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Supplementary Information for

High nitrous oxide fluxes from rice indicate the need to manage water for both long- and short-term climate impacts

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Text section 1: Farm, agro-ecological region, and seed variety description

(See also SI Figs. S1-S2, SI Tables S2 to S9)

Our study was carried out in three Food and Agriculture Organization (FAO) defined agro-ecological regions (AER) at five farms (farmer managed fields) with a range of flooding regimes (SI Fig. S1) in peninsular India (SI Fig. S2). All of the chosen farms did single-cropping where every year farms were left fallow before or after the rice-growing season. With the exception of an extra subplot (control with no N input) at Farm 4 in AER 8.3, all other farms were divided into two subplots that received one of two treatments, baseline practices (BP) or alternate practices (AP). GHG replicate measurements were made at three well-separated spots within each subplot.

We note that multiple aeration events similar to what we observed at our study farms are common in both irrigated and rainfed rice farms in India[1,2], Pakistan[2], Nepal[3], Bangladesh[4], China[5] and South America as a result of high evapo-transpiration rates, unreliable water/electricity supply, rainfall regimes, soil characteristics, and topography[6].

Detailed farm descriptions, seed varieties, weather conditions and treatments are presented in Tables S4-S9.

The rice cultivation alternative practices (AP) were decided via an iterative process involving local NGOs and agronomists. The goal of the iterative process was to find alternative rice farming practices that will *1)* maintain yields; *2)* eliminate or reduce the use of external fossil fuel-dependent inputs such as synthetic fertilizers and chemical pesticides (which in the long term leads to improved health and resilience of agricultural ecosystems and can improve N use efficiency and input costs); and *3)* decrease GHG emission intensity[7]. Yields were estimated from each treatment at maturity after separating grain from the straw and sun drying to a constant weight. Please refer to SI text for more details.

Farms 1 and 2 (AER 3.0): Agro-ecological region (AER) 3.0 is hot and arid, dominated by a short growing season length of ~90 days[7]. AER 3.0 includes portions of the districts of Bijapur, Bagalkot, Gadag, Koppal, Bellary, Davanagere and Chitradurga in the state of Karnataka, as well as the Anantapur district in the state of Andhra Pradesh[7]. Seed variety BPT 5204 (parentage GEB-24xT(N)1xMahsuri) used in this AER was developed by Anantapur Agricultural University Rice Research Unit in Bapatla. This variety is resistant to blast and has a yield potential of 5700 kg ha^{-1} (ANGRAU)[8]. The amount of inorganic N recommended for this seed variety is 190 kg N ha^{-1} (Efresh)[9]. The results of surveys of conventional farmers are presented in SI Tables S10-S13.

Farms 3 and 4 (AER 8.3): This AER is characterized by a hot semi-arid ecosystem with a growing period of 120-150 days and includes the Chittor district of Andhra Pradesh, and Vellore, Dharmapuri, Salem, Cuddalore, Chengalpattu, Periyar, Kanchipuram, Erode, Tiruchirapalli, Pudukkottai and Tuticorin in the state of Tamil Nadu[10]. Average annual rainfall range in this AER is 550-1000 mm[10]. At this farm, AP and BP plots were separated by a 9 m wide fallow area. Seed variety ADT 39, used in this AER, with parentage IR8/IR20 was developed at Tamil Nadu Rice Research Institute Aduthurai with a potential yield of 5800 kg ha^{-1} (RKNP)[11] and average yield of 5000 kg ha^{-1} (TNAU)[12]. It is a semi-dwarf variety suitable for irrigated low lands, resistant to blast and sheath rot)[11] with a blanket recommendation of 150 kg ha^{-1} of inorganic N which applies to all seed varieties grown in this state[13]. The results of surveys of conventional farmers are presented in SI Tables S14-S21.

Farm 5 (AER 8.1): This AER is characterized by a hot semi-arid ecosystem with mixed red and black soils and a growing period of 90-120 days[10]. The region receives an annual average rainfall of 800-1100 mm[10], while the Tirunelveli district receives an average annual rainfall of 879 mm (District Groundwater Brochure). The ASD 16 seed variety, used in AER 8.1, has a parentage of ADT 31/CO39, and was developed by the Rice Research Station of Ambasamudram. It has an average yield of 5600 kg ha^{-1} (TNAU)[12] with a recommendation of 150 kg ha^{-1} of inorganic N which applies to all seed varieties grown in this state[13]. The results of surveys of conventional farmers are presented in SI Tables S22-S23.

Text section 2: Estimation of C & N content of organic inputs (Tables S4-S9)

The range of percentage C in different organic inputs presented in Table 1 (and utilized in our regression analysis) is based on maximum and minimum values reported in published literature (see Tables S4-S9 for range of % C in specific inputs)[7,14-17].

