Do cover crops increase or decrease nitrous oxide emissions? A meta-analysis

Andrea D. Basche and Fernando E. Miguez
Iowa State University, Department of Agronomy

INTRODUCTION

There are many well researched ecological benefits to incorporating cover crops into crop rotations, such as their potential to decrease soil erosion, reduce nitrate leaching and increase soil organic matter. Some of these benefits impact other elements of the agroecosystem given the coupling of nutrient cycles, notably C and N. Some field research does point toward an increase in nitrous oxide emissions where cover crops are present. This work, however, is limited and comes from sites utilizing a range of cover crops generally measured on short time scales (2 years or less). A meta-analysis of this research can provide a more robust investigation into the influence of cover crops on nitrous oxide emissions.

OBJECTIVES

1. To summarize quantitatively the effect of cover crops on nitrous oxide emissions. 2. To improve an understanding of the mechanisms behind this effect, through evaluating the impact of both environmental and management variables.

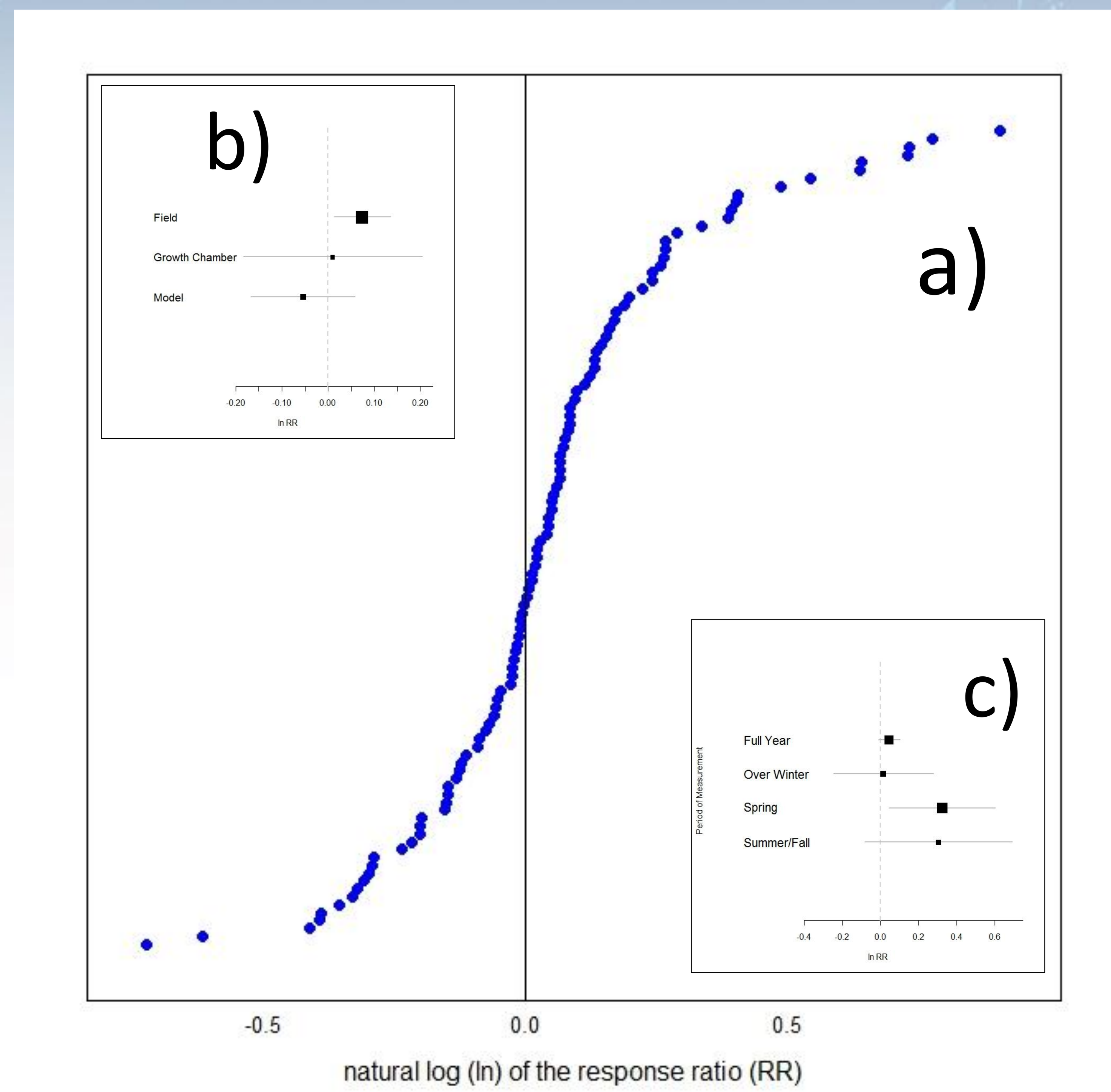
MATERIALS & METHODS

To date, 25 peer reviewed articles resulting in 104 data points are analyzed according to their response ratio, the natural log of the N_2O flux with a cover crop divided by the N_2O flux without a cover crop.

