Relationships of Nitrous Oxide Emissions to Fertilizer Nitrogen Recovery Efficiencies in Corn: Research Foundation Building
IPNI-2015-USA-4RN28

Tony J. Vyn and Rex A. Omonode

Preliminary Report: 2015 Cropping Season

Abstract

Little research has been conducted that evaluated relationships between nitrous oxide (N_2O) emission and fertilizer nitrogen (N) recovery efficiency (NRE) even though the common hypothesis is that an increase of NRE will result in N_2O emission reductions. In 2015, seasonal N_2O emissions were determined in two experiments involving multiple N management practices. In West Lafayette, IN, a Global Maize (sponsored by IPNI) trial site has compared corn yield and N uptake responses in an ecological intensification (EI) system relative to typical farmer's practice (FP) since 2012. The EI treatments involved increased plant population (96,000 plants ha^{-1}) managed at 3 higher N rates (0, 180, and 240 kg N, but with nitrapyrin (nitrification inhibitor) compared to FP treatments at a lower population (74,000 plants ha^{-1}) with 0, 112, and 180 kg N ha^{-1} (but without a nitrification inhibitor). In Wanatah, IN, a late-split N timing experiment involved UAN applications at 0, 155, 200, and 245 kg N ha^{-1}) at early sidedress (V3), and 2 additional 200 and 245 kg N rates applied in splits of 155 kg and 200 kg N at V3 and supplemental 45 kg N applied at V12-14 growth stage. Results indicated that EI management, even at 240 kg N application (with nitrapyrin), reduced N_2O emissions by up to 12% compared to the highest level of FP at 180 kg N rate. A relatively weak (r^2 = 0.42) but negative linear relationship existed between N_2O and NRE across treatments in the EI/FP trial, and this suggested that N_2O emission was likely to be reduced as NRE increased in corn production systems. Split application with intentional late-vegetative N application did not affect cumulative

N_2O emissions at agronomic optimum N rates, but tended to increase cumulative N_2O emissions at a greater than optimum N rate.

Introduction

Nitrogen management strategies are often implemented during crop production with the overall objectives to improve crop nitrogen (N) recovery efficiency (NRE) and/or yield, and to reduce nitrate-N loss to surface waters and N gas (e.g. N_2O) losses to the atmosphere. Nitrous oxide is (N_2O) a greenhouse gas with nearly 310 times the global warming potential of carbon dioxide. Understanding the relationship between N_2O and N use efficiency as affected by soil and N management will help to identify N management options that have the potential to simultaneously improve NRE and reduce N_2O emissions. However, while it is a common assumption that increasing NRE will lead to significant reduction of N_2O emissions, little research has been conducted to determine the nature and extent of the relationship between nitrogen (N) use efficiency (NRE) and nitrous oxide (N_2O) emission during corn production.

Objectives: The overall objective of this research project was to determine the relationship between nitrous oxide emissions and N recovery efficiency for different soil and N management systems. Our specific objectives were to assess the effects of (i) relative effects of ecological intensification and farmer's practice as related to population and N rates, and (ii) N rate and intentional late split N application - on seasonal N_2O emissions and their relationship to N uptake and recovery during corn production.

Materials and Methods

Research to meet the Objective #1 was initiated on a silty clay loam Mollisol at the Purdue University's Agricultural Center for Research and Education (ACRE) near West Lafayette, IN. Treatments consisted soil and N management by ecological intensification (EI) that consisted increased corn population (96, 000 plants ha-1) managed at 3 N levels (0, 180+Instinct, 250+Instinct (nitrapyrin) relative to usual farmer's practices (FP) that consisted of relatively low corn population and sidedress N inputs in the following treatment combinations:

FP-1: low input/control N (0 kg N; 74,000 plants ha^{-1})

FP-2: intermediate N (112 kg N; 74,000 plants ha-1)

FP-3: normal N (180 kg N; 74,000 plants ha^{-1})

EI-1: low input/control N (0 kg N; 96,000 plants ha^{-1})

EI-2: intermediate N (180 kg N+Instinct; 96,000 plants ha^{-1})

EI-3: high N (240 kg N: 180 kg N+Instinct (early sidedress) + 60 kg N late sidedress; 96,000 plants ha^{-1}).

Note: Instinct is a water-soluble nitrapyrin especially formulated to be applied with liquid fertilizers such as urea-ammonium nitrate (UAN) that was used in this experiment.

