precipitation

the

rotation

the

Abstract

Nitrous oxide

Agricultural soil with fertilization is a main anthropogenic source for atmospheric (N_2O). N_2O fluxes from a maize-wheat field in the North China Plain (NCP) were investigated for four successive years using static chamber method. The annual N_2O fluxes from control (without fertilization) and fertilization plots were 1.5 ± 0.2 and 9.4 ± 1.7 $\mathrm{kg\,N\,ha^{-1}\,yr^{-1}}$ in 2008–2009, 2.0 ± 0.01 and 4.0 ± 0.03 $\mathrm{kg\,N\,ha^{-1}\,yr^{-1}}$ in 2009–2010, 1.3 ± 0.02 and 5.0 ± 0.3 $\mathrm{kg\,N\,ha^{-1}\,yr^{-1}}$ in 2010–2011, and 2.7 ± 0.6 and 12.5 ± 0.1 $\mathrm{kg\,N\,ha^{-1}\,yr^{-1}}$ in 2011–2012, respectively. Fertilizer-induced emission factors (EFs) in the corresponding years were 2.4, 0.60, 1.1 and 2.9 %, respectively. Significant linear correlation between fertilized-induced N_2O emission (Y, $\mathrm{kg\,N\,ha^{-1}\,yr^{-1}}$) and ~~rainfall~~ 4 day before and 10 days after fertilization (X, mm) was found as $Y = 0.04760X - 1.06453$ ($N = 4$, $R^2 = 0.99247$, $P \in 0.00253$). Therefore, the remarkable interannual variations of N_2O emissions and the EFs from the agricultural field were mainly ascribed to the rainfall. The total N_2O emission from the agricultural field in the NCP was estimated to be 144 $\mathrm{Gg\,N\,yr^{-1}}$ based on the average flux derived from the measurements of four years, and the fertilizer-induced N_2O emission accounted for about 76 % (110 $\mathrm{Gg\,N\,yr^{-1}}$) of total emission.

Annual
Direct

< 0.01

intensity

It is not reasonable to estimate the emission of the NCP region using measurements at a single site.

1 Introduction

Emissions of nitrous oxide (N_2O) to the atmosphere have attracted much attention because of its significance for greenhouse effect and depletion of stratospheric ozone (Crutzen, 1970; Bolle et al., 1986). Agricultural soil has been recognized as a main source of anthropogenic N_2O emissions to the atmosphere (Khalil et al., 2006) and contributes about 65 % of total anthropogenic N_2O emission (Smith, 1997). It is well known that N_2O is a by-product in microbial nitrification and an intermediate in denitrification process (Firestone and Davidson, 1989). N_2O emissions from soils are strongly affected by many factors, e.g. soil temperature and moisture, soil aeration status and w

** Direct emission factor (EFd) is consistent with the IPCC concept, and thus is suggested ~~[illegible]~~ use in this study.

nitrogen (N)

carbon availability (Smith et al., 2003; Ruser et al., 2006), crop type and residue management (Raich and Tufekcioglu, 2000; Huang et al., 2004; Chen et al., 2008), and the management of N fertilizer (Hao et al., 2001; Bouwman et al., 2002). Among the various influence factors, fertilization, soil temperature and moisture play important roles on N_2O emission. Fertilization directly provides substrate for soil nitrifying and denitrifying microbes, and soil temperature and moisture have major impacts on soil microorganisms (Smith et al., 2003). The microbial process generally increases exponentially with soil temperature when other factors are not limiting (Meixner and Yang, 2006). Soil water content plays important roles not only on the substrate supply for the microorganisms (Meixner and Yang, 2006) but also on gas diffusivity (Smith et al., 2003). Increasing soil moisture is conducive to produce anaerobic condition and thus promotes N_2O formation via denitrification (Dobbie and Smith, 2001). Large temporal-spatial variation of N_2O emission from agricultural fields could be expected due to the changes of the various influence factors, e.g. there are great uncertainties in N_2O emission from agricultural fields with the reported emission factors (EFds) of 0–7 % for mineral soils (Bouwman, 1996). Therefore, it is necessary to conduct long-term N_2O flux measurements from different agricultural field to reduce the uncertainties of N_2O estimation (Barton et al., 2008; Scheer et al., 2008).