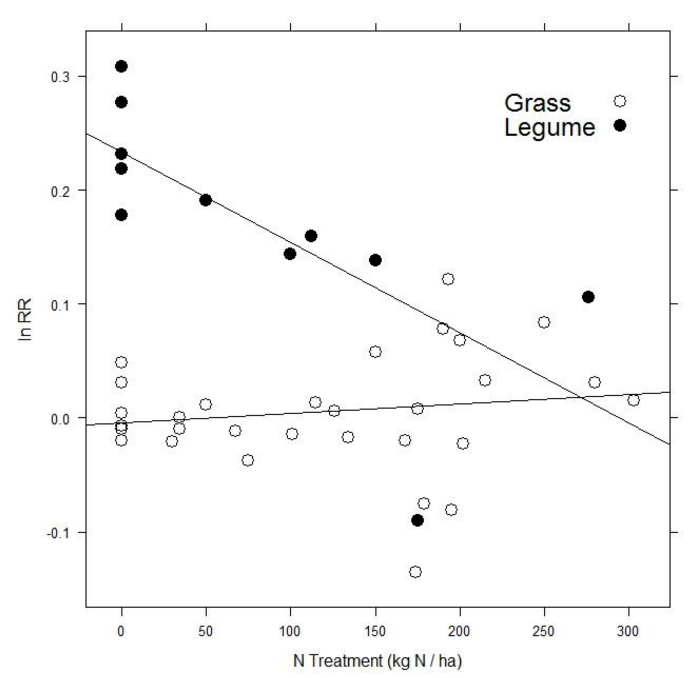
- Database development: For the purposes of this study, we defined a cover crop treatment as any alternative management with an additional crop grown during a traditionally fallow period, in between the harvest of cash crops. Experiments needed a control treatment varying only in the inclusion of a cover crop (keeping all other tillage practices, N additions, etc. equal).
- Response ratio equation (RR):
  RR = N_2O flux with cover crop / N_2O flux without cover crop
  Response ratios were log transformed to ensure normality.

Winter rye cover crop growing on the landscape in Iowa (left) and adjacent plot without a cover crop (right).

RESULTS & DISCUSSION



Figures 1a, 1b, 1c. 1a. (center) Full distribution of all 104 points in the dataset, representing the natural log of the response ratio, the N_2O flux with a cover crop divided by the N_2O flux without a cover crop. 1b. (top left) Natural log of the response ratios and standard errors, grouped by type of experiment included in the dataset. The size of the box represents the number of data points included: Field (79), Growth Chamber (9) and Model (16). 1c. (bottom right) Dataset separated by the study's measurement period. The size of the box again indicates the number of data points included in each group: full year (24), spring (36), summer/fall (8), and over winter (10). Spring period corresponded to cover crop decomposition and incorporation, while summer/fall corresponded to the growth of the main cash crop.



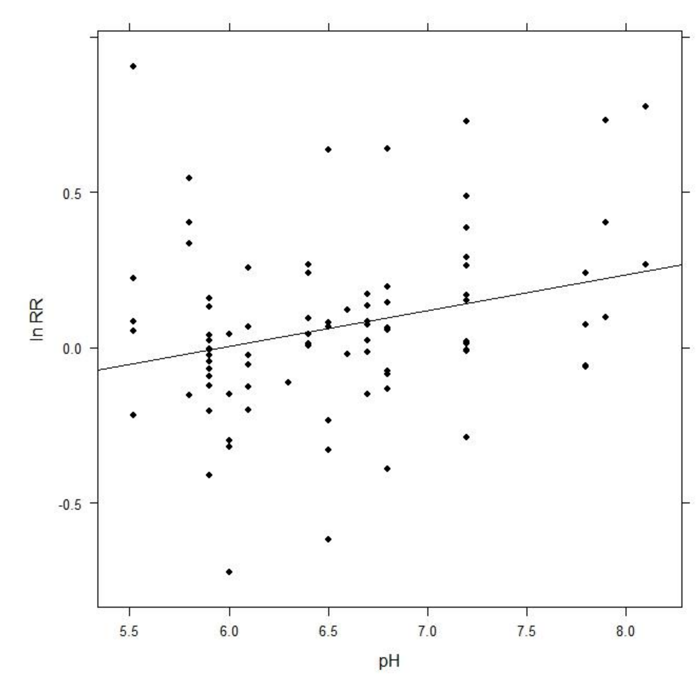


Figure 2 (left). Interaction of fertilizer application rate and the type of cover crop in each study. There is a significant interaction between these two main effects. In studies where N treatment equaled zero, legume cover crop systems had higher response ratios than grass cover crop systems. As N application increased across the studies, the response between grass and legume cover crops became more variable. Figure 3 (right). Relationship of soil pH to the natural log of the response ratio. As soil pH increased across the studies, the response ratios increased as well.

- 42% of the data points collected show a decrease in nitrous oxide emissions when cover crops were present in the agroecosystem, while the remaining 58% show an increase.
- It is important to consider the period of each study's measurement (Fig 1c). The highest response ratios were observed during the cover crop decomposition period in the spring. On average, studies measuring over a full year had response ratios slightly higher than zero.
- One potential mechanism where cover crops led to an increase in nitrous oxide emissions is the interaction of additional soil moisture and the cover crop's carbon contribution. While soil microbes consume more C, anaerobic soil conditions may develop if oxygen is not replaced by atmospheric diffusion. This can occur under higher soil moisture conditions.
- If soil moisture conditions are not a predominant factor in nitrous oxide emissions, soil properties may be contributing to higher response ratios, as is seen in the soil pH analysis.
- Fertilization may also be a strong predictor of the response ratio, depending upon the cover crop species utilized.
- There was high within study variability for many of the papers included in this analysis, illustrating the episodic nature of nitrous oxide emissions.

CONCLUSIONS

- Cover crops have the potential to increase or decrease nitrous oxide emissions, depending upon the N fertilization level, soil pH, period of measurement and type of cover crop (grass or legume).
- In order to fully assess the impact of cover crops on nitrous oxide emissions, studies should analyze over multiple years to understand the effects of variable environmental factors.

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