Except Azolla, biofertilizer used on Farm 3 in 2012 (SI Table S6), the percentages of total N in organic inputs is a fixed value based either on measurements performed as a part of our initiatives in India or as reported in regional published literature (see Tables S24-S29 for % N in specific inputs)[18-21]. All of the N content in any organic input is not labile. In addition, the labile N in organic inputs added at a given point of time mineralizes slowly over a period of ~3 years[22]. Thus for every rice-growing season, cumulative available N (or mineralized N) contributed by organic matter was influenced by OM added over three years (the season of interest plus the two preceding rice-growing years). The % organic N mineralized during a fixed time interval depends on seasonal temperature, soil properties, microbial activity, etc[23,24]. In the absence of any regional measurements of mineralization rates of organic N, we used three different sets of mineralization percentages (% total organic N mineralized in the first (that is, year of) and second, and third years (after) the addition of organic matter) to calculate the maximum and minimum N content utilized in our regression analysis (Table 1, Main text). One set of N mineralization rates (13%, 7.0% and 5.5%, respectively, in the first, second, and third year after application) was based on the Uchida model developed for Japan[22,25]. Another set of mineralization percentages (45%, 20% and 10%) were based on studies made by several agricultural extension centers in the Unites States[23,26]. The third set of mineralization percentages (10%, 40% and 15%) were based on local expert advice which suggested that if farmers add organic inputs every third year in peninsular India for both non-rice and rice crops, they get maximum yields in the second year after application of organic inputs. Additionally, it was suggested that, in peninsular India, yields are significantly lower during the year of organic application and during the third year after the organic application. We are not in a position to evaluate which of these mineralization rates is best applicable to our farms and hence present the minimum and maximum possible mineralized N available due to addition of organic inputs at all farms in Table 1.

While some organic inputs (e.g., FYM) are known to immobilize mineral N[24], we did not have a systematic way to take this immobilization effect into consideration.

Text section 3: Water index (cumulative water levels) & impact of drainage

A field water tube (FWT) is a 40-cm-long perforated tube inserted 20 cm into the soil next to each sampling chamber. Field water tube water levels were linearly related to soil moisture ($R^2 > 0.9$) and the soil moisture levels when the fields were flooded at soil level were directly related to soil % clay or water holding capacity ($R^2 = 0.7$ or 0.8, respectively).

With the exception of farm 3 (SI text section 3), FWT level observations (on days when fields were irrigated) were made right before the beginning of irrigation for the day. At Farm 3, the field water tube water level was observed 1-2 hours after irrigation on the same day. Therefore, we corrected the observed water level data by subtracting the average reduction in water levels over ~24 hours at that Farm in the season of interest from the observed value. The average reduction in water levels was calculated by averaging the decrease in water levels between a day when irrigation was done and the following day when no irrigation was done.

Significant CH_4 and N_2O emissions are associated with drainage (i.e., water level less than -7.5cm and/or <0 cm after >5 days of flooding) both between and at the end of a growing season (SI Tables S30 and S31 and SI Figs. S3-S14). It is quite likely that our data has not captured coincidence of drainage and high N_2O flux for some days/seasons (especially at Farm 3) because the water levels presented in this study represent a snapshot taken once a day.

We note that if the soil is sandy, the irrigation frequency will need to be higher to maintain a given level of water index as compared to clayey soils. Therefore, water index implicitly captures some of the impact of soil texture on GHG emissions.

Text section 4: N_2O emission rate measurement & importance of high intensity sampling

The reliability of direct N_2O flux measurements depends on a sampling design that captures spatial and temporal variability[27] (See SI Figs. S3-S14 and Tables S2- S3 and S43). We infer that the reason that high N_2O fluxes were not detected in earlier studies is twofold. Since the early 1980s when the first set of rice GHG measurements were made[28], most studies were conducted within long-term research stations at well-irrigated and continuously flooded plots. It is well established that redox conditions of flooded paddies are conducive for methanogenesis but not for nitrification-denitrification. According to our analysis, continuously flooded rice fields will have a high water index (i.e., >150 cm) and very low N_2O emission rates. In contrast, our work was done on farmer managed fields in varying soil conditions with a range of conventional and alternate water and N management regimes that were/are actually followed by farmers in the respective agro-ecological zones (Figs. S2 and S3). More importantly, very few studies to date have employed a field sampling intensity sufficient to accurately describe N_2O emission rates given the high temporal variability in N_2O flux (which is usually much higher than what is required to capture seasonal CH_4 emissions) (Tables S1 and S43). About 40 recent studies done in India to measure rice GHG emissions and, except one, all of them have a sampling intensity of less than 22% (Average sampling intensity = 12% ± 6% Standard Deviation). The Indian study which had the highest sampling intensity (36%) also had the highest N_2O emission rate (1.4 tCO_2e_{100} ha^{-1} $season^{-1}$, SI Table S1).

Nitrous oxide emission rate measurement methodology: We note that our complete sampling and analysis methodology has been previously published[27]. Briefly, manual closed chamber based air sampling followed by detection by a gas chromatograph (Thermo Fisher Trace GC 600) was used to quantify N_2O and CH_4 emission rates. Field sampling for N_2O flux measurement was performed on 35-65% of the days, with a minimum of twice a week sampling and daily sampling for 3-5 continuous days after all "events" e.g. sowing, fertilizer application, irrigation, rainfall and weeding. Manual chambers (50cm*50cm*40cm) were deployed on anchors (also referred to as base-frames) with a water trough to receive the bottom of the chamber. After 50 to 70 days of rice growth, it was necessary to vertically stack two chambers to keep the plant from being bent (or getting distorted) during sampling. Since the ambient temperature in our study areas could get as high as 45^0C and chamber temperatures routinely increase by up to 10^0C over the course of half hour sampling period, all calculations were corrected for temperature changes and temperature increase did not create gradient of GHG concentration within chamber's headspace volume.

