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RESPIRATION CO_2 AND N_2O EMISSION FROM GRASSLAND ECOSYSTEMS

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Cropland ecosystems cover approximately 45% of Europe, and thus play an important role in the overall greenhouse gases (GHGs) budget of the continent. However, the estimation of their emissions remains an uncertain issue due to the diversity of environment and climatic factors as well as the crop structure acute influence of human the management. Based on the continuous observation of soil-plant respiration and environmental factors in a several crop ecosystems from early June to early July in 2011, the spatial and temporal variation of soil-plant respiration and their controlling factors was analyzed. A survey was conducted to identify important criteria, and several crop fields were treated.

The research was conducted on the local measurement and comparing the impact of environment physical indices on agro ecosystems productivity at crop habitat scale. The research was conducted in intensive grassland, barely, winter wheat and maize ecosystems of the conventional farm (54°28′ N, 23°38′ E, Kalvarija distr., Lithuania). The data have been collected in a real time using the digital sensors of humidity, pressure, gas concentration, solar intensity, wind speed and temperature. The relationships between the analysed physical data and agrochemical productivity indices were evaluated with the respect to the stages of plant growth. The research covered both productive grasslands (i.e. manure and chemical fertilizing) and various crop fields of different geographical location. The measurement of soil factors that impact fluid storage and transport, viz. compaction, enabled to establish certain quality indicators for sustainable crop management systems.

Key words: respiration, CO_2, N_2O emission; grassland, fertilizing, environment.

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INTRODUCTION

Emission of the greenhouse gases (GHGs), particularly CO_2, N_2O have radically increased during the last century of Anthropocene. These were fuelled by the human-impacted supply of available N to soils and water bodies via organic and chemical amendments (IPCC 2007, Forster et al. 2007). Terrestrial vegetation absorbs CO_2 from the atmosphere by photosynthesis and releases CO_2 by autotrophic respiration. Also, decomposers and herbivores release CO_2 by heterotrophic respiration (Yi et al. 2010). Moreover, CO_2 flux from soils constitutes a relevant indicator of the overall biological activity or soil vitality, and maybe used when analysing the soil carbon cycle. At the global scale, the net effect of photosynthesis and respiration is an uptake of about 7–8% of the atmospheric pool of 2785 Pg CO_2 (Chapin et al. 2002, Prentice et al. 2001). Valladares and Niinemets (2008) found out that solar radiation is the main source of energy for carbon assimilation and growth, affecting plant evolution and acclimation. Consequently, physiological processes, including GHG emissions are related to the environment conditions, and thus must be monitored together. The relationships between terrestrial carbon exchange and climate is fundamentally important for the climate–carbon cycle feedback could significantly accelerate (or decelerate) the future climate warming (Zeng et al. 2005). Nitrous suboxide is predominantly produced in oxic and anoxic soil microsites through microbial nitrification and denitrification, respectively (Granli & Bøckmann 1994). Moreover, CO_2 and N_2O differ in terms of global warming potential (GWP). With a GWP 298 times higher than that of CO_2 observed over 100 years (IPCC 2007), N_2O has the potential to convert a positive ecosystem GHG balance (uptake) into a negative one (release). It is well known that the production of N_2O is tightly coupled to the soil organic carbon status (SOC) (Li et al. 2005). Such increase in the SOC status has been confirmed in a meta-analysis (Jastrow et al. 2005) and might be related to the elevated atmospheric CO_2 concentrations due to increased plant litter inputs (Kool et al. 2010). Consequently, it could be presumed that N_2O emissions may rise with increasing atmospheric CO_2 concentrations during the vegetation period.

Even though the global net effect of photosynthesis and respiration is a small uptake, the changes in land cover, soil nutrients, atmospheric CO_2 concentration and abiotic environment conditions affect C and N balance. Given the current increase in atmospheric CO_2 and the resulting change in the global climate, it is important to monitor CO_2 and N_2O exchange in terrestrial ecosystems. However, directly observed relationships between climate and terrestrial CO_2 and N_2O exchange with the atmosphere across crop ecosystems are rather limited. National and international requirements for greenhouse gas emissions demand the development of more accurate inventories and mitigation options in agroecosystem backgrounds. Thereafter, the main aim of this research was to evaluate the respiration CO_2 and N_2O emissions in differently fertilized agro ecosystems of the grain crops (mostly wheat, *Triticum aesitvum* L., maize, *Zea mays* L.) and grasslands.