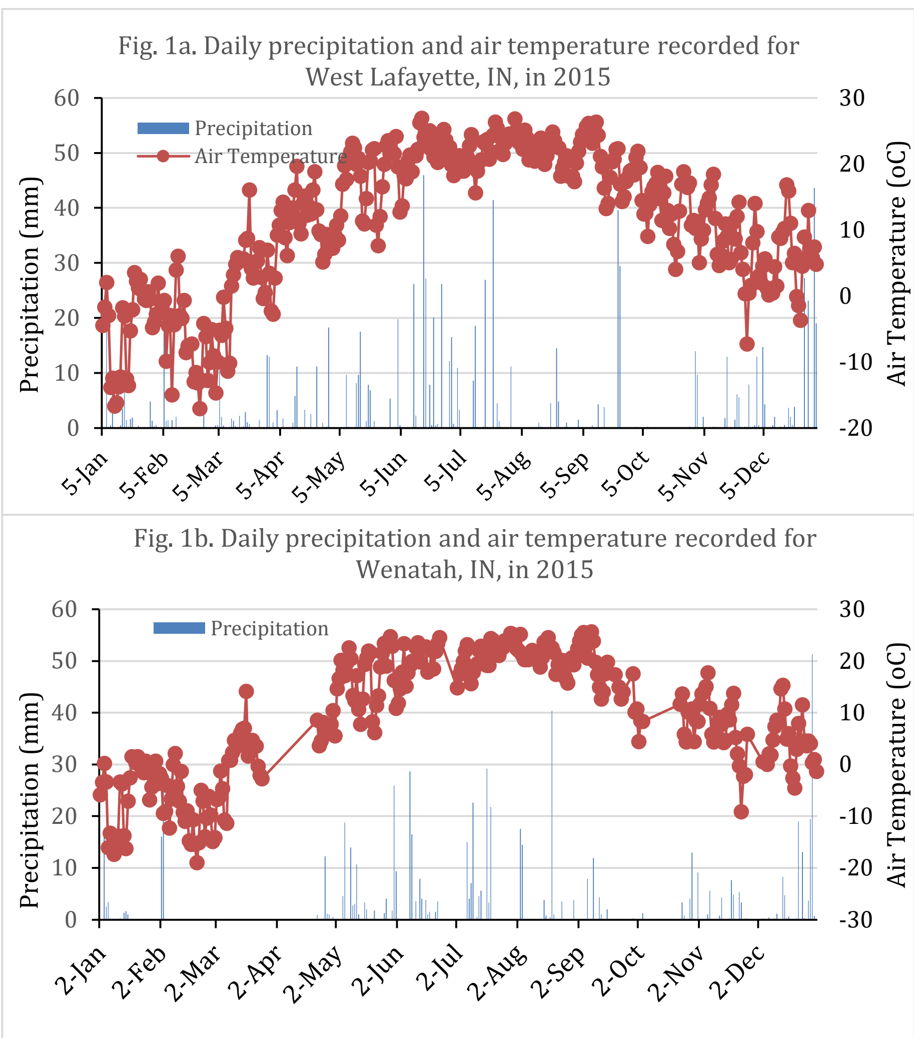
For this location, treatments were applied on 22 May 2015 as early sidedress except for EI-3 that was split between early sidedress (180 kg N), and late sidedress of 66 kg N applied on 11 June 2015. The experiment to meet Objective #2 was established on a sandy loam Alfisol at the Purdue Pinney Agricultural Center (PPAC) at Wanatah, IN. Treatments consisted of N application rates of 0, 155, 200, and 245 kg N ha^{-1} applied as early sidedress (V3) on 4 June 2015, and 2 additional 200 and 245 kg N rates applied in splits of 155 kg and 200 kg N at V3 and supplemental 45 kg N applied at V12-14 growth stage applied on 11 July, 2015, to give a total of 6 treatment combinations of follows: 0, 155, 200, 200(S) 245 and 245(S).

Following treatment application, intensive gas sampling was conducted twice weekly for 6-8 weeks and weekly thereafter till corn maturity, and daily and cumulative seasonal N_2O emissions were calculated. At corn maturity, corn was harvested (grain and above ground stover), grain and stover N concentrations and uptake determined, and NRE was calculated by the difference method as follows: NRE (%) = ($NU_{(N\ Rate)}$ - $NU_{(control)}$)/NR*100; where NU is above ground N uptake.