Trace GC 600 (Thermo-Fisher Scientific, USA) is a dual channel, packed column GC with ECD, FID and thermal conductivity detectors (TCD). Altogether, the three Porapak Q columns (1/8" stainless steel outer diameter, 2mm inner diameter, 80–100 mesh size, Restek catalogue number #PC16737) separated the sample components at 60°C isothermal oven temperature. One channel consisting of a 1m long pre-column and a 3m long main analytical column separated and detected N_2O on ECD with 10 mCi strength Ni^{63} as electron source while the other channel with a 3m column detected CH_4 on FID.

The GC was calibrated every day with four standards: 0.197, 0.393, 0.795 and 1.615 ppmv N_2O (Bhuruka Gases, Bengaluru; NIST certified at 2% RSD). Concentration (in ppm) at each time point, as measured by GC, was converted to a mass equivalent (in µg) using ideal gas equation and corrected for temperature, chamber volume and pressure. Daily flux rates were calculated as follows

$G_t = C * V * M * P / R * T_t$
$F =[\Delta Gt / \Delta t]*60*24/A$

Where:

t	Time (in min)
G_t	concentration of GHG at time *t* (µg L^{-1})
C	concentration of GHG (ppmv)
V	Chamber headspace corrected for plant volume (L)
M	molecular weight of GHG: 44 $g.mol^{-1}$ N_2O; 16 g $g.mol^{-1}$ CH_4
P	pressure corrected for elevation (atm)
R	universal gas constant (0.0820575 L atm . K . mol)
T_t	chamber temperature in K at time t (= temperature in °C + 273.15)
F	total daily GHG flux in µg . m^{-2}. d^{-1}
A	area sampled (base-frame footprint) (m^2)

The minimum detectable N_2O flux was determined to be 28 ppb h^{-1} (based upon a 30 minute chamber deployment period, four sampling points under linear regression, and RSD of 2% (Parkin et al. 2012). That translates to to ~15 µg N_2O m^{-2} h^{-1} for our chambers with an volume of ~100L, ambient temperatures in the range of 35-45^{0}C and base-frame footprint of 0.25m^2. Following the recommendations of GRACEnet protocol (Parkin and Venterea 2010), we reported the actual measured value even if it falls below the MDL. For values above MDL, the linearity of increase in concentration of GHG over time was monitored and slopes with (coefficient of determination) R^2 values less than 0.85 were not included in cumulative seasonal emission. Cumulative N_2O emission for the entire cropping season was computed by plotting the daily flux against the days of sampling, calculating the area covered under the plot by linear interpolation (i.e., by adding the areas of trapeziums formed by the daily flux rates; see below for further discussion). Cumulative emissions were calculated separately for each replicate plot before calculating the average emissions for BP and AP. Negative emissions were dealt in the same way as positive emissions. The details of the design of Perspex chambers and base-frames, sample storage, GC optimization and daily calibration, data analysis have been described elsewhere (Tiwari et al. 2015).

Linear interpolation: When sampling frequency is lower, linear interpolation can results in both substantial over and under-estimation of cumulative seasonal GHG emission (especially for N_2O which exhibits much higher temporal variation than CH_4). This occurs when the spikes in N_2O, which usually occur following fertilization and/or rainfall or drainage, are not captured by the field sampling or more commonly, when either the rise or decline of N_2O peak is not fully captured by the field data.

N_2O emissions generally exhibit peaking behavior and the peak flux decay is usually exponential which has led to concern over the use of linear interpolation / trapezium method (see Tiwari et al 2015 for references)[27]. Even when the sampling frequency is adequate in general (>40% of the crop growth days), it is possible that no (reliable) samples are available at a few critical times (e.g., right before or after a N_2O emission peak). To deal with such rare cases, we used the following strategy: when the decline of a N_2O emission peak with a height greater than 10 times the MDL (i.e. >200 µg h^{-1} m^{-2}) was not captured by field measurements, the spikes were decayed to MDL levels (or the available measured data) by adopting a best-fit exponential equation for each spike. When possible, number of days needed for an emission spike to "come down" to MDL levels were derived from other measured peaks for the same crop and replicate treatment. While this strategy is far from perfect and is subjective, we think it might be more reasonable than linear interpolation for N_2O peaks. Please see more details in Tiwari et al (2015). In general, we found that linear interpolation overestimated the flux by 50-100% as compared to 1) exponential decay of the peak value and 2) a "least possible emission approach" where a constant value, which was equal to the least measured flux rate immediately before or after the gap period was presumed for all days in the "gap period". The extent of over-estimation depended on the a) length of gap period and b) the height of the peak. The emissions estimated by the "least possible emission" approach was lower than the estimated emissions calculated with the "exponential curve method".

