

Biogeosciences Discuss., author comment AC1
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Reply on RC1

Alison Bressler and Jennifer Blesh

Author comment on "Episodic N₂O emissions following tillage of a legume–grass cover crop mixture" by Alison Bressler and Jennifer Blesh, Biogeosciences Discuss., <https://doi.org/10.5194/bg-2022-39-AC1>, 2022

Section 1: "This manuscript explores short-term N₂O emissions after incorporation of cover crops – clover, rye and a clover/rye mix – at two field sites. There are many studies of N₂O emissions after incorporation of plant material (cover crops, crop and tree residues), including those that compare legumes vs non-legumes, and so the novelty of the work you present, and the additional knowledge that this provides, are not apparent."

Author's Response: Thank you for your comment. The novelty of our study is not in comparing legume and non-legume cover crops, but as we discuss in the paper, to our knowledge only two other studies have measured N₂O emissions from fields with legumes as the sole external N input in organically managed grain agroecosystems (lines 306-310). Other studies have measured N₂O following legume N inputs + fertilizers/manure, which typically increases overall N inputs compared to our study and does not isolate the effect of legume N sources in organically managed soils. Our study is also one of the first to include measures of labile SOM fractions relevant to internal nutrient cycling processes (i.e., POM) in a study of N₂O emissions. We found one other study (Kong et al. 2009) that measured how soil organic matter fractions and N₂O change over time after conversion to no-till under irrigation in a Mediterranean climate. Based on our review of the literature, our study thus provides new knowledge about episodic N₂O emissions following tillage in agroecosystems with only legume N sources and is also unique for including measurements of SOM fractions.

Section 2: "This is confounded by your study being limited in number of spp – legume, non legume and a mix – and only over a two week period, so that relationships between crop characteristics (eg N content, biomass) or functional traits, can not be rigorously determined, and consequently the discussion provides little insight into trait effects on emissions. I don't consider this limited selection to truly represent 'functional diversity'. You state that little is known about multiple spp, but you are only using one mixture of two spp, and there have been other studies that have measured emissions from these spp, and more rigorously examined effect of spp mixtures."

Author's Response: Thank you for this feedback. We have double checked that the manuscript does not claim to draw conclusions about the role of functional traits or functional diversity per se, which was not our intention. In the paper, we simply intend to convey that we increased the functional trait diversity of the main treatment of interest (the two species mixture) by planting a legume and a grass together, which is expected to impact N₂O through effects on plant litter quality and soil N availability. We plan to better justify this in the introduction with the following language: "In agroecosystems, even

small increases in crop functional diversity (e.g., 2-3 species cover crop mixtures with complementary traits) can substantially impact ecosystem function (e.g., SOC, N cycling processes, microbial biomass, weed suppression) (Drinkwater et al., 1998; McDaniel et al., 2014; Tiemann et al., 2015; Blesh, 2017)." And in the discussion with: "There is growing evidence that small increases in cover crop functional diversity can simultaneously enhance multiple agroecosystem functions, including nutrient retention (Storkey et al., 2015; Blesh 2017; Kaye et al. 2019). For instance, Storkey et al. (2015) found that low to intermediate levels of species richness (1-4 species) provided an optimal balance of multiple ecosystem services when species exhibited contrasting functional traits related to growth habit and phenology." We also propose to change headings of sections 3.3. and 4.1 to specify that we are discussing a legume-grass mixture and not functional diversity more broadly. Please see the justification for intensively measuring N₂O during the weeks following tillage on **lines 50-58**. We have further supplemented this argument with: "Gomes et al. (2009) found greater N₂O emissions during the first 45 days after terminating cover crops with a roller cutter and herbicide compared to the rest of the year."

Gomes, J., Bayer, C., Costa, F. D., Piccolo, M. D., Zanatta, J. A., Vieira, F. C. B., and Six, J.: Soil nitrous oxide emissions in long-term cover crops-based rotations under subtropical climate. *Soil Tillage Res.* 106, 35-44, <https://doi.org/10.1016/j.still.2009.10.001>, 2009.

Section 3: "The magnitude of emissions will depend on the chemical composition of the plant material, and this is well established in the literature. The magnitude of emissions from the mixture will depend on the ratio of the component material, and so I find it disappointing that you only applied one ratio of the mix."

