

## **Cover crop residues as driver for N<sub>2</sub>O emissions - mechanisms and mitigation**

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### **Extended Abstract**

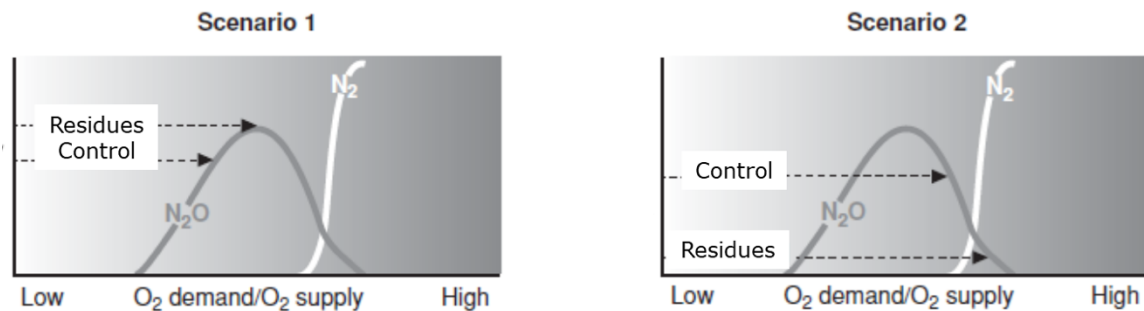
Cover crops (CC) have been used for many years as a strategy to, e.g., improve nutrient retention, prevent soil erosion, and protect water quality. In Europe, the Common Agricultural Policy requires farmers to set aside land as Ecological Focus Areas, and growing CC is one option frequently used. A similar trend is seen in other regions with intensive crop production, and hence the amounts of crop residues returned to soil under winter and spring conditions are increasing. CC residues often have a lower C-to-N ratio than residues at harvest, they are returned at a time where soil moisture is higher, and soil N status during residue decomposition may be higher than after harvest due to fertilisation of the next crop. As a result, there is a significant potential for N<sub>2</sub>O emissions, and a need for more information about this emerging source.

The fact that organic hotspots in soil can sustain anaerobic processes is well established [1], and the detritosphere associated with decomposing residues is important both in terms of spatial extent and temporal stability [2]. In contrast to N<sub>2</sub>O emissions from mineral N fertilisers, which are highly dependent on rainfall and bulk soil conditions, CC residues may be a consistent and temporally stable source of N<sub>2</sub>O irrespective of – but not independent of – soil conditions [3]. It implies that N<sub>2</sub>O derived from CC residues may not, in contrast to the principles of the IPCC methodology, be a simple proportion of residue N. A better understanding of main drivers and interactions with soil conditions could improve predictions of N<sub>2</sub>O emissions, and support the search for effective mitigation strategies.

A laboratory study with three CC residues (red clover, winter vetch and ryegrass) incubated in sandy loam soil at 40, 50 or 60% water-filled pore space (WFPS) indicated that net mineralisation of residue N during 28 d was 41-56% from the two leguminous CC, but ~0% from ryegrass [4]. The corresponding N<sub>2</sub>O emission factors were 0.8-1.9% of residue N for red clover and winter vetch, but only 0.3-0.4% for ryegrass, and hence the N<sub>2</sub>O response was non-linear. By <sup>15</sup>N enrichment of the soil nitrate (NO<sub>3</sub><sup>-</sup>) pool, it was possible to demonstrate that denitrification was the main source of N<sub>2</sub>O at all three WFPS levels. For bulk soil it is well established that denitrification is insignificant below ~60% WFPS, and this result therefore accentuates the need to better account for N transformations associated with organic hotspots.

The oxygen (O<sub>2</sub>) consumption associated with residue decomposition is critical for maintaining niches sustaining denitrification. The balance between O<sub>2</sub> demand and O<sub>2</sub> supply may be a better predictor of the extent of anaerobic degradation than soil WFPS alone, and hence of

the potential for N transformations resulting in N<sub>2</sub>O emissions. The conceptual model in Fig. 1 can account for the complex response of residue amendment, where for example light-textured or dry soils (Scenario 1) will often show enhanced emissions of N<sub>2</sub>O following residue amendment, whereas compacted, clayey or wet soil (Scenario 2) may show no change or even a decline in emissions due to residue-induced O<sub>2</sub> demand shifting the N<sub>2</sub>O-to-N<sub>2</sub> product ratio. The potential for N<sub>2</sub>O emissions *via* denitrification further depends on NO<sub>3</sub><sup>-</sup> availability as determined by i) soil N status and ii) net N mineralisation and nitrification of residue N.



**Figure 1.** A conceptual model of the effect of residue amendment on the balance between O<sub>2</sub> demand and supply, and the effects on N<sub>2</sub>O and N<sub>2</sub> emissions (modified from [5]).

While these various mechanisms are well-known, they point to N<sub>2</sub>O mitigation opportunities. For example, reduced tillage, where residues are decomposing closer to the soil-air interface, will increase the potential for aerobic decomposition, but also the potential for N<sub>2</sub>O escaping from the soil. Field studies indicate that reduced tillage can mitigate N<sub>2</sub>O emissions in well-drained soil, whereas the opposite effect may occur in poorly aerated soil [6]. The choice of tillage method, and the timing of tillage, are management options to avoid high-risk scenarios for CC termination.

Soil NO<sub>3</sub><sup>-</sup> availability during CC residue decomposition is influenced by fertilisation, and by the potential for net N release and subsequent nitrification. Strategies to limit NO<sub>3</sub><sup>-</sup> availability for denitrification include the use of non-leguminous CC species, and timing of fertilisation to uncouple C and N transformations. In a new application of the nitrification inhibitor 3,4-dimethyl pyrazole phosphate (DMPP), we have found that the oxidation of ammonia released from decomposing CC residues may be delayed, and the associated N<sub>2</sub>O emissions significantly reduced, but there are significant interactions with soil-residue contact and O<sub>2</sub> supply, which must be investigated [7].

This presentation provided evidence that denitrification is the main pathway of N<sub>2</sub>O formation, even in well-aerated soil. Nitrous oxide emissions from CC residues are generally significant, but the magnitude of emissions will depend on residue quality and soil properties, and the synlocation of C and N transformations is critical. Scale is a significant challenge for better predictions of N<sub>2</sub>O emissions from CC residues. Existing models typically consider cm-dm scales, and gaseous emissions of N are predicted from bulk soil properties, as modified by C and N (and water) input [8]. However, experimental evidence shows that accounting for the concurrent transformations of C and N in mm scale gradients may be necessary for accurate estimation of N<sub>2</sub>O emissions.

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### OECD disclaimer

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