direct

//

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estimates

North China Plain (NCP) is one of the greatest grain production areas in China. Maize and wheat, the main grain crops in this region, provide 39 % and 48 % of the total maize and wheat yields in China, respectively (Liu and Mu, 1993). The NCP has a cultivated land area of 17.95 million ha, which accounts for 18.6 % of the total agricultural area in China (Liu et al., 2001), and consumes about 30 % of the total national N-fertilizer (Zhang et al., 2004). As N-fertilizer is the necessary substrate for soil nitrification and denitrification, the huge amounts of N-fertilizer applications in this region can greatly stimulate N_2O emission. Therefore, N_2O emissions from the agricultural fields in the NCP have been investigated intensively (Zeng et al., 1995; Dong et al., 2000; Meng et al., 2005; Ding et al., 2007; Sun et al., 2008; Wang et al., 2008; Wang et al., 2009; Li et al., 2010; Cui et al., 2012; Cai et al., 2013). However, among the ten re-

incomplete ~~[illegible]~~ review of the previous reports!!

? complete review?

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Interactive Discussion

ports on N_2O emissions from the fields, nine studies conducted one year, and only the study of Cai et al. (2013) implemented the N_2O measurement for three years (2004–2007). According to these treatment-site-year data, large differences of N_2O emissions (ranging from 0.77 to 6.0 kg N ha^{-1} yr^{-1}) and EF~~s~~ (in the range of 0.10–1.4 %) from the agricultural fields in the NCP were obtained. a

skipp off 1.4 % from the list in table 4.

In this study, the N_2O flux from maize-wheat rotation system in the NCP was investigated from 2008 to 2012. The objectives of this study were: (1) to understand the interannual variation characters of N_2O emission; (2) to determine the key influence factors on N_2O emission; and, (3) to assess the total N_2O emission from the maize-wheat field in the NCP.

2 Materials and methods

2.1 Field experiment

This study was conducted in a summer maize (*Zea mays* L.) and winter wheat (*Triticum aestivum* L.) rotation system in Wangdu County (38°71′ N, 115°15′ E), Baoding City, Hebei Province, China. The detail information about the experiment field had been mentioned in our previous papers (Zhang et al., 2011, 2012).

NP

replicate

The field experiment was conducted with two different treatments: control plot (CK, without fertilization) and chemical N fertilizer plot (NP). Only with the exception of fertilization, the two plots were identically managed. Each plot (6.5 × 3.5 m^2) was separated by a 1.2 m broad zone to prevent nutrient transfer between treatments. Maize and wheat were planted in June and October each year, respectively, and the field was tilled before wheat sowing. Field managements including fertilization, irrigation, herbicide and pesticide applications strictly followed the cultivating manner of local farmers. The detail information about fertilizer management is listed in Table 1.

How many replicates for each treatment?

You have to present very detailed descriptions of the methods and procedures applied so that readers are able to judge the reliability of N2O fluxes.

2.2 N$_2$O fluxes measurement

This is true for the 2010–2011 rotation, but not for the others! How did you fill the big gaps and dealt with the uncertainty when you estimate annual/seasonal emissions and emission factors?!

N$_2$O fluxes were investigated in the summer maize-winter wheat field from June in 2008 to October in 2012. Static chambers (60 × 60 × 90 cm^3) were adopted to monitor N$_2$O fluxes. Three stainless steel pedestals were inserted 10 cm into the soils of each plot during the whole growing season. Four maize seeds (in June) and about 280 wheat seeds (in October) were kept in each pedestal, respectively. N$_2$O flux was measured every day with duration of at least 10 days after fertilization, then once or twice weekly during other periods of crops' growing seasons. On each sampling day, ~~N$_2$O flux was measured~~ at 9.30 a.m. (Beijing time).

within

A

from a replicate plot

How did you deal with the maize plants when they were higher than the chambers?

gas samples were taken

around

N$_2$O concentrations were determined using a gas chromatography (Model SP3410, Beijing Analytical Instrument Factory) equipped with ^{63}N electron capture detector (Zhang et al., 2011, 2012). The N$_2$O flux (F, ng N m^{-2} s^{-1}) was calculated by the following equation:

of gas samples

How many gas ~~sample~~ samples were taken to determine each flux, with ~~intervals of how long?~~ What time interval?

$$F = H \times \frac{\Delta C}{\Delta t} \times \frac{P}{RT} \times M_N \times 10^3. \quad (1)$$

Four concentrations and the linear model are questionable to some extent for determine a flux.

where H is the chamber headspace height (m), $\Delta C/\Delta t$ is the slope (ppbv s^{-1}) of the linear regression of N$_2$O concentration in the chamber with time ($R^2 > 0.85$), P is the atmospheric pressure (atm) measured in the field, R is the gas constant (0.082 atm L K^{-1} mol^{-1}), T is the ambient air temperature (K) and M_N is the molecular weight of N$_2$O-N (28 g mol^{-1}).

