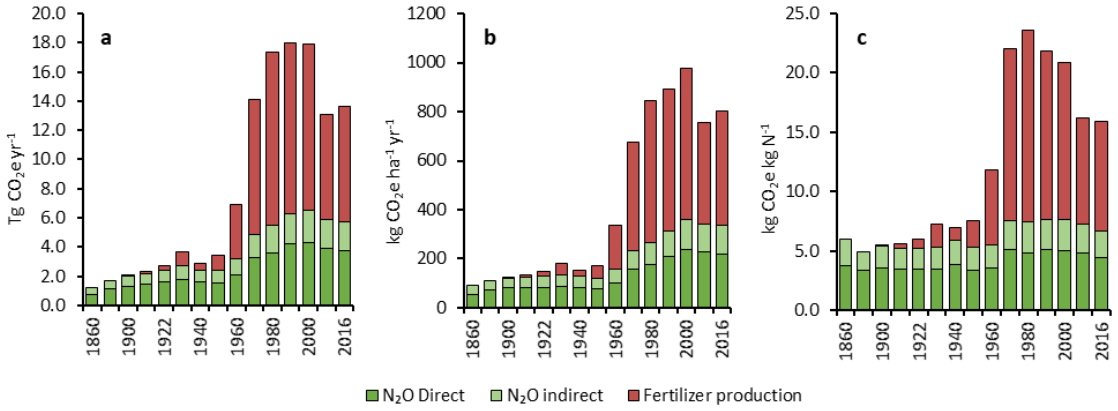

Fig. 1: Global warming potential of N management in Spanish cropland, expressed as absolute emissions (a), area-scaled emissions (b) and yield-scaled emissions (c)