ResidueGas DELIVERABLE NO. 2.1

Database on N_2O emissions from crop residues

March 2021

Authors:

NORSØK: Tatiana Rittl and Sissel Hansen

This report is a publicly accessible deliverable of the ResidueGas project. The present work has been carried out within the project ‘Improved estimation and mitigation of nitrous oxide emissions and soil carbon storage from crop residues’, which is funded in the frame of the ERA-NET FACCE ERA-GAS. FACCE ERA-GAS has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 696356.

Rittle, T., Hansen, S., 2021. Database on N2O emissions from crop residues. ResidueGas deliverable report 2.1. July 2021.

Table of Contents

1. Summary **2**

2. Introduction **3**

3. Materials and methods **4**

4. Results and discussions **5**

4.1 Database description 5
4.2 Database summary 6
4.3 Daily N_2O emissions 7
4.4 Challenges 8

5. Conclusions **9**

6. References **10**

1. Summary

The database contains collected field data of pairwise comparisons between treatments with and without application of crop residues combined to the estimated chemical quality of the returned crop residues derived from the database made in WP1. The database will be public assessable and published in connection with a data in brief article: ”Meta-analysis data for two field studies on N_2O emissions associated with the return of crop residues.” The database is used into two meta-analyse studies on cumulative N_2O emissions associated with the return of crop residues regarding the effect of return crop residues on cumulative N_2O emissions: “Field emissions of N_2O associated with crop residues – a meta-analysis” (WP2) and “Effectiveness of crop residue management for mitigating N_2O emissions (meta-analysis)” (WP6).

2. Introduction

Meta-analyses are a useful tool to systemize data. However, to do this pairwise comparisons between treatments are needed. To study the impact of crop residues identical treatments with and without return of crop residues are thus needed. The objective of this database is to provide relevant data for meta-analyses on N_2O emissions related to application of crop residues. New for this data collection is that we have included more crop species than in earlier data-collections as well as data on biochemical quality, experiment length in normalized days and indexes for residue maturity and aridity index.

3. Materials and methods

The database was built by collecting data from field studies with cumulative N_2O emissions derived from returning crop residues. Peer-reviewed research articles published before 1 January 2020 with the following keywords and their combinations, nitrous oxide emissions, crop residue, greenhouse gas emissions and emission factor were searched in Google Scholar and Web of Science. Publications were scanned for additional references. Unpublished data from studies under the ResidueGas project were included after passing by quality control by the authors. Only pairwise comparisons between treatment (return crop residues) and control (without return of crop residues) were added. The only exception was the grassland studies, where the grassland renewal (treatment) was compared to permanent grassland (control). The database includes the publication data, total cumulative N_2O emissions from treatments with the return crop residue and control, crop residue amount and quality, fertilization type and amount, soil and geographical characteristics and experimental site data. When not available, biochemical quality of the crop residues was estimated based on average values for the actual crop residue in the WP1 database on residue quality according to crop type and type of residue generated (Thiébeau et al. in Prep.; Thiébeau et al. 2021). When the published paper provided the amount of residue-N input and the dry matter (DM) added, then the residue-N concentration was calculated. When C and N added were provided in the paper, the crop residue C:N ratio was calculated.

The database was first built in Access, and later converted to Excel, to facilitate the dissemination. Each row of the database corresponds to a pairwise comparison between treatment and control, where the only difference between these two groups is the return or not of residues, all other factors are the same. The only exception is the grassland, as explained above. Data was aggregated in different groups. A detailed description of each group is given on the two research articles “Field emissions of N_2O associated with crop residues – a meta-analysis” (WP2) (Abalos et al., in prep) and “Effectiveness of crop residue management for mitigating N_2O emissions (meta-analysis)” (WP6) (Abalos et al., in prep).

Based on Sylvester-Bradley et al. (2015), crop residues were classified as mature or immature, based on the stage of physiological maturity of the crop at which they were generated either by cultivation practice (harvesting at the end of the cycle, harvesting of root crop or vegetable crops, mechanical destruction, grassland mowing or grassland renewal) or possibly naturally (senescence), irrespective of the type of plant.

To provide a quantitative indication of the magnitude of N_2O fluxes induced by crop residue incorporation, the average cumulative N_2O emissions of each crop type in g N_2O-N ha^{-1} for each study and treatment, were divided by days with reported N_2O flux measurements to estimate the fluxes in g N_2O-N ha-1 day^{-1}. Excel was used to create boxplots with median, mean, quartiles and outliers of the daily N_2O emission (g N_2O-N ha^{-1} day^{-1}) and net N_2O emissions (when emission from control plots were subtracted from the treatment plots with residue addition).