How could you deal with the nonlinear cases? (see Wang et al., 2013, Agr. Forest Meteorology)!

2.3 Measurement of soil characteristics

Four soil samples in each plot were collected from 0–10 cm soil layer using a stainless steel soil sampler and were mixed carefully for the analysis of soil mineral N (NH$_4^+$-N and NO$_3^-$-N) concentrations. Soil water-filled pore space (WFPS) was determined at 5 cm depth by a ring sampler (100 cm^3) (Zhang et al., 2011, 2012). Soil temperature was recorded on each gas-sampling day at a depth of 10 cm, while only the

This test does not apply here!

soil temperatures in the CK plot~~s~~ were record in 2008. The data of precipitation were from http://www.wunderground.com.

2.4 Date calculation and statistical analysis

The statistical analysis was conducted by Origin 8.0 (Origin Lab Corporation, USA) and SPSS 13.0 software (SPSS Inc., Chicago, USA). Prior to analysis, ~~normal distributions~~ data of N_2O fluxes and driving factors were tested using the Shapiro–Wilk test and data were log-transformed as needed to normalize the distributions. Paired-samples *T* test was adopted to analyze the difference between CK and NP treatments during the no fertilization periods. Stepwise linear regression analysis was performed to examine the relationships between N_2O fluxes and important driving factors, and only the regression equations that have statistical significance are listed in this study. Significance of all tests was accepted at $P < 0.05$.

The T-test does not apply for you case!

The N_2O fluxes presented in the figures are the arithmetic means of the replications in each treatment. The cumulative N_2O emission from each treatment was estimated by linear interpolations between the sampling days. The EFs during the investigation periods were calculated as the difference between the cumulative N_2O-N emission in the fertilized plot and control plot divided by the amount of N fertilizer applied.

//

3 Results

3.1 Environmental variables

rotations

The variations of soil moisture were mainly regulated by precipitation and irrigation. Generally, soil moisture would increase quickly after irrigation (WFPS > 60 %), and it could reach 80 % or above when precipitation happened just after irrigation (Fig. 1a–d). The annual precipitation was 352, 356, 306 and 383 mm during the 2008–2009, 2009–2010, 2010–2011 and 2011–2012 maize-wheat seasons, respectively, and the precipitation in the maize season accounted for 75 %, 62 %, 64 % and 79 % of the

Your discorption of methods provides little information for readers to judge how reliable these negative fluxes are. You need to convince readers with more detailed supporting materials, e.g. checking the stability of N_2O during storage and transportation with gas bags, ~~determine~~ measuring the flux detection limit (at 95% confidence interval) by injecting gases with known concentrations into gas bags and analyzing later, or using more strict critera to accept a negative flux.

total amount in each year, respectively. The mean soil moistures (WFPS) in the CK and NP plots were 57 % and 65 %, 48 % and 64 %, 55 % and 55 %, 68 % and 69 % in the 2008–2009, 2009–2010, 2010–2011 and 2011–2012 maize-wheat rotation ~~years~~, respectively. The average soil temperatures of the CK and NP plots were 26.7, 22.5, 26.4 and 25.5 °C in the 2008, 2009, 2010 and 2011 ~~maize growing seasons~~, and were 12.9, 11.0, 11.0 and 9.3 °C in the corresponding wheat seasons, respectively.

Or

/ignore!

3.2 N_2O fluxes and key influence factors

The temporal variations of N_2O fluxes from the CK and NP plots during the four years are illustrated in Fig. 2. N_2O emissions from the CK plot were in the range of −37–70 ng N m^{-2} s^{-1}, and obvious emission pulses occasionally occur after irrigation and rainfall events. As for the NP plot, the relatively high N_2O emissions (75–624 ng N m^{-2} s^{-1}) usually occurred after fertilization, and the N_2O emission was from −19 to 33 ng N m^{-2} s^{-1} during the periods of pre- and post-fertilizer application. Negative N_2O fluxes (uptake, i.e. fluxes from the atmosphere to the soil) were occasionally observed in the CK and NP plots in this study, which accounted for 4–10 % of total investigation data in each maize-wheat season. The lowest detectable flux of the GC-ECD is 0.57 ng N m^{-2} s^{-1} in this study, and thus the extremely low N_2O uptakes are probably caused by the fluctuations of instrument. Nevertheless, the larger N_2O uptakes (−7 to −37 ng N m^{-2} s^{-1} in the CK plot; −7 to −19 ng N m^{-2} s^{-1} in the NP plot) can be ascribed to denitrification and nitrifier denitrification by reduction of N_2O to N_2 (Chapuis-lardy et al., 2007). Yamulki et al. (1995) and Mahmood et al. (1998) also reported evident negative N_2O fluxes from agricultural fields.