MATERIAL AND METHODS

Study site**.** The measurements of the emissions were conducted in the newly-sown intensively managed cultural grasslands, oat-vetch mix (cover of the 1st year grasses), maize and winter wheat (w. wheat) fields (54°28‘N; 23°38‘E) situated at the dairy farm, Lazdijai district (Lithuania), during the plant vegetation period of 2011. The site is located in 5-6 hardiness zone (Peel et al. 2007) of temperate climate (C) with moderate warm summer and moderate cold winter. Mean annual temperature is 5.5-7.5ºC with annual precipitation of 670 mm. The total solar radiation inflow amounts to 3600 MJ m^{-2} in Lithuania.

Field experiments. In order to compare the impact of the organic and mineral fertilizing on CO_2 and N_2O exchange, the experimental sites of sown productive grassland were treated in accordance with different fertilizing schemes: 1) organic fertilizer - liquid cattle manure, LM rate of 25 m^3 ha^{-1} (50 % dry matter, 3.8% N: 50 % available ammonia and nitrated N, and 50 % organic N) in spring and 2) complex mineral fertilizers, MF rates of 300 kg ha^{-1} $N_5P_{15}K_{30}$ (N34) in spring. Additionally, 100 kg ha^{-1} rate of ammonia saltpetre (NH_4NO_3) was applied after the 1st and 2nd cuts of all grasslands and maize. Two cuts scheme was applied in both grassland sites during the vegetation period. Grasslands were cut at the beginning of grass flowering stage. The productive grassland was composed of sown plant species: 10% p. ryegrass *Lolium perenne* ‘Sodrė’, 15 % x *festulolium* ‘Punia’, 15 % t. eraičiniai ‘Dotnuvos-1’; 10% timothy *Pleum pratense* ‘Gintaras’; 10 % bluegrass *Poa pratensis* ‘Lanka’; 10% lucerne *Medicago sativa*

Table 1. Grassland and crops fertilizing and productivity

Crop	Fertilizing			Yield, t ha^{-1}
	LM, m^3 ha^{-1}	MF (NPK), kg ha^{-1}	NH_4NO_3, kg ha^{-1}	
Grassland LM (3.8% N)	25 (in spring)	-	100+100	53
Grassland MF		$N_5P_{15}K_{30}$, rate of 300 kg ha^{-1}	100+100	58
Oat-vetch (cover)		$N_5P_{15}K_{30}$, rate of 300 kg ha^{-1}		64
W. wheat		$N_5P_{15}K_{30}$, rate of 300 kg ha^{-1}		5.7
Maize for silage	40 (in summer)	$N_5P_{15}K_{30}$, rate of 300 kg ha^{-1}	100	50

Table 2. Soil agrochemical mean parameters at the end of vegetation period ($p<0.05$)

Crop	Agrochemical indices					
	Humus, %*	pH	SOC, %	N_{total}, %	P_2O_5, mg kg^{-1}	K_2O, mg kg^{-1}
Grassland LM	2.9	7.1	1.62	0.59	171	219
Grassland MF	2.8	7.0	1.56	0.51	170	218
Oat-vetch (cover of the I yr. grass)	2.6	6.9	1.51	0.46	168	215
W. wheat	2.6	7.0	1.50	0.47	167	216
Maize	2.6	7.0	1.51	0.46	169	217

'Birutė' , 5% red clover *Trifolium pratense* 'Liepsna' and 10 % 'Arimaičiai', and 15% white clover *Trifolium repens* 'Sūduviai'. Grassland productivity was evaluated by weighting the biomass (t ha^{-1}; Table 1).

The 300 kg ha^{-1} spring fertilizing rate of $N_5P_{15}K_{30}$ was applied for the oat-vetch mix (cover of the 1st year grasses), maize 'Morella' and winter wheat 'Ada'. Additionally, maize was fertilized 100 kg ha^{-1} NH_4NO_3 (N34) and 40 t ha^{-1} of manure in summer.

Physical-meteorological measurements of the environment. All the sites featured the same soil type, namely clay loam topsoil over silt loam (*Calc(ar)i-Endohypogleyic Luvisol*, FAO, 1997). Humus horizon was 20 cm deep. Soil pH ranged in between 6.9 and 7.1. the soil also featured 2.9-2.6 % humus content, 167-171 mg kg^{-1} P_2O_5, and 215-219 mg kg^{-1} K_2O (Table 2). P_2O_5 and K_2O content exceeded the average values thus indicating a nutrient-rich topsoil favourable for plant growth (Table 2).

