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No-tillage systems linked to reduced soil N_2O emissions in Mediterranean agroecosystems

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Most emissions of nitrous oxide (N_2O) are linked to the use of nitrogen (N) fertiliser in agriculture, highlighting a need for agricultural management practices that reduce emissions while maintaining agronomic productivity. A new study has assessed the long-term impact of conventional tillage (CT — where soil is prepared for agriculture via mechanical agitation) and no-tillage (NT) systems on soil N_2O emissions and crop productivity in rain-fed Mediterranean conditions. The findings show that, over a period of 18 years, mean yield-scaled (i.e. per unit grain yield) soil N_2O emissions (YSNE) were 2.8 to 3.3 times lower under NT than CT. The researchers therefore recommend NT as a suitable strategy by which to balance agricultural productivity with lower soil N_2O emissions in rain-fed Mediterranean agroecosystems.

N_2O is a greenhouse gas (GHG) with significant global warming potential. Most N_2O emissions originate from soils treated with N fertiliser as a result of nitrification and denitrification processes. Different agricultural management practices can modify these processes, influencing N_2O emissions. If the population's rising food needs are to be met in a sustainable way, management practices must contribute to reduced N_2O emissions without damaging agronomic productivity.

In CT systems, land is tilled, causing crop residues to become buried. In NT systems, land is untilled and crop residues remain at the soil surface, enhancing water storage. Since water status in NT soils is usually higher compared to CT soils, it has been claimed that NT systems are associated with increased N_2O production and emissions[1]. However, long-term use of NT also greatly modifies the soil's physical properties in a way that reduces susceptibility to denitrification and N_2O production[2].

To determine the relationship between CT and NT systems, soil N_2O emissions, and potential yield, a team of scientists combined experimental and simulated approaches to assess the long-term impact of CT and NT systems and N-rates on soil N_2O emissions in rain-fed Mediterranean conditions. First, long-term soil water and mineral N dynamics, crop biomass and yields, and 2011-12 soil N_2O emissions and ancillary variables were measured using a field experiment that ran from 1996 to 2014 in Agramunt, north-eastern Spain (an area that is representative of rain-fed semi-arid Mediterranean conditions).

The experiment measured barley (*Hordeum vulgare* L.) production under a combination of tillage scenarios (CT and NT) and N rates (0, 60, and 120 kilograms of N per hectare (kg N ha^{-1})). The researchers used ammonium nitrate (33.5% N) as N fertiliser for all treatments. Two N fertiliser applications were carried out: one third of the fertiliser was applied before sowing and the other two thirds were applied as top dressing (i.e. with the crop at an early stage of development). Under CT, nitrogen fertiliser was applied on the soil and buried/incorporated with tillage operations; while, under NT, the fertiliser remained on the soil surface. Under both tillage systems, a second application of nitrogen fertiliser was applied on the soil surface. The type of fertiliser, as well as method of placement used in the experiment, are the most common in the area for rain-fed winter crops.

Continued on next page.

1. Smith, P., Goulding, K. W., Smith, K. A., *et al.* (2001). Enhancing the carbon sink in European agricultural soils: including trace gas fluxes in estimates of carbon mitigation potential. *Nutrient Cycling in Agroecosystems*, 60: 237-252.

2. van Kessel, C., Venterea, R., Six, J., *et al.* (2013). Climate, duration, and N placement determine N2O emissions in reduced tillage systems: a meta-analysis. *Global Change Biology*, 19: 33-44.

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No-tillage systems linked to reduced soil N_2O emissions in Mediterranean agroecosystems *(continued)*

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The researchers then used a dynamic soil-crop-atmosphere model named *STICS (Simulateur mulTIdisciplinaire pour les Cultures Standard* - Multidisciplinary Simulator for Standard Crops) and observed data to simulate the soil N_2O emissions of each tillage system, over 18 years, under increasing N rates (0, 30, 60, 90, and 120 kg N ha^{-1}), and to identify optimum management strategies to reduce YSNE.

The results showed that, over 18 years, NT increased grain yield by an average of 10%, 47%, and 53% compared to CT when applying 0, 60, and 120 kg N ha^{-1} respectively. Moreover, YSNE for the same period were 2.8 to 3.3 times lower under NT compared to CT. The YSNE indicator is a suitable tool for evaluating the extent to which agronomic and emissions goals are achieved under a given agricultural practice, as it takes into account the relationship between yield and N_2O emissions. Under CT, N application would increase YSNE in most years, whereas under NT, YSNE was more resilient to increasing N rates.

The researcher suggests that similar behaviour could be expected for all winter cereals (wheat, triticale and oats are also common under rainfed Mediterranean conditions), since their N fertiliser requirements are similar. He adds, however, that, within agronomy research, results are usually highly affected by pedoclimatic (microclimate within soil that integrates the effects of its temperature, water content and aeration) conditions and by the type of cropping system (i.e. a combination of crop rotation and management practices). But he emphasises that any generalisations must be made carefully.

The researcher therefore recommends the use of long-term NT systems and medium N fertiliser rates (30-60 kg N ha^{-1}) in rain-fed Mediterranean agroecosystems. Experimental and modelling data identify this as an effective strategy to use in order to maximise agricultural productivity while maintaining low N_2O emissions. It is worth noting that the emission factor for NT is almost half of that proposed by the International Panel on Climate Change (IPCC) in semi-arid Mediterranean conditions — this must be considered when evaluating the contribution of agriculture to GHG emissions. Additionally, this recommendation is made in reference only to soil N_2O emissions; as such, current debates on the impact of different tillage systems on carbon storage, soil erosion, soil compaction and biodiversity are not addressed.

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