?

As shown in Fig. 2, N_2O emission peaks induced by fertilization usually occurred at the 1st–5th day after fertilization following irrigation in each growing season, while they delayed 1–2 days when rainfall events occurred just after fertilizations, e.g. on 21 August 2008, 5 July and 5 August 2009 (Fig. 2a and b). Generally, the N_2O peaks only lasted for one day and then decreased quickly, while the high N_2O emissions

I don't think the negative fluxes are believable, Unless you are able to confirm them. They are likely caused by improper operation or instable instrument signal during sampling, sample transportation and analysis in lab.

(about 550 ng N m^{-2} s^{-1}) sustained 3 days after basal fertilization following showers (from 1 July to 2 July) in 2011 maize season (Fig. 2d). Therefore, precipitation coincided with the fertilization would probably promote N_2O emission because of the substrate supplement and development of anaerobic soil condition.

The N_2O emission peaks from the NP plot were 294, 142, 503 and 558 ng N m^{-2} s^{-1} in 2008, 2009, 2010 and 2011 maize seasons, respectively, and were 75, 100, 147 and 624 ng N m^{-2} s^{-1} in 2008–2009, 2009–2010, 2010–2011 and 2011–2012 wheat seasons, respectively. The N_2O emission peaks after basal or supplemental fertilizer application were usually higher during the maize seasons than during the wheat seasons, which might be due to the relatively low soil temperature in the wheat seasons (Fig. 1e–h). However, the maximal peak of N_2O emission (624 ng N m^{-2} s^{-1}) from the NP plot among the four investigated years appeared in the 2012 wheat season after the supplemental fertilization, which was 4–8 times higher than those in other wheat seasons. During the period of the N_2O peak emission from the NP plot in the 2012 wheat season, the soil WFPS (78 %) was evidently higher than those in 2009 (66 %) and 2011 (60 %) wheat seasons (Fig. 1a, c and d). Although higher WFPS (82 %) was observed after the supplemental fertilizer application in the wheat season of 2010, the obvious low soil temperature (10 °C) compared with that (15.5 °C) in 2012 greatly restricted the activities of soil microorganisms (Meixner and Yang, 2006). Therefore, the higher N_2O emission in the wheat season of 2012 was due to the synergistic effect of appropriate soil temperature (15.5 °C) and WFPS (78 %), which could build the soil micro environment in favor of denitrification, and thus promote the N_2O emission (Dobbie and Smith, 2001).

To elucidate the influence of various influencing factors on N_2O emission, the regression analysis between N_2O fluxes and important driving factors was conducted as shown in Table 2. Evidently, soil mineral N, temperature and WFPS were positively correlated with N_2O emission. Soil temperature and WFPS could explain 27–52 % and 18–31 % of the total N_2O emission, respectively. However, not all influence factors displayed the significant ~~relationships with~~ the N_2O emission in each year and treatment,

influence on

→ N_2O emission correlated with
positively

→ what does "total N_2O emission" mean?
~~Does it~~ Do you mean the total variance in N_2O fluxes?

Delete this part as the fitting is not significant !

rotations

4-Year

and the similar conclusion has been drawn by other studies (Wang et al., 2005; Rowlings et al., 2012).

3.3 Cumulative N_2O emissions and emission factors

[illegible]

The cumulative N_2O emissions and EFds are listed in Table 3. The lowest emissions always occurred in the CK plots with the 4 yr mean fluxes of 0.6 kg N ha^{-1} in the maize season, 1.3 kg N ha^{-1} in the wheat season and 1.9 kg N ha^{-1} in the whole year. The annual cumulative N_2O emissions from the NP plots in 2009–2010 and 2010–2011 were close, and extremely high N_2O emissions were observed in the 2008–2009 and 2011–2012 maize-wheat ~~seasons~~. Mean cumulative N_2O emissions from the NP plots in the maize, wheat growing seasons and the whole year were 4.4, 3.3 and 7.7 kg N ha^{-1}, with the variation coefficients of 46, 90 and 51 %, respectively.