Text section 5: Factors influencing N_2O emissions

We don't have pre-treatment information for our plots before the seasons we studies them and cannot be entirely sure how much different locations at single farms varied before intervention.

Influence of inorganic N input on N_2O flux: Ultimately, N input is necessary for nitrous oxide production, be this from existing soil pools or from organic or inorganic fertilizer input.. However, unless the paddy soils have the right redox conditions and right range of water filled pore capacity, N_2O is either not produced or is consumed. Why? When farms are truly flooded and oxygen content of soils is low, ammonia doesn't nitrify and no substrate is available for denitrification. Also, the last step on denitrification which converts nitrous oxide to dinitrogen gas is highly oxygen sensitive. When fields are flooded and there is close to no oxygen in the soils, nitrous oxide converts to dinitrogen (if there is sufficient organic matter to support microbial activity). Lastly, if the farm remains flooded for an extended period of time after fertilization, N is converted to into organic forms which are much less amenable to denitrification even after intermittent flooding is introduced later in a rice cropping period (SI Figure S18).

Influence of organic matter addition on N_2O flux: Suppression of N_2O? When inorganic N is added without simultaneous addition of organic matter, a N_2O peak emerges within an average of 4 (range 0-12) days after the addition of inorganic fertilizer and N_2O flux remains high for an average of 10 (range 1-21) days after fertilization. However, in several cases where a large amount of organic inputs were added at the beginning of the season (e.g. Farm 2, Farm 3 [2013] and Farm 4), no N_2O was seen until very late in the season. Furthermore, when the added N is either exclusively from organic inputs or from both inorganic and high organic inputs, a peak emerges later and stays higher over a longer period of time as compared to when the added N is exclusively in the form of inorganic N. With the addition of inorganic N, N_2O flux remains high an average of 16 (range 9-28) days relative to after addition of organic N with N_2O flux remaining high for an average of 34 (range 11-92) days after fertilization (SI Table S30) (SI Figure S20).

Influence of soil texture (%clay to %sand ratio) on N_2O flux (SI Figure S22): The high correlation coefficient found for clay/sand ratio ($R = 0.63$) suggest that soil texture characteristics could play a role in the level of N_2O emissions. However, when added to the multivariate regression model, soil texture did not explain any additional variance and was dropped from the model. This could be a consequence of the water index, which explains most of the variance in emissions at the farms. For a larger sample size, with greater variability in soil characteristics (e.g., clay/sand), it would be expected that soil characteristics would appear as a parameter that explains variance in N_2O emissions. The maximum global clay/sand ratio is 94 (data not shown), while for the sampled dataset the ratio is 0.1-0.44. This wider range of higher clay content illustrates the need for future work that analyses the relationship between high clay/sand ratios and N_2O emissions.

Text section 6: Factors influencing CH_4 emissions

Methane is a microbial end product of labile organic matter decomposition under anaerobic soil conditions (at a redox potential or Eh close to -150 mV). The soil redox state is influenced by the water levels, soil texture and Eh-pH buffering capacity of the soils and the concentration of labile organic substrates that changes with rice variety (which controls the extent of root exudation, and dead and decaying roots and plant litter at different crop growth states) as well as the timing and type of added organic fertilizers and crop residues. From negligible values at the beginning of the season, CH_4 emissions generally show a continuous gradual rise during the vegetative phase correlating with increasing plant biomass, peaking near panicle differentiation, a period of rapid root development[28]. While there were high CH_4 emissions during multiple growth stages at different locations (SI Table S31), we did not clearly observe the phenomenon of continuous gradual rise in CH_4 except at Farm 2 for two BP replicates. This is likely because fluctuating water levels disturb soil redox conditions, a phenomena which is not conducive for continuously increasing CH_4 flux. Instead, we observed clear evidence during multiple seasons that drainage events triggered CH_4 fluxes (SI Table S31) which are different from end-of-season drainage-related GHG emissions that have been documented earlier[29]. We surmise that both mid-season and end-of-season drainage triggers a sudden release of CH_4 when the soil was drained enough to allow CH_4 to escape directly to the atmosphere.

Impact of organic matter application rates on CH_4: The highest CH_4 fluxes from continuously flooded rice farms are recorded in fields with high OM inputs[28,30]. We observed a positive correlation of rice-CH_4 with soil organic matter (SI Figure S28) but not between CH_4 and organic matter inputs (SI Figure S27).This lack of effect of OM inputs on farms with lesser flooding has been previously reported[31] and likely results from reduced flooding oxygenating soils and producing unfavorable redox conditions for methanogenesis, irrespective of OM application.

Range of hourly CH_4 emissions are high but seasonal fluxes are low: Our maximum hourly CH_4 fluxes are higher (18.5-125 mg CH_4 m^{-2} h^{-1} [SI Figures S9-S14] *vs* 20-58[28,31] mg m^{-2} h^{-1}) but the cumulative seasonal fluxes are lower (~1-336 [Table 1 and SI Table 31] *vs* 954-1550[28,31] kg ha^{-1}) than previously reported across the world. This is likely because 1) our high resolution sampling captured low CH_4 fluxes between high flux periods which when interpolated decrease the net seasonal flux (SI Figures S9-S14) and 2) intermittently flooded paddies have lower emissions than constantly flooded paddies[28,31].