Results and Discussion

<u>Weather: 2015 Growing Season</u>

Daily precipitation and air temperature recorded for the West Lafayette and Wanatah locations in 2015 are shown in Fig 1. Frequency and intensity of precipitation in 2015 especially during the early part of the growing season were greater than the 30-yr average recorded for these locations.



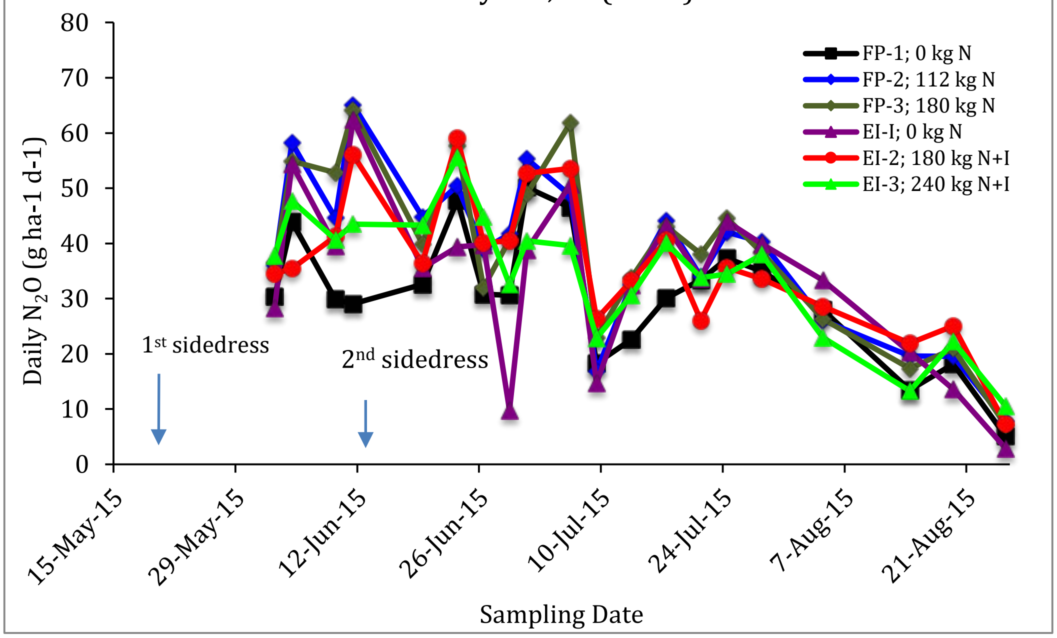
For West Lafayette, annual precipitation for 2015 was 992 mm compared to the 30-year average of 970 mm. However, precipitation for the months of June and July of 2015 were 198 and 116 mm respectively, compared to 104 and 107 mm for the 30-yr average June and July precipitation. At Wanatah (Fig. 1b), annual precipitation was similar to 30-yr average but precipitation for June and July were respectively, 154 and 113 mm compared to the 30-yr average June (108 mm) and July (109 mm) precipitation. For both locations, average annual temperature was similar to the 30-yr average of about 11^{o} C.

Experiment #1: Ecological Intensification vs. Farmer's Practice

N$_2$O Emissions:

The daily N$_2$O emissions across treatments for 2015 are shown in Fig. 2. Across treatments, N$_2$O emission peaked on several days that included 4 June (~14 d after application), 11 June, and 6 July, when emissions increased from initial levels of about 28 g N d^{-1} to over 60 g N ha^{-1} d^{-1}).