The annual EFds were 2.4 %, 0.6 %, 1.1 % and 2.9 % in 2008–2012 maize-wheat ~~seasons~~, respectively (Table 3). The mean 4 yr EFd in the maize season (2.2 %) was 1.8 times higher than that in the wheat season.

4-Year

rotations

Error for each ? You are able to calculate the error at the 95% confidential interval since you know the errors of the emission fluxes involved in the EFd calculation.

4 Discussion

4.1 Interannual variation of N_2O emission

In fact it is not significant at all.

The above results well revealed evident interannual variation of N_2O emissions from the agricultural field during the four successive years. Considering the nearly identical N-fertilization rates and similar irrigation operations in each year, the interannual variation of N_2O emissions was mainly ascribed to the changes of meteorological condition that affected the soil temperature and moisture. The annual cumulative N_2O emissions (F_1, kg N ha^{-1}) from the CK plots significantly correlated with the annual total rainfall (X_1, ~~mm), and the relationship fitted the following equation:~~

$$F_1 = 5.6 \times 10^{-10} X_1^{3.7}, \quad N = 4, \quad R^2 = 0.754, \quad P < 0.013. \tag{2}$$

< 0.05

I don't think the fitting with $R^2 = 0.754$ for $n = 4$ is significant at $P < 0.05$!

Case of "$n = 4$" requires $R^2 = 0.90$ to meet $P = 0.05$!

Why are the parameters given so precisely?

The decimals should be determined by your measurement precision of no emission!

mean ?

ecc

< 0.01

It indicated that rainfall was a dominant factor for controlling N_2O emission from the agricultural field without fertilization. As for the NP plot, there was no evident correlation between the annual cumulative N_2O emissions and total rainfall. However, there was a significant linear correlation ($N = 4$, $R^2 = 0.99241$, $P = 0.00253$) between the annual fertilizer-induced N_2O emissions (F_2, $\mathrm{kg\,N\,ha^{-1}}$) during the periods of 10 days after fertilization and the amounts of rainfall (X_1, mm) 4 days before and 10 days after each fertilization in each year. The equation could be expressed as:

ly mean

from

to

$$F_2 = 0.04767X_1 - 1.06453. \tag{3}$$

5 ecc

Because the cumulative N_2O emission from the NP plot during the periods of 10 days after fertilization accounted for ~ 50 % of the total cumulative N_2O emissions, the rainfall events far from fertilization events only made modest contribution to the total cumulative N_2O emissions. The rainfall events just before and after fertilization might favor fostering the community of microorganism and promoting N_2O formation. Therefore, it is easy to understand why the strong correlation only limited between the yearly mean fertilizer-induced N_2O emissions during the periods of 10 days after fertilizations and the amounts of rainfall around fertilization events in each year.

ecc

There were no significant differences between the CK and NP treatments during the ~~no fertilization~~ periods in the four years (T test, $P = 0.056–0.177$) and the yearly management (fertilization rate and irrigation) of the agricultural field was almost the same in recent years. [Only based on the rainfall, the correlations between the N_2O emissions and the rainfall could be useful to estimate the cumulative N_2O emissions (F, $\mathrm{kg\,N\,ha^{-1}}$) from the agricultural field:

$$F = 5.6 \times 10^{-10}X_2^{3.7} + 0.04767X_1 - 1.06453. \tag{4}$$

5 ecc

$(N = 4, R^2 = ?, P < ?)$]

It should be mentioned that the above estimation could be only applied to limit area where the rainfall is nearly identical and fertilization rate is similar with this study. Because the cumulative N_2O emissions usually linearly correlate with fertilization rates

rates and irrigation practice are

excluding the 10-day periods following each fertilization events. You can not use T-test in your case.

Directly present this fitting if $P < 0.05$, and rewrite the part in "[ ]".

Lu et al. (2006, Chemosphere, 65: 1915–1924) report a function to link N_2O emission, precipitation and N-fertilizer input. What's your + comments about that as compared with yours?

annual rate or rate of individual fertilization events?

(Henault et al., 1998; De Klein et al., 2006; Halvorson et al., 2008), the above experiential algorithm for estimating the annual cumulative N_2O emissions (Y, kg N ha^{-1}) from agricultural fields could be expressed in more general form:

$$Y = AX_{d}^{n} + F/BX_{d} \boxed{-} C, \qquad (5)$$

where n, A, B and C are emperical constants which can be ~~derived from the correlation of~~ estimated with field measurements, and F is the application rate of N-fertilizer. To verify the applicability of the above algorithm, more field studies in various agricultural fields are needed. If the applicability of the above algorithm was verified, the ~~global~~ regional, or even global, annual cumulative N_2O emissions from agricultural fields could be ~~easily~~ widely estimated just based on fertilization rates and rainfall in different regions.