Text section 7: Recommendations for lowering climate impacts of rice

Here we present generalized recommendations for integrating (simultaneously using) multiple "good" production practices on the basis on local soil/weather conditions that could reduce net climate impacts of rice. Based on our in-depth analysis of GHG emissions at each farm, we offered the following general recommendations to farmers in the study region. Without region-specific studies that confirm that these recommendations will hold in a new region, application of these recommendations to new regions outside of study area might not yield desired climate benefits.

- Keep water index for the whole season between -250 and 250 cm (mild intermittent flooding) such that flooding is shallow.
- Limit the number of times water stays above soil level for more than 3 days.

- Add as little inorganic N as really necessary to maintain crop yields. For regions that remain intermittently flooded, add inorganic N in split doses right before a flooding event.
- Don't let the fields drain too much and keep water levels above -5 to -7 cm during the growing season (except close to harvest)
- For farms like Farm2, Farm4 and Farm5 where water likely does not percolate down quickly (or water index is high), reduce organic matter use to reduce CH_4 emissions.
- For farms like Farm1 or Farm3 where water likely percolates down quickly (or water index is low), higher amount of organic carbon can be added to reduce N_2O emissions without increasing CH4 emissions.

Text section 8: Limitations of our geospatial extrapolation

Empirical models vs. biogeochemical model: Given difficulties and resource-intensiveness with field measurements, GHG mitigation programs across the world have always looked to modeling-based approaches for quantification to GHG emission reduction. There are two types of modeling approaches used:

1. Empirical models. Regression analysis is used to extrapolate existing research and data to develop regionally explicit emissions factors. The regression equations produce GHG response curves for different management impacts (or for just nitrogen input for Tier 1 models). They can be specific to conditions at the ecozone (or agro-ecological region). They can be developed without the use of a complex model (which is usually much more input data-hungry) and are relatively easy and transparent to use. They do not capture the effects of spatial and temporal variability on GHG dynamics at finer scales, and can be less flexible in handling variable management combinations.

2. Process-based biogeochemical models. These models use mechanistic equations based on substantial long-term research to represent growth, nutrient, water, soil, and GHG dynamics. The models can be used in two distinct ways:

a. At a regional (Tier 2) scale, covering area with similar soils and climate, to produce reasonable, regionally sensitive emissions factors that can be used to develop a protocol or program accounting methodology. This approach can be relatively simple, transparent, and low-cost. However, using models at this scale may not reflect the spatial/temporal variability of GHG dynamics at a particular local site in the region.

b. At a farm or project (Tier 3) scale which can be used for a quantification tool within a protocol or program accounting methodology. At this scale models can capture fine-scale variability and dynamics but require significantly more site-level data inputs and detailed verification.

DNDC and Daycent are the two current process based biogeochemical models that predict rice-CH_4. The current Daycent model only predicts methane; nitrous oxide emissions are not estimated. We have confirmed with DNDC development team (William Salas, Applied Geosciences, Personal communication) that they have published no other report that uses DNDC to predict global nitrous oxide emissions from rice farms other than the study we have already cited. Other DNDC based studies are limited to one field or one small geographic area.

The use of multiple regression based empirical models is not new in the field of agricultural greenhouse gas mitigation. Many GHG emission reduction protocols, including those being approved the state of California for agricultural C offset programs and many other International carbon registries like VCS or Gold Standard, use empirical models to predict agricultural GHG emission reductions. We note that IPCC still uses Tier 1 simple and universal equation to determine N_2O emissions from upland (non-rice) crops. Our results were used to develop a multiple regression derived Tier 2 empirical model with multiple parameters for extrapolation which we consider to be better than the IPCC Tier 1 emission factor for the Indian subcontinent.

Our robust measurements at individual farms show large differences between treatments (AP vs BP). We do note that we don't have information on GHG emission rates from our study plots before the study period and it is possibile that different locations at single farms significantly varied with respect to soil biogeochemistry (and thus GHG emission rates) before our study began and different treatments were applied to different subplots.

We understand that extrapolating our model based on five farms to other rice growing regions in a subcontinent should be done with significant caution. We are encouraged, however, to present our extrapolated results because one of the previous reports[32] to give an estimate of global or regional rice nitrous oxide emissions includes assumptions that are coarser than some of our assumptions (e.g., geospatial N or extent of flooding, see below) and is based on an even more limited empirical rice-N_2O dataset, at least for the Indian subcontinent (see SI Table S1 for a compilation of existing Indian rice GHG studies).

Extrapolating our regression outputs at a large scale for this GIS analysis entails making a series of assumptions and using standardized datasets. As such, there are several constraints to consider when interpreting these maps and resulting rice-N_2O risk assessments.