4. Results and discussions

4.1 Database description

The information available in the database is:

Reference: observation number, study number, name first author, year of publication, journal name or source name, digital object identifier (DOI)

N_2O emissions: cumulative N_2O emissions treatment and control (g N_2O-N ha^{-1}), standard deviation treatment (SD) treatment and control, number of repetitions (n), duration of the experiment in days, start and end day of the N_2O measurements (d.mm.yyyy), normalized days (ND15), average daily N_2O emissions treatment and control (g N_2O-N ha^{-1} day^{-1}) and net daily N_2O emissions (g N_2O-N ha^{-1} day^{-1}).

Emission factors (EF): EF (%), ln(EF).

Crop Residue: crop name as in the source, group crop type, crop function, maturity criteria, type of residue generated, group type of residue generated, residue size, application method, group application method, date of residue return, season residue return, fresh and dry residue amount (kg residue ha^{-1} yr^{-1}), application rate nitrogen crop residue (g N ha^{-1} yr^{-1}), application soil depth (cm), total N (g N / kg residue), total C (g C / kg residue), C:N ratio, soluble VS fraction (% total dry matter), hemicellulose (% total dry matter), cellulose (% total dry matter), lignin (% total dry matter), lignocellulose index (LCI), water soluble nitrogen (WSN, as % total N), water soluble carbon (WSC, as % total C).

Fertilizer: type of fertilizer, single and total N amount (kg total N ha^{-1} yr^{-1}), date of fertilizer application, group fertilizer (yes or no), fertilizer type (organic, synthetic or mixture), glyphosate application, inhibitors, microbial inoculation.

Soil characteristics: soil classification, texture, sand (%), coarse sand (%), fine sand (%), clay (%), silt (%), pH ($CaCl_2$ and H_2O), soil organic carbon (SOC, g kg^{-1}), soil organic matter (SOM, g dm^{-3}), total N (g kg^{-1}), C:N, bulk density (g cm^{-3}).

Climatic conditions: mean annual air temperature (°C), mean air temperature during the experiment (°C), total annual precipitation (mm), total precipitation during the experiment (mm), potential evapotranspiration (ETo), aridity index (AI), group aridity index (AI<1>AI), climatic class (UNEP, 1997), average frost days.

Experimental site location: country, coordinates (latitude and longitude).

Table 1. An overview of the groups used in the papers as well the number of observations in each category.

Groups	Factors	Number of observations	Description of categorical factors and range for numerical factors
Residue-N	N crop residue application rate (kg N ha^{-1} yr^{-1})	276	5 to 418
Crop type	Crop type	346	cereal, cover crop, grassland, legumes grain, rice, sugar cane, vegetable, double cropping
Residue type	Type of residue generated	346	green plant biomass, mature above ground biomass, senescent plant biomass, straw
	Maturity index	346	immature; mature
Residue quality	Residue C:N ratio	336	C:N lower than 20; C:N between 20-60; C:N higher than 60
	Soluble VS (% total DM)	323	6 to 71
	Cellulose (% total DM)	325	10 to 49
	Hemicellulose (% total DM)	324	6 to 55
	Lignin (% total DM)	331	2 to 26
	Lignocellulose Index (LCI)	323	0.041 to 0.306
	Water soluble carbon (% total C)	267	3 to 68
Soil properties	Soil texture	199	clay, loam, sandy
	Clay (%)	198	3.1 to 66%
	Soil pH	267	acid (<6), neutral (6-7), alkaline (>7)
	Soil organic carbon (g C /kg SDW)	305	2 to 55
	Soil bulk density (g/cm^3)	157	0.76 to 1.6
	Soil total N (g N/kg SDW)	257	0.14 to 3.9
Weather conditions	Normal precipitation (mm/year)	346	350 to 2115
	Annual mean temperature (°C)	206	5.3 to 27.4
	Aridity index values	342	<1, >1
	Normalized days at 15°C	192	4.7-1001

4.2 Database summary

The database includes 75 studies from 62 sites in 19 countries around the world, which derived 346 observations of field cumulative N_2O fluxes between treatments (with return of crop residues) and controls (without addition of crop residues) (Table 1). Field studies from Europe contributed with 148 of the 346 comparisons (43%). Data from different types of crop contribute differently to the database, 29% of the data were from residues classified as cereal, 26 % as cover crop, 10% as grassland, 5% as legumes grain, 11% as rice, 6% as sugarcane and 12% as vegetable. According to the crop type, 47% of the data was classified as green plant biomass, 37% as straw, 10% mature above ground biomass, 20% as senescent plant biomass. Regarding fertilization, 60% of the N_2O comparisons were from situations where fertilizer was applied. In Europe, 32% of the data were from residues classified as cover crop and 80% as green plant biomass; 60% of the N_2O comparisons were from situations where fertilizer was applied. Regarding climate, 60% of our comparisons comprised dry climate (Aridity Index (AI) < 1) and 40% wet climate (AI >1).