4.2 Comparison with previous studies and assessing the total N_2O emission in the NCP

The results of studies from maize-wheat rotation fields in the NCP are shown in Table 4. It is evident that there are very large temporal-spatial variations of the cumulative N_2O emissions and EF_ds reported in the NCP. With only the exception of the data in 2009–2011 maize-wheat seasons, the cumulative N_2O emissions from the NP plot in this study were 33–108 % greater than the upper limit value reported in the literatures. The EF_d value of 0.60 % in 2009–2010 was in good agreement with the values reported by Dong et al. (2000) and Ding et al. (2007), and of 1.1 % in 2010–2011 was in line with the values reported by Li et al. (2010), Sun et al. (2008) and Cai et al. (2013). The EF_ds from the NP plot in 2008–2009 and 2011–2012 were two times greater than the upper limit value reported in the NCP, but were still within the uncertainty range recommended by the IPCC (0.3–3 %, De Klein et al., 2006).

To check the possible influence of the soils from different areas in the NCP on N_2O emission, soil samples were collected from four sampling sites (Fengqiu, Luancheng, Yucheng and Beijing) where N_2O emissions have been investigated. N_2O emissions from the four fields were simultaneously measured under the same fertilization and

You review here involves incomplete reports for the NCP study on N_2O emission. You'd better collect all available literatures for the review and discussion!

irrigation at the agricultural field of this study (data not shown), and no remarkable difference of N_2O emissions from the four agricultural soils was found in comparison with the uncertainty of the triplet treatments for the agricultural soil investigated in this study. Therefore, the very large temporal-spatial variations of the cumulative N_2O emissions and EFs from the agricultural fields in the NCP might also be partially ascribed to the different weather conditions (especially rainfall as mentioned above) in different areas and years during the investigations. To some extent, the field simulation experiment confirmed that the results investigated at any agricultural fields in the NCP could be applied for estimating the annual cumulative N_2O emission and the fertilizer-induced N_2O emission from the agricultural field in the NCP. The estimation would be more representative based on the average value of many years' investigations, because the multi-years rainfall in one small region might partially reflect the uneven distribution of rainfall in different areas of the NCP.

The NCP has a cultivation area of 17.95 million ha (Liu et al., 2001) and the average fertilization rate is about 350 kg N ha^{-1} yr^{-1} (Table 4). Based on the four years' average cumulative N_2O emission from the CK plots and EF obtained by this study, the annual total N_2O emission and fertilizer-induced N_2O emission from the agricultural fields in the NCP were estimated to be 144 Gg N and 110 Gg N, respectively.

① How much are the uncertainties of these estimates at the 95% confidential interval?
② Why didn't you make the estimates based on your data as well as the data from literatures?

5 Conclusions

Large interannual variations of N_2O emissions were observed from the maize-wheat field in the NCP during the four successive years. Precipitation was primarily responsible for the temporal-spatial variation of N_2O emission. The significant correlation between cumulative N_2O emission and precipitation obtained in this study may be used to estimate N_2O emission from the area where the rainfall and fertilization rate are similar with this study.

inter-annual

//

provide an approach option to

Acknowledgements. This study was funded by the National Science & Technology Pillar Program (No. 2013BAD11B03), the Strategic Priority Research Program of the Chinese Academy

Are they same?

regulating

2

Table 2. Regression analysis between N_2O flux and its control factors in the maize-wheat field.

Treatment	Factors	B^a	R^2	Equation
				2009–2010 maize-wheat season
CK	WFPS	0.021	0.306	$\lg N_2O = 0.021\text{WFPS} + 0.052\text{ST} - 0.935$
	ST^b	0.052	0.516	$(N = 17, R = 0.817, P < 0.001)$
NP	WFPS	0.012	0.184	$\lg N_2O = 0.012\text{WFPS} + 0.334\lg NH_4^+\text{-N} + 0.488$
	$\lg NH_4^+\text{-N}$	0.334	0.287	$(N = 20, R = 0.684, P = 0.005)$
				2010–2011 maize-wheat season
NP	WFPS	0.018	0.225	$\lg N_2O = 0.018\text{WFPS} + 0.041\text{ST} + 0.011NO_3^-\text{-N}$
	ST^b	0.041	0.270	$+ 0.599\lg NH_4^+\text{-N} - 1.412$
	$NO_3^-\text{-N}$	0.011	0.067	$(N = 30, R = 0.610, P = 0.016)$
	$\lg NH_4^+\text{-N}$	0.599	0.118	
				2011–2012 mazie-wheat season
NP	$\lg NH_4^+\text{-N}$	0.767	0.196	$\lg N_2O = 0.767\lg NH_4^+\text{-N} + 0.871$
				$(N = 28, R = 0.485, P = 0.011)$

<0.01

<0.05

<0.05

[a] Unstandardized coefficient; [b] Soil temperature. ← What depth?

units of N_2O flux and the influencing factors?