Inorganic fertilizer input dataset: The data documented in Mueller et al. (2012) depicts application rates standardized to the year 2000[33]. Although this is the most recent globally consistent and spatially referenced data, application rates will have increased (and perhaps significantly so) in the last 16 years. This aspect may therefore shift relative risks to be higher in regions where increases in N application rates during this period have been greater than average.

Seasonal changes in water levels: Another key aspect for consideration is the concept of seasonality. In many parts of the world, rice is farmed over two (and sometimes three) consecutive seasons in a single year. We were limited by our inability to differentiate between rice vs rice-rice cropping cycles. Additionally, fertilizer inputs from Mueller et al. (2012) describe total annual (and not seasonal) amounts. Thus, there may be regions in the Indian subcontinent where our estimates are less accurate due to the need to better standardize water indices for single- *vs* double-cropped paddies.

Water index and frequency of flood events: The range of hypothetical values for the water index and number of flooding events for each rice management system is based on an informed opinion. Ideally, a preferred approach such as remote sensing would be used to impute typical values. Field water tube measurements vary greatly across time and soil types. As an integral of this, the water index (cumulative water level) variable is sensitive to these fluctuations.

However, appropriately extracting a remotely sensed record of both water index and flood events is not feasible for several reasons. First, while critical soil characteristics such as water retention are known, the frequency of irrigation events in rice paddies is not documented in a standardized manner. Second, water table depth in fields cannot be reliably assessed through remote sensing at a high enough frequency. With 30m x 30m imagery, LANDSAT potentially has a high enough resolution to accomplish this, yet lacks the appropriate coverage and temporal frequency to capture daily changes in water levels. MODIS, while having had some measure of success in mapping flooded rice paddies[34-38], does not have a high enough spatial resolution to be calibrated and validated to our field data, which in all cases were sub-0.25 km^2 plots. Further challenges are presented by cloud contamination and regional differences in normalized reflectance indices such as LSWI (land-surface water index) that would indicate flooded paddies.

Extrapolation beyond the range of empirical data: The geospatial extrapolation is applied to regions where the range of values for all variables (inorganic N use rates, water indices, number of flooding events) spans a wider range than that which was obtained empirically from our field studies and in turn, the dataset that generated regression results. This extrapolation relies on the assumption that N_2O emissions scale linearly beyond this range. There is no evidence that would allow us to characterize this relationship as nonlinear or otherwise, however it is quite likely that there are important nuances not captured by our analysis.

Text section 9: Temporal estimation of cumulative radiative forcing

Assessing the combined climate implications of different GHGs is challenging because their effect is time dependent. In the case of rice cultivation systems, emissions from both CH_4 and N_2O — a short-lived and a long-lived climate pollutant, respectively — require that the climate implications are analyzed as a function of time, and not as snapshots at particular years after the emissions took place.

By looking at the cumulative radiative forcing over a continuous timeframe, it is possible to observe offsets in which reductions/increases of one climate pollutant have different climate impacts at different points in time. This temporal dimension of radiative forcing highlights the importance of an integral management that focuses on reduction of both short-lived and long-lived climate pollutants[39,40].

The commonly used method of comparing different climate pollutants through global warming potentials (GWP) compares a given GHG against CO_2, which requires an arbitrary selection of a time horizon. The most commonly used time horizon is 100 years, which undermines the climate impacts of short-lived pollutants such as CH_4 in the near term. Reporting the implications of specific mitigation options over both the short-term GWP (20 years) and long-term GWP (100 years) gives a more complete picture of climate impacts[41]. Nonetheless, the only way to completely depict the trend and offsets of more than one GHG emitted by the same system throughout its lifetime is to visualize the cumulative radiative forcing as a function of time.

As an additional challenge, GWP establishes a direct comparison to CO_2. This is useful in order to compare total emissions from different systems (e.g., agriculture *vs* energy).

However, within the rice cultivation system, there are no significant CO_2 emissions. Thus a framework that allows a more direct integration of the GHGs of interest (CH_4 and N_2O) simplifies the analysis of adequate management and emissions reduction scenarios.

Here we use the technology warming potentials (TWP) framework developed by Alvarez et al.[42]. This framework was originally used to analyze the climate implications of the natural gas system and different natural gas fuel-switching scenarios. We extend this analysis to rice cultivation systems by estimating the cumulative radiative forcing of different management practices.

The TWPs at each point in time represent the ratio of cumulative radiative forcing from two different management practices. The choice of the denominator could be seen as a base case of emissions or a benchmark used to compare against a switch in management practices. Thus, the TWP used to compare CH_4 and N_2O emissions from two management practices could be expressed as:

$$TWP = \frac{E_{1,CH_4} TRF_{CH_4}(t) + E_{1,N_2O} TRF_{N_2O}(t)}{E_{2,CH_4} TRF_{CH_4}(t) + E_{2,N_2O} TRF_{N_2O}(t)} \qquad \textbf{(Equation S1)}$$

where $E_{i,j}$ represents the emission rate (in kg ha^{-1}) of climate pollutant *j* from management practice *i*, and $TRF_j(t)$ represents the total radiative forcing values of each pollutant j. Estimation of emission rates and selection of management practices scenarios are discussed below.