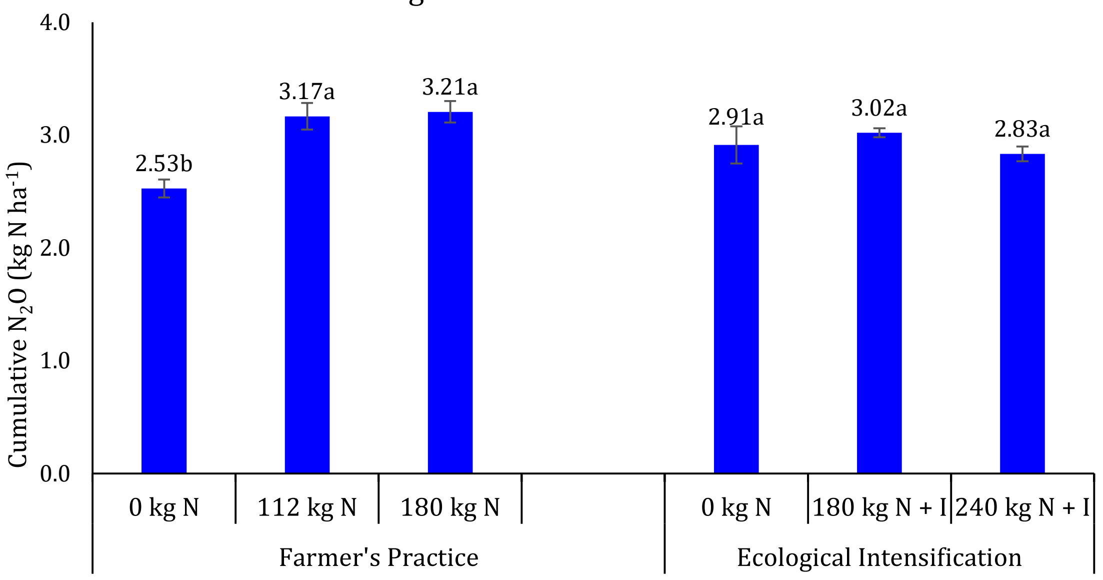
Fig. 2. Daily N$_2$O emissions under ecological intensification and farmer's practice management systems in West Lafayette, IN (2015)



Emissions also declined to baseline levels rather gradually in late July and August.

Cumulative seasonal N_2O emissions for FP and EI for the growing season are shown in Fig. 3. Under FP, cumulative N_2O was lowest for low input N (0 kg N) but was not different between intermediate (110 kg N ha^{-1}) and high (180 kg N ha^{-1}) N rates. In contrast, cumulative N_2O emission for EI increased in the order: high EI (split 240 kg + Instinct) < control (0 kg) < intermediate EI (180 kg N + Instinct) rates (Fig 1). Compared across EI and FP practices, cumulative N_2O emission due to N rate was significantly lower for EI-3 (240 kg N+I) compared to FP at medium (112 kg N) and normal N rates (180 kg N).

Fig. 3. Cumulative seasonal N_2O under farmer's practice and ecological intensification treatments in 2015 .



Overall, the fertilizer induced emission factor (EF; N_2O emitted per kg of applied N) was generally low and was less than 1% of applied N, regardless of management practice (Table 1). However, under EI, EF was particularly low and was negative for EI-3 which implied that greater N application under increased plant population reduced N_2O to as low as background levels in 2015. Similarly, EI-2 and EI-3 treatments reduced N_2O by about 9 and 12%, respectively, when compared to normal farmer's practice (FP-3) (Table 1). However, we note that these results may have been affected by relatively late gas sampling that commenced 11 days after the first sidedress N application, coupled with unusually high cumulative N_2O emissions from the control plots that received no N fertilizer presumably due to the high amounts of precipitation that occurred in June and July (Fig. 3).

Table 1. Farmer's Practice and Ecological Intensification Effects on Cumulative N_2O Emissions.