What does it mean?

Cumulative
Nitrous oxide (N_2O)

direct emission factors (EFds)

of the investigated rotations

Table 3. N_2O fluxes (mean ± SE) and EFs from different treatments ~~in different years~~

Year Rotations	Period	Treatment	N_2O cumulative fluxes (kg N ha^{-1})	EFd (%)
2008–2009 ~~maize-wheat season~~ rotation	Maize	CK	0.6 ± 0.2	–
		NP	7.2 ± 1.2	3.8
	Wheat	CK	0.9 ± 0.001	–
		NP	2.2 ± 0.5	0.80
	Annual	CK	1.5 ± 0.2	–
		NP	9.4 ± 1.7	2.4
2009–2010 rotation ~~maize-wheat season~~	Maize	CK	0.9 ± 0.02	–
		NP	2.8 ± 0.02	1.1
	Wheat	CK	1.1 ± 0.01	–
		NP	1.3 ± 0.03	0.12
	Annual	CK	2.0 ± 0.01	–
		NP	4.0 ± 0.03	0.60
2010–2011 rotation ~~maize-wheat season~~	Maize	CK	0.4 ± 0.01	–
		NP	3.0 ± 0.1	1.5
	Wheat	CK	0.8 ± 0.03	–
		NP	2.0 ± 0.1	0.73
	Annual	CK	1.3 ± 0.02	–
		NP	5.0 ± 0.3	1.1
2011–2012 rotation ~~maize-wheat season~~	Maize	CK	0.5 ± 0.3	–
		NP	4.7 ± 0.3	2.4
	Wheat	CK	2.3 ± 0.3	–
		NP	7.8 ± 0.4	3.3
	Annual	CK	2.7 ± 0.6	–
		NP	12.5 ± 0.1	2.9

Table 4. Summary of N_2O emissions from maize-wheat soils in the NCP.

Location	Total N ($kg N ha^{-1} yr^{-1}$)	Accumulative fluxes ($kg N ha^{-1} yr^{-1}$)	EF (%)	References
Wangdu, Hebei	335	9.4	2.4	This study, 2008–2009
	333	4.0	0.60	This study, 2009–2010
	341	5.0	1.1	This study, 2010–2011
	341	12.5	2.9	This study, 2011–2012
Quzhou, Heibei	270	4.9	0.96	Li et al. (2010)
	135	5.0	1.0	Wang et al. (2008)
	270	6.0	0.87	
Luancheng, Hebei	200	0.89	0.12	Wang et al. (2009)
	400	1.1	0.10	
	600	1.4	0.13	
	300	1.6	0.23	Zeng et al. (1995)
Yucheng, Shandong	420	2.9	0.67	Dong et al. (2000)
	312	4.4	1.4*	Sun et al. (2008)
Huantai, Shangdong	600	4.0	0.59	Cui et al. (2012)
Fengqiu, Henan	300	0.77	0.21	Meng et al. (2005)
	300	2.5	0.61	Ding et al. (2007)
	500	4.5	0.77	
	300	2.4	0.63	Cai et al. (2013)
	300	3.0	0.95	
	300	2.9	0.88	

* Background N_2O emission wasn't subtracted.

year

year?

Skip off this EF value as it is not comparable at all with the others.