Soil compaction (kPa) was measured by Compaction meter SC 900, Campbell, soil temperature (°C) by CM 107, soil humidity (%) by sensor HydroSense CS-620[47]. Meteorological variables observed include air temperature, net radiation and precipitation (Fig. 1). Air temperature (°C) and humidity (%) were measured by mobile air station Meteo Multi, Campbell (sensor FMA510, humidity sensor PS 2174).

Fluxes measurement. GHG emissions were measured one week after fertilizing which was applied after each cut in the end of May and July in absence of frost stress for biota. Soil-plant fluxes, namely CO_2 (mg h^{-1} m^{-2}) and N_2O (µg h^{-1} m^{-2}) were assessed by static chamber method (Hutchinson & Livingston 1993). We used transparent and opaque chambers for estimation ecosystem respiration (R) (Baldocchi et al 2001, Law et al. 2002) related to ecosystem exchange of CO_2 between the biosphere and the atmosphere (Nemani et al. 2003, Smith et al. 2010).

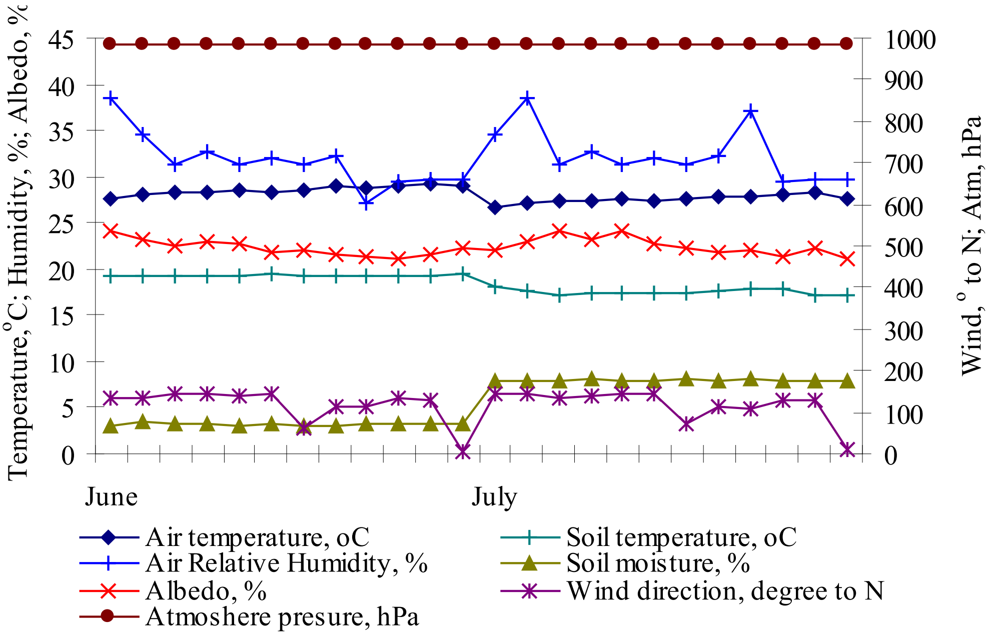


Fig.1. Variation of the site meteorological parameters during the GHG measurement in June-July.