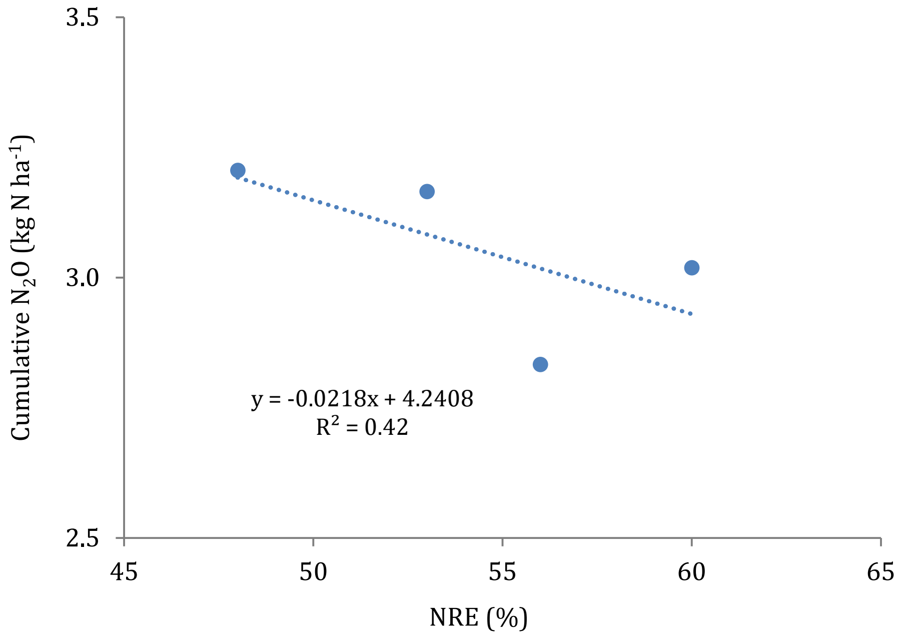
Practice	N rate ($kg\ ha^{-1}$)	Cumulative N_2O ($kg\ ha^{-1}$)	EF (%)	ERζ (%)
FP	0	2.53c	-	
	112	3.17a	0.57	
	180	3.21a	0.38	
EI	0	2.91ab	-	
	180+I	3.02ab	0.06	9.35
	240+I	2.81bc	-0.03	11.83

ζ = ER calculated relative to FP-3 (180 kg N); FP = farmer's practice; EI = ecological intensification; EF = emission factor; ER = emission reduction; I = nitrapyrin (Instinct).

Relationship between N_2O and N recovery efficiency:

Relationship between seasonal cumulative N_2O and NRE across management (FP and EI) using simple regression model is shown in Fig. 4. Although relatively weak, a negative linear relationship existed between cumulative N_2O and NRE ($r^2 = 0.42$), and this indicated that N_2O emission decreased as N recovery efficiency was increased. Overall, the linear regression model suggested that cumulative N_2O emission may be reduced by about 4% as NRE was increased by by 1%, especially under EI management.

Fig.4. Relationship between cumulative N_2O and NRE averaged across treatments in 2015.



Experiment #2: N Rate and Timing Effect

N_2O Emission:

Nitrous oxide loss from the sandy soils at Wanatah was generally lower compared to emissions from the finer-textured soils in West Lafayette, even for same N application rate. Across treatments, highest N_2O emissions were observed on 12 June (8 days after the sidedress UAN application) and on 18 June. Thereafter, emission declined rapidly to background levels (Fig. 5a). Overall, intentional late supplementary N application did not appear to result in any noticeable decrease of daily N_2O emissions relative to a single N application at the same total N rate.

Fig. 5a. Daily N_2O emissions due rate and timing of N application at Wanatah, IN, 2015.