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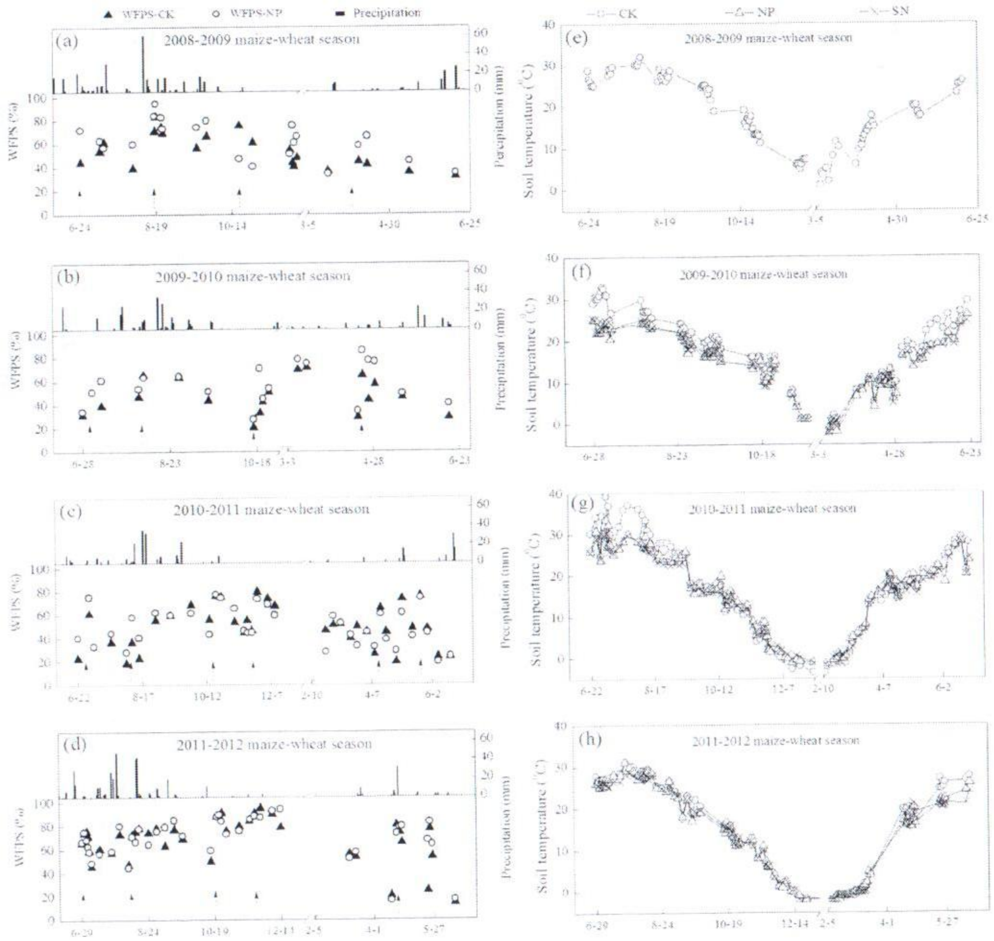
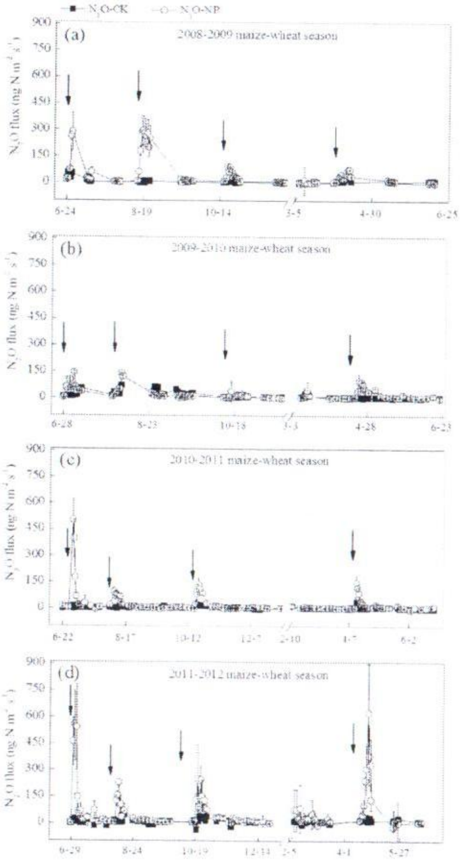


Fig. 1. Precipitation, soil WFPS **(a, b, c, d)** and soil temperatures **(e, f, g, h)** in the CK and NP plots during 2008–2012 maize-wheat seasons. Dash arrows show irrigation events.

rotation



as the

Fig. 2. N_2O emissions from the CK and NP plots during the N_2O measurement periods ~~of~~ 2008–2009 ~~maize-wheat season~~ **(a)**, 2009–2010 ~~maize-wheat season~~ **(b)**, 2010–2011 ~~maize-wheat season~~ **(c)** and 2011–2012 (d) maize-wheat ~~season~~ ~~**(d)**~~ rotations. Arrows show fertilizer applications.