4.3 Daily N_2O emissions

Overall, daily N_2O emissions ranged between -0.2 to 147 g N_2O-N ha^{-1} day^{-1} (Mean 13.8 g, Median 7.7 g and SD 18.9 g N_2O-N ha^{-1} day^{-1}) and net emissions between -44 to 147 g N_2O-N ha^{-1} day^{-1} (Mean 5.0 g, Median 1.3 g and SD 14.8 g N_2O-N ha^{-1} day^{-1}) (Figs. 1 and 2).

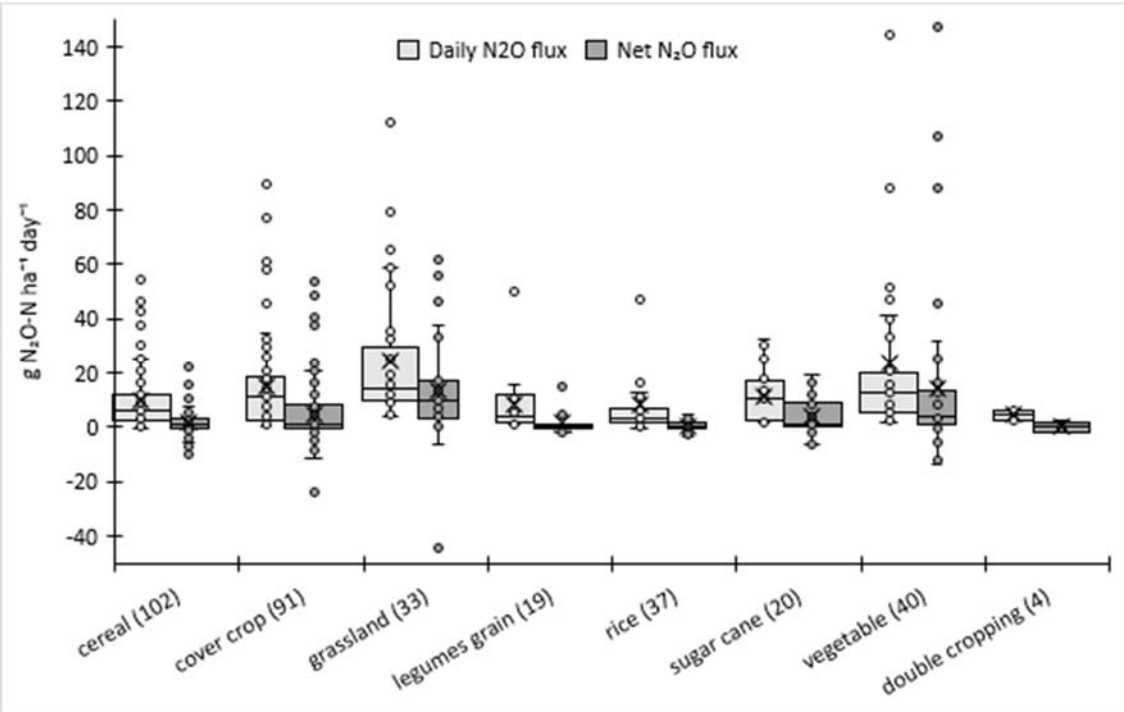

Figure 1. Boxplot values with median (line), mean (x), quartiles and outliers for g N_2O-N ha^{-1} day^{-1} for total daily emissions in plots with crop residues applied and net effect of crop residues (N_2O emissions on control plots are subtracted from N_2O emissions on plots with crop residues) for the crop groups used in the meta-analyses. The crop groups are cereal (which includes mature harvested cereals and rape seed), rice (because cereals and rice are cultivated differently, we separated these groups, although we did not distinguish between wet and dry rice cultivation), cover-crop (including immature cereals, clover, brassica cultivated as cover-crops or one year green manure), grassland (perennial, temporary grassland with or without legumes included), legumes grain (legumes harvested at maturity), vegetable (cauliflower, lettuce, onion and sugar beet), sugar cane, and double cropping (combination of two species at different biomass ratios). Note that crop type implies all the management

(fertilization, sowing, etc.), cropping length and soil cover, amount, and type of residue for a given crop. The number of observations is given in the parentheses.