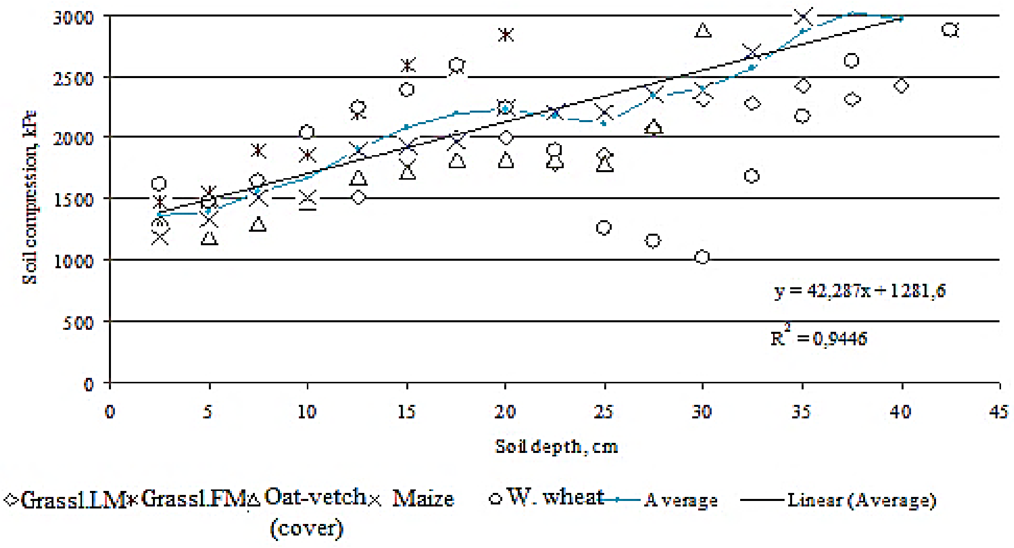


Fig. 2. Soil compaction alteration depending on depth in different crop fields.

Table 3.Correlations (r) between meteorological indices and emissions

Emission	Air temperature	Soil temperature	Air Relative Humidity
CO_2, mg h^{-1} m^{-3}	0,6	-0,5	0,5
N_2O, µg h^{-1} m^{-3}	0,6	-0,3	0,4

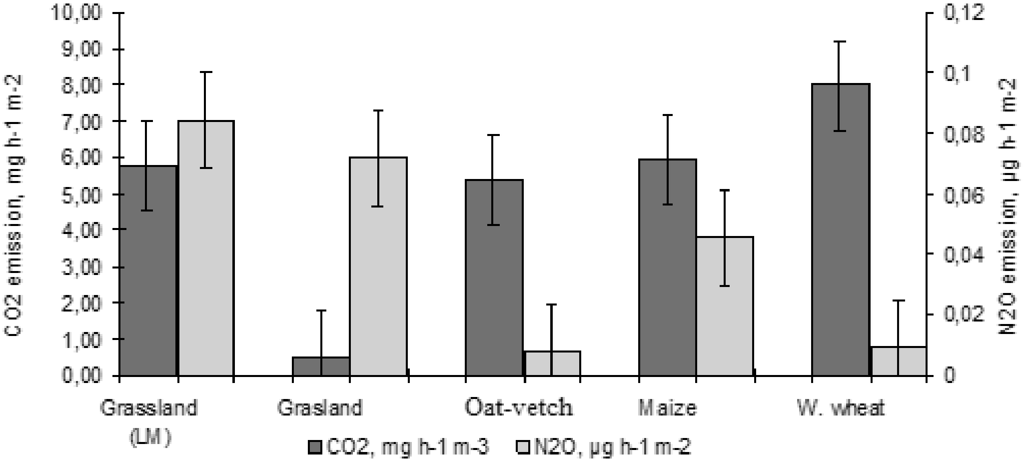
Statistics. Results were obtained in five sites of each study field (n=10). The inter-dependency and correlation of solar intensity, temperature of environment, pressure, and wind speed, soil density were investigated. The air temperature and humidity results were collected evaluating change of the humidity, temperature etc. in the time of dry period. The confidence limits of the data were based on Student's theoretical criterion at the level of statistical significance $p<0.05$.

RESULTS AND DISCUSSION

Meteorological conditions, namely temperature, humidity and exposure, impacted not only plant growth and productivity, but also correlated with gas emission processes (Table 3). These conditions were rather similar during measurement and favourable for plant vegetation. The relative air humidity ranged in between 27.2% and 38.5% in June and between 29.5% and 38.5 % in July (Fig. 1), and thus caused higher atmospheric pressure in June (984.6-985.2 hPa), than in July (9823- 982.9 hPa). June was also specific with a higher air and soil temperature (27.7- 29.2°C and 19.3-19.4°C respectively), if compared to July (26.7-28.2°C and 17.1-18.0°C respectively) possibly due to more northern direction of wind in July. Consequently, significant lower soil moisture was measured in June (3-3.4%), than in July (7.9-8.1%). Nonetheless, albedo composed only 21-24% due to continuous plant cover in the analysed crops which actively absorbed sunlight involved in photosynthesis.