Derivation of $TRF_j(t)$ values is provided in Alvarez et al.[42]; our main set of results assumes that both climate pollutants are emitted continuously and indefinitely at a constant rate, $E_{i,j}$. In this case, TRFs needed in equation S1 can be expressed as:

$$TRF(t) = \int_0^{t_{max}} \int_{t_E}^{t} REf(x, t_E) dx \, dt_E \qquad \textbf{(Equation S2)}$$

where RE represents the radiative efficiency of the gas. Direct radiative efficiency is $3.6 \times 10^{-4}\, Wm^{-2}ppb^{-1}$ for CH_4 and for $3.0 \times 10^{-3}\, Wm^{-2}ppb^{-1}$ N_2O[43]. Following the IPCC convention, we include the indirect effects for both climate pollutants. For CH_4, the direct RE is enhanced by 50% and 15% to account for indirect forcing due to ozone and stratospheric water, respectively; resulting in $6.0 \times 10^{-4}\, Wm^{-2}ppb^{-1}$. For N_2O[43], the indirect effects decrease RE to 93% of the direct effect resulting in $2.8 \times 10^{-3}\, Wm^{-2}ppb^{-1}$.

The inner integral in equation S2 sums radiative forcing from the year in which the gas was emitted (t_E) to year t. Similarly, the upper bound in the outer integral, t_{max} represents the maximum time of emissions. In our case we examine emissions for the first 200 years.

Finally $f(x, t_E)$ represents the exponential decay of both pollutants in the atmosphere:

$$f(t, t_E) = e^{-\frac{t - t_E}{\tau_M}} \qquad \textbf{(Equation S3)}$$

where τ_M is 12.4 years for CH_4 and 121 years for N_2O.

Assumptions about rice cultivation management practices (for Figure 3)

SI Table S39 summarizes the different hypothetical management practices that we considered for our temporal radiative forcing analysis. As shown in the multiple regression analysis, a given set of flooding conditions affects CH_4 and N_2O emissions inversely. The selected management practices represent a wide spectrum of flooding conditions that allow us to assess the implications of different levels of emissions of the two climate pollutants.

Because the flooding conditions (water index and number of periods of continuous flooding$_{>3\ \mathrm{days}}$) explain the majority of the variance for both pollutants, for this analysis we only focus on their changes, leaving the other inputs (e.g., SOC and inorganic N input) fixed.

To analyze the climate implications from different management practices, we plot the ratio of cumulative radiative forcing (Equation S1) as a function of time, leaving the CH_4 and N_2O emissions constant and looking at the time-dependent offsets. When looking at the results, values below one represent climate benefits (lower cumulative radiative forcing than the base-case); while values above one represent adverse climate implications relative to the base-case or denominator. In our analysis we select two management practices as denominators in Equation S1.

Explanation of Figure 3 in the main paper We established irrigated continuous flooding scenarios as the base case (red dotted line, Fig. 3A) where high water index and elevated number of flood events$_{>3\ \mathrm{days}}$ result in zero N_2O emissions and high CH_4 emissions. Thus, other water management practices represent choices that tend to reduce CH_4 emissions while triggering N_2O emissions. Intense-intermittent flooding scenarios cause an initial reduction of CH_4 emissions with an initial reduction of ~50% of the relative cumulative radiative forcing during the short term, however, this management practices increase N_2O emissions which offset the net climate benefits significantly eroding the initial climate benefits after ~150 years.

Switching from continuous to medium- or mild-intermittent flooding for water management also underscores the long-term effect of N_2O emissions. The exact extent of climate benefit over the base case of continuous flooding will depend on the exact nature of water management (water index and flood events).

Text section 10: Change in emission factors for Indian rice systems

Our high resolution data updates both rice CH_4 and N_2O emission factors for rice farms with intermittent flooding as well as upland/drought-prone rainfed farms. A recent research study by the Indian government[44] updates India's last submission to United Nations Framework Convention on Climate Change[45] with respect to agricultural emissions. According to this study[44], ~18 million ha of rice is grown under intermittent flooding and ~14 million ha under drought-prone rainfed or upland rice systems emitting 0.03-66 kg CH_4 ha^{-1} but no N_2O (see Table 2 in Bhatia et al, 2013). Our high resolution measurements show that CH_4 emissions from baseline intermittently flooded farms are significantly higher at ~120 CH_4 kg ha^{-1}. In addition, baseline intermittently flooded farms and those with water index >-1000 cm show rice-N_2O to be an average of >9 and >14 kg N_2O ha^{-1}, respectively. Even without any changes in CH_4 emissions from upland or drought-prone rainfed paddies, these corrections add ~125 million tCO_{2e100} to the total Indian rice GHG budget (see below), at the least a 100% increase over the 120 million tCO_2e_{100} $year^{-1}$ estimate presented by the government[45] (at CH_4 GWP_{100} = 34).