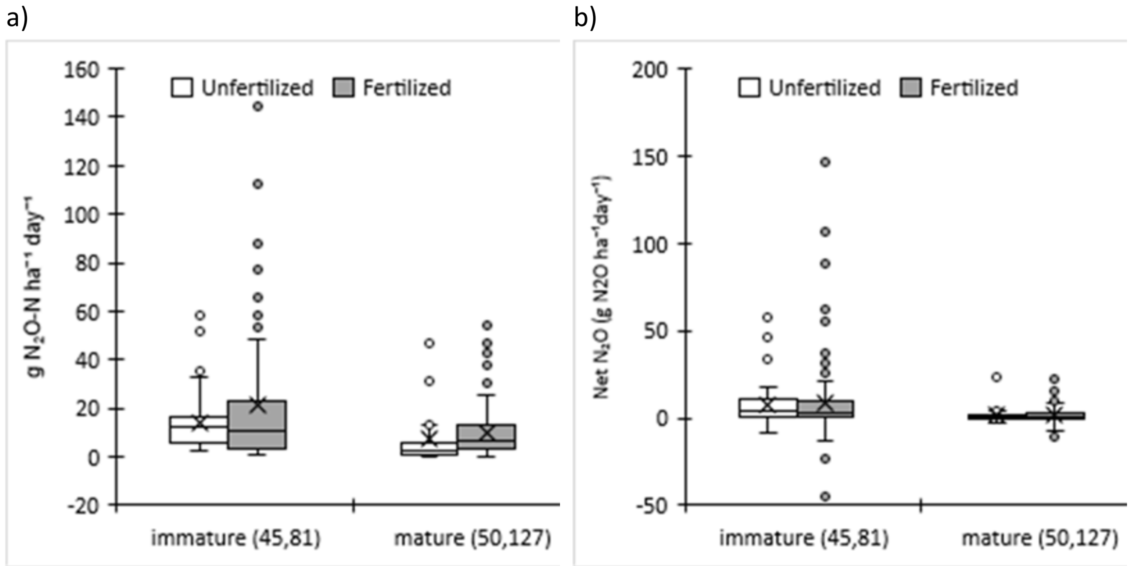

Figure 2. Boxplot values with median (line), mean (x), quartiles and outliers for g N_2O-N ha^{-1} day^{-1} for total daily emissions in plots with immature and mature crop residues applied a) impact of fertilization and other factors included) and b) net effect of crop residues (N_2O emissions on control plots are subtracted from N_2O emissions on plots with crop residues) for the crop groups used in the meta-analyses. The number of studies and observations is given in the parentheses.

4.4 Challenges

A limitation of our database must be noted. Our residue quality data is derived from a different dataset, what means we do not have specific measured data for the biochemical quality of the residues applied for each observation as we have for the cumulative N_2O emissions. Instead, we have average values for each type of residue for a given crop. Having residue quality data measured in every study would have improved the value of this database.

5. Conclusions

This database is a unique selection of data on N_2O emissions associated with the return of crop residues combined with biochemical quality of similar residues and categorized according to crop type, residue type, crop maturity, normalized days, residue management, fertilization, soil characteristics, and climatic conditions.

6. References

Abalos, D., De Notaris, C., Rittl, T., Olesen, J.E., n.d. Effectiveness of crop residue management for mitigating N2O emissions (meta analysis). In prep. for STOTEN.

Abalos, D., Rittl, T.F., Recous, S., Thiebeau, P., ..., Hansen, S., n.d. Field N2O emission factors associated with the application of crop residues. In prep. for STOTEN.

Thiebeau, P., Jensen, L.S., Ferchaud, F., Recous, S., n.d. Data in Brief Dataset of biomass and chemical quality of crop residues from European areas. Data Br.

Thiébeau,P, Jensen, LS, Ferchaud, F, Recous, S (2021) Biomass and chemical quality of crop residues from Europe area, Data INRAE, v1. https://doi.org/10.15454/LBI3U7

Sylvester-Bradley, R, Thorman, RE, Kindred, D R, Wynn, S C, Smith, KE, Rees, RM, Topp, CF, Pappa, VA, Mortimer, ND, Misselbrook, TH, Gilhespy, S, Cardenas, LM, Chauhan, M, Bennett, G, Malkin, S and Munro, DG (2015) Minimising Nitrous Oxide Intensities of Arable Crop Products (MIN-NO). Project Report No. 548. Kenilworth: AHDB Cereals and Oilseeds.