Author's Response: This is an important point, which we plan to expand on in the discussion at the end of section 4.1. We note that findings would likely differ for mixtures of different ratios of legume to grass. We conducted our experiment at two sites with contrasting soil fertility levels and did not have the capacity to increase the number of treatments to also test different ratios of legume to grass. However, the strength of our study is that the mixture had similar ratios at both sites, allowing for better comparison of results across sites, and we also achieved a relatively even mixture with strong legume presence, which allowed us to understand the role of fixed N inputs specifically. A growing literature on mixtures argues that mixture evenness is related to agroecosystem multifunctionality, and evenness is thus an important goal of management with mixtures. We have added this point to the discussion. We also note that testing a range of mixture ratios is an important and interesting future research need (lines 341-344).

Section 4: "In the introduction text why do you just focus on emissions from the US? This is a global issue, and by focusing just on the US you are limiting the reach and reader interest of your work."

Author's Response: Thank you for this suggestion. We plan to add the global context to the beginning of the introduction with: "Globally, N₂O emissions from agricultural soils increased by 11% from 1990 to 2005 and are projected to increase by another 35% between 2005 and 2030 (USEPA, 2012)."

Section 5: "Line 53 – 20 years – do you mean 20 days?"

Author's Response: Gelfand et al.'s paper reporting on a long-term study at KBS measured N₂O emissions over 20 years. The point we are making here is that by measuring N₂O over 20 years, the authors found that differences in emissions between years were driven by the episodic emissions immediately following tillage every year, which we use to justify the timing of our sampling to address our research question focused on this particular emissions event following overwintering cover crops.

Section 6: "Can you please explain why you measured N₂ fixation in the legume, rather than just the total biomass N – above + belowground?"

Author's Response: Yes, we will better explain why N₂ fixation is an important aspect of our study to address our question about the role of legume N sources by adding the following to the first paragraph of the introduction: "Generally, total N inputs are correlated with N losses (Robertson and Vitousek 2009). However, diversified grain rotations with legume N sources which add biologically fixed N₂ to fields, better balance N inputs with harvested exports and have lower potential for N losses compared with synthetic fertilizer inputs (Drinkwater et al., 1998; Blesh and Drinkwater, 2013; Robertson et al., 2014)."

From an ecosystem perspective, total N inputs to an agroecosystem (regardless of source) are correlated with N losses through leaching or as a gas. For instance, a meta-analysis on N₂O emissions in agroecosystems found that higher total N inputs drive higher N₂O losses by increasing N mineralization (Han et al. 2017) (lines 292-294). Legume cover crops add a new N source to soil by fixing atmospheric N₂. It is therefore important to partition the legume N into the "new" N, which represents an external input (and is, in principle, more likely to explain loss pathways), compared to N that is assimilated from soil N mineralization and recycled. We also recognize that cover crops (including non-legumes) can increase internal nutrient cycling over time by scavenging and accumulating N and other nutrients in biomass and returning them to soil in relatively labile forms. This dynamic also seems to be a factor in our study and we discuss these processes in the discussion in section 4.2.

Section 7: "Did you measure changes in soil mineral N after incorporation? I don't see this data, but it will be essential in helping explain the impact on soil processes resulting in emissions, for example net N immobilization (line 317). It is a major omission not to include this data. Likewise, I don't see any measure of CO₂ emissions, despite residue addition likely to stimulate microbial activity."

Author's Response: Thank you for the suggestion to include soil mineral N. We did measure this and will add methods and a table with soil inorganic N data at two different time points at each site (on the day after tillage, and 12-13 days later). We will also add this component throughout the discussion. We did not measure CO₂ emissions in this study but agree that microbial activity increased with the addition of fresh cover crop residue (e.g., as shown by the release of inorganic N and flux of N₂O measured in our experiment).

Section 8: "I may have missed this, but I don't see data of the chemical characteristics of the clover, rye or weeds?"

Author's Response: In Figure 1 and section 3.2 of the results, we report on litter N and C:N ratio for all cover crop treatments. We did not include other measures of litter chemistry (e.g., lignin) in this study.

Section 9: "It would be helpful to have the daily fluxes of N₂O also presented as fluxes per biomass or % C applied basis. I think you give this for cumulative N₂O, but not for the daily fluxes."

Author's Response: Thank you for this suggestion. We will add a table to the appendix with daily N₂O/aboveground cover crop biomass and biomass N.