In accordance with previous findings on the porosity changes upon compaction (Alaoui et al., 2011; Naderi-Boldaji et al., 2013), the field measurement showed a significant correlation between soil compaction and soil depth (y 42,287x + 1281,6; r=0.9) across the study sites (Fig. 2). The structural changes leading to soil compaction constitute the major cause of soil degradation in modern agriculture and forestry. Indeed, it is soil degradation that affects water retention and hydraulic conductivity functions here. The compactness of 1000-2500 kPA was obtained in surface layers for 5-25 cm depth. Nonetheless, the subsoil compaction ranged in between 1000 and 3000 kPa across different crop fields. The observed compaction levels observed higher than the upper limit of compaction, and thus indicated the direction to be taken to improve the model of applied soil machinery.

Corresponding to the previous findings for different crops (Baldocchi et al. 2001, Gilmanov et al. 2012, Ma et al. 2013), the described environmental conditions as well as crop species impacted GHG emissions in the evaluated agroecosystems. Based on studies by Nemani et al. (2003) and Smith et al. (2007, 2010), we treated the components of GHG emission, as the indicator of ecosystem function of short-plant croplands. The intermittent chamber measurements were employed to obtain the latter data. In this study we focused on the carbon dioxide (CO_2) released by ecosystem respiration (autotrophic and heterotrophic). The CO_2 and N_2O emissions rate varied across time and crops, which were specific with different growth, photosynthesis type and activity throughout the GHG estimation period. Moreover, 'biomass ratio hypothesis' (Grime 1998), suggest that ecosystem properties and functions (i.e. carbon and nitrogen cycles) should be related to the trait values of the dominant contributors to the plant biomass. Consequently, the lower CO_2 exchange rate was observed in June than that in July. It could be explained by a more robust development and heterotrophic respiration of soil microbiota. This development occurs during middle summer (July) due to improvements of the abiotic environment, specifically temperature which stimulated biota



Fig, 3. Ecosystems respiration CO_2 and N_2O emissions from grasslands and different crops in June.

in ecosystems (Frantz et al. 2004, Mielke & Schaffer 2010).

A strong correlation between emissions and crop yields was determined. Correlation between CO_2 exchange rate (r=0.6) and crop yield (t ha^{-1}) was positive: y = 0.9867x + 2.1559. Nonetheless, a negative strong correlation (r=-0.8) between N_2O emissions and crops yield (represented by a pair-wise regression y = -0.0178x + 0.097) indicates a possibility for N assimilation and bounding by increasing the crop biomass.

Respiration CO_2 gains were obtained across different crops and varied throughout June and July (Fig.3-4). The observed CO_2 emissions were lower in June than those in July. It ranged in between 0.51 mg h^{-1} m^{-3} and 5.93 mg h^{-1} m^{-3} in June and between 4.72 and 99.38 mg h^{-1} m^{-3} in July. The relatively high air and soil temperatures observed in June were favourable for CO_2 assimilation, possibly stimulating CO_2 absorbtion by photosynthesis and an intensive plant growth. Fallowing Schlesinger and Andrews (2000), soil respiration is the primary path by which CO_2 fixed by land plants returns to the atmosphere and currently is recognized as one of the largest fluxes in the global carbon cycle. Changes in environment temperature conditions constitute a well-known driver of respiration production (Davidson et al. 1998). Our results correspond to these conclusions by exhibiting a strong correlation (r=0.7) between respiration intensity and environment temperature.

Corresponding to the previuos findings (Aubinet et al. 2009, Baldocchi 2003, Zheng et al. 2012, Franks & Hadingham, 2012), that the advantage of integrated soil–crop system management obviously influenced the GHG emission rate, we found a negative correlation between CO_2 emissions and sequestered carbon in SOC (r= -0.6) and soil N deposition (r= -0.5). Although a strong positive correlation (r=0.9) was observed between soil N deposition and N_2O emissions (Lund et al. 2009), a weak correlation was observed between SOC and N_2O emission (r=0.3).

Among the analysed crops, winter wheat (7.99 mg h^{-1} m^{-3}) and maize (143 mg h^{-1} m^{-3}) featured the highest CO_2 rate (Figs 3, 4). Meanwhile, the CO_2 emissions of maize (5.93 mg h^{-1} m^{-3}) and early crops (5.77 mg h^{-1} m^{-3} of grassland LM and 5.38 mg h^{-1} m^{-3} of barley) were similar and lower than that of w. wheat in June.