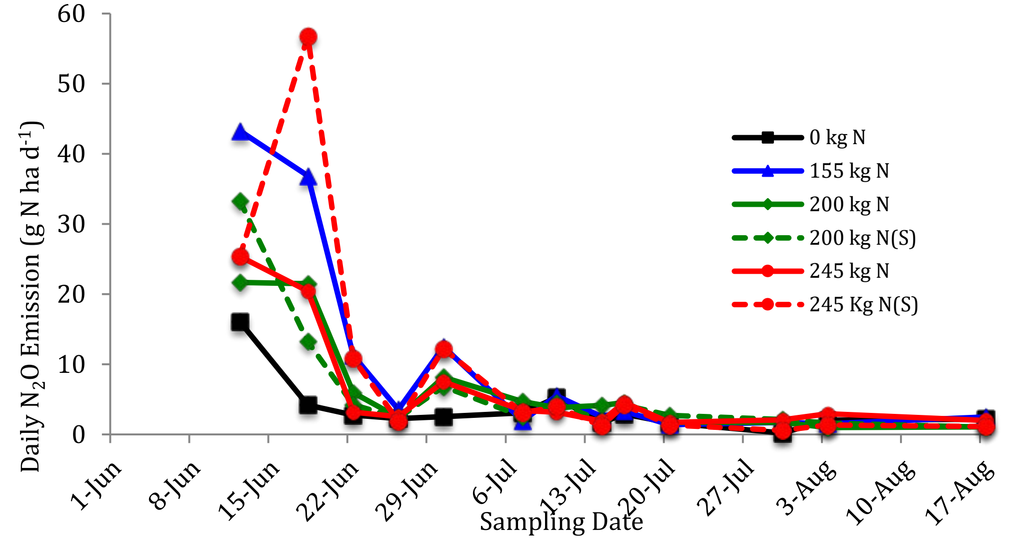
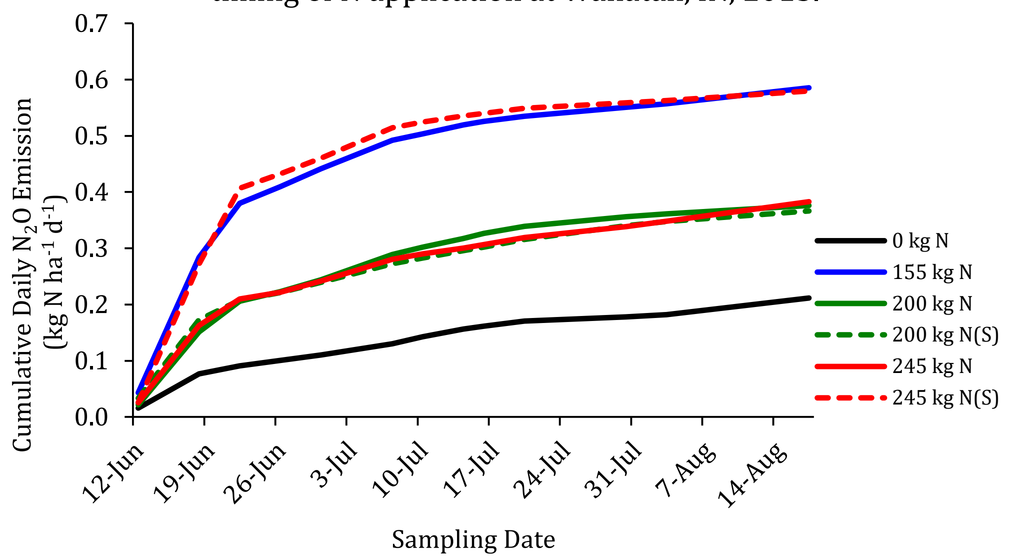


Fig. 5b. Cumulative daily N_2O emission due to rate and timing of N application at Wanatah, IN, 2015.



However, cumulative daily emission rose sharply in the 2-3 weeks following N application, regardless of rates. Rate of cumulative emission increase decreased significantly between 10-17 July, and thereafter leveled off starting around 24 July - a time frame that corresponded to the periods when emissions reached background levels (Fig. 5b).

Cumulative N_2O for treatments estimated across the growing season growing are presented in Table 2. Overall, the magnitude of emission was in the order: 155 kg = 245(S) > 245 = 200 = 200(S) > 0 kg N. The relatively greater cumulative N_2O for the 155 kg N rate was unexpected because N_2O emission is generally expected to increase with N rate; therefore, this needs to be further investigated. The results further indicated that split application did not significantly reduce cumulative seasonal N_2O emission but may result in greater N_2O emissions at higher N rates especially > 200.

Table 2. Nitrogen application rate and intentional late supplementary application effect on cumulative N_2O emissions in a sandy loam soil at Wanatah, IN in 2015.

N rate (kg ha^{-1})	Cumulative N_2O (kg ha^{-1})	EF (%)
0	0.21b	-
155	0.58a	0.23
200	0.38b	0.09
200(s)	0.36b	0.08
245	0.39ab	0.07
245(s)	0.57a	0.15

<u>Expected Data:</u>

Corn N uptake data for PPAC at the Wanatah location is still being processed and will be added to the final report in the next couple of weeks.

Tentative Conclusions

Available results so far indicated that soil and N management by ecological intensification that involved increased plant population and N applications at equal or higher rates with a nitrification inhibitor may help to reduce N_2O emissions compared to current farmer's practice. However, split application that involved a late vegetative stage application did not appear to lower N_2O emission near the agronomic-optimum recommended N rate, but may impact emissions at N rates above agronomic optimum. Nitrous oxide emissions appeared to have a significant but relatively weak negative linear relationship with NRE in the Global Maize trial; this trend suggests an increase in NRE in 2015 was accompanied by a N_2O emission reduction. However, the results presented here are for one growing season with precipitation well above the 30-yr average; the rainfall distribution may have uniquely impacted the N_2O emission data relative to years with a normal rainfall distribution. Both experiments will be continued in 2016.