It is obvious that the carbon inputs through the spring organic manure amendments induced higher CO_2 emission in organically fertilized grassland (LM). Subsequently, 0.51 mg h^{-1} m^{-3} CO_2 emission was the lowest one in grassland MF in June. Nonetheless, an additional LM application for highly productive maize yielded

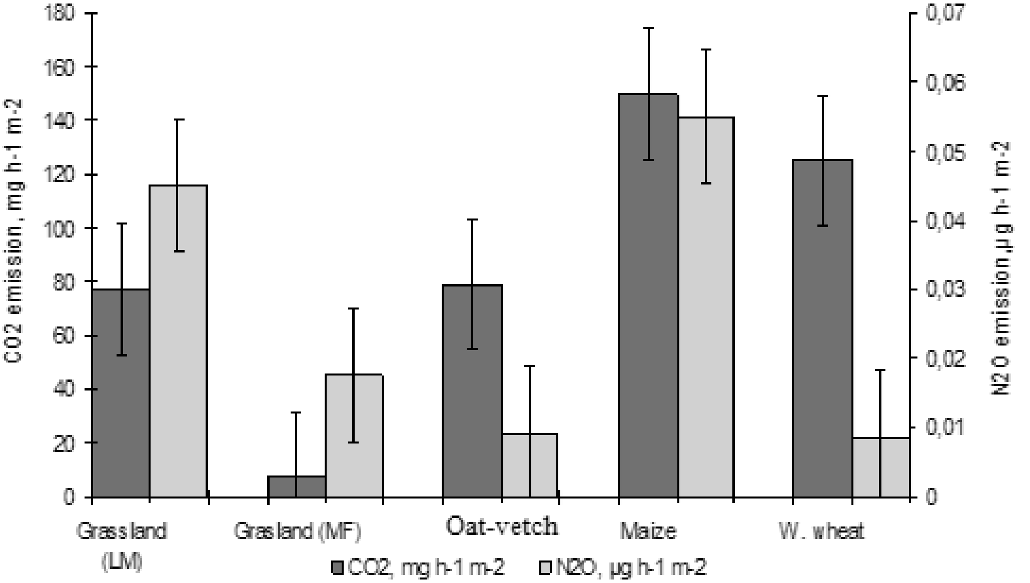


Fig. 4. Ecosystems respiration CO_2 and N_2O emissions from grasslands and different crops in July.

the highest rates of the emitted CO_2 across the analysed crops in July (Fig. 4).

In accordance the previous studies (Aguilera et al. 2013, Kong et al. 2013), N_2O emission was very dependent on the fertilizing technology, particularly with N availability (Lund et al., 2009). Thereafter, a strong positive correlation (r=0.9) between soil N deposition and N_2O emission can explained the highest emission rates in grassland MF (0.085 and 0.02 $\mu g\ h^{-1}\ m^{-3}$) and maize crop (0.046 and 0.06 $\mu g\ h^{-1}\ m^{-3}$) (Fig. 3-4). These crops were additionally supplied with N fertilizers during the plant vegetation. Nonetheless, a negligible N_2O emission (0.085-0.06 $\mu g\ h^{-1}\ m^{-3}$) indicated rather reasonable N fertilizing rates, which are fully assimilated by plants and soil biota, thus leading to a decrease in N_2O emission and climate change mitigation.

CONCLUSION

This study investigated CO_2 and N_2O agricultural emissions from five differently managed grassland and crops ecosystems. The meteorological conditions, namely temperature, humidity and exposure, were correlated with the gas emission indicators. Soil porosity changes due to compaction were significantly correlated with soil depth (r=0.9). Furthermore, the subsoil compaction ranged in between 1000 and 3000 kPa across the different crop fields altering environment conditions for soil biota. Soil agrochemical content differently impacted GHG emissions. CO_2 emissions negatively correlated to SOC (r= -0.6). Correlation between SOC and N_2O emissions determined weak (r=0.3).

Integrated soil–crop system management impacted ecosystem respiration and N_2O emission. N deposition significantly (r=0.9) stimulated N_2O emissions. Negative effects of N nutrient addition were found for CO_2 emission (r= -0.5).

The CO_2 and N_2O emissions differed across the fertilizing regimes, viz. organic and chemical, and ecosystem plant species (due to their biological peculiarities). Indeed, the highest discrepancies were observed between grassland and arable fields, thus highlighting the need for spatial disaggregation to improve the accuracy of the inventory.

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