Our new estimate for intermittently flooded paddies:

- N_2O emission from intermittently flooded paddies = 18 million ha $year^{-1}$*9 kg N_2O ha^{-1}*0.298 tCO_2e_{100} kg^{-1}) = 48 million tCO_2e_{100} $year^{-1}$.
- CH_4 emission from intermittently flooded paddies = 18 million ha $year^{-}$*120 kg ha^{-1}*0.034 tCO_2e_{100} kg^{-1}) = 73 million tCO_2e_{100} $year^{-1}$.
- Total GHG emission from intermittently flooded paddies = 74 + 48 = 122 million tCO_2e_{100} $year^{-1}$
- The original estimate for intermittent flooding by the government[45] is 775 Gg CH_4 which equals 26 million tCO_2e_{100} $year^{-1}$ which makes the increase due to intermittently flooded paddies = 122-26 = 96 million tCO_2e_{100} $year^{-1}$.

Increase due to drought-prone rainfed and upland paddies: We did not measure climate impacts of rice cultivation at upland or drought-prone rainfed paddies. However, our findings show clear impact of reduced flooding (which increases drying and wetting cycles) on rice-N_2O (Equation 1 in the main text). While not flooded as much as our experimental farms, upland and drought-prone rice systems do experience several drying and wetting cycles. When we use half the rate of N_2O fluxes seen at our least flooded farms as a conservative estimate of N_2O fluxes from upland or drought-prone farms, we add 29 million tCO_2e_{100} $year^{-1}$ to climate impact of Indian rice cultivation.

14 million ha $year^{-1}$*14 kg N_2O ha^{-1}*0.5*0.298 tCO_2e_{100} kg^{-1}= 29 million tCO_2e_{100} $year^{-1}$.

Hence, the total increase as compared to previous estimates will be 125 (= 96 + 29) MMT tCO_2e_{100} $year^{-1}$.

Text section 11: Importance of measuring soil carbon

We note that the net climate impact of rice is the combined effect of CH_4, N_2O and soil C loss (or gain) (e.g., GWP_{100} = 31*CH_4+ 298*N_2O + 3.66*[soil C loss]), and soil organic content affects soil health and long-term rice productivity. Because soil C sequestration potential for flooded rice farms can be significant[46-48] and low N use, reduced flooding and/or low organic matter use can decrease that potential, we recommend long-term measurements of soil C at rice farms concurrent with CH_4 and N_2O flux measurements.

All SI Figures

All figure legends are below the figure. In case of some multi-part figures, a general description of the figure is presented above the figure.

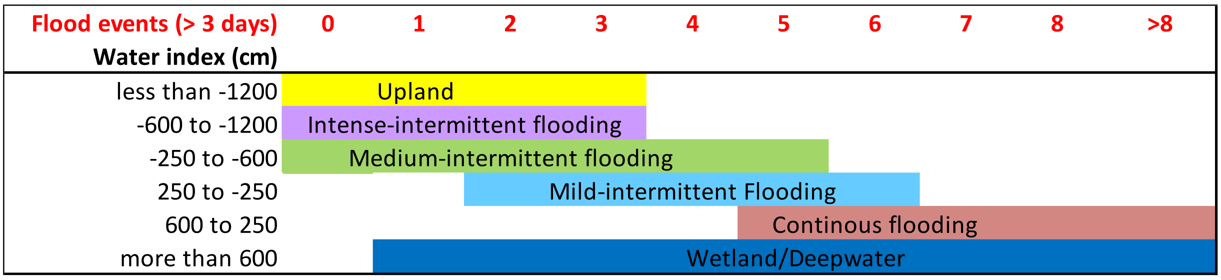


***Figure S1: Definition of flooding regimes in this study**. The primary determinant of a flooding regime, according to this classification, is water index. It is a measure of cumulative extent of flooding and is the sum of daily water levels in a vertical field water tube. Flood events$_{>3\ days}$, another water-use variable, is the number of times a plot had flooding (>0 cm water level) for more than 3 days and described the number of multiple aeration events for a given water index. As water index decreases, the cumulative flooding at a given farm will decrease. The actual extent of water used to maintain a given water index at any location will be a function of soil texture and local evapo-transpiration rates. As the water index decreases, number of practically allowable long flood events (that are over 3 days long) decrease. This is because as number of long flood events increase, the burden of reducing water index to negative values falls on lesser and lesser number of non-flooded days. We define reduced flooding as either medium-intermittent flooding or intense-intermittent flooding. Alternate wetting and drying usually advocated to reduce CH_4 emissions includes allowing water to drop down to 15 cm below soil level and roughly corresponds to our medium-intermittent flooding regimes.*

For a given range of water index, when there are more continuous flood events that are >3 days in duration, shorter duration flooding (<3 days) is less frequent. This reduces the number of multiple aeration events which can reduce N_2O fluxes while increasing chances of higher CH_4 emissions. The number of flooding events in wetland/deepwater systems could be just one but our equations 1 and 2 might not apply well to such systems. A key difference between upland and intense-intermittent flooding regimes is the degree of saturation of the root zone of the rice plant. With an average maximum root depth of 15 cm, intense-intermittent flooding keeps the rice plant's root zone much more flooded than upland systems. Mid-season drainage (-20 cm for 7-8 days) implies a net water index of 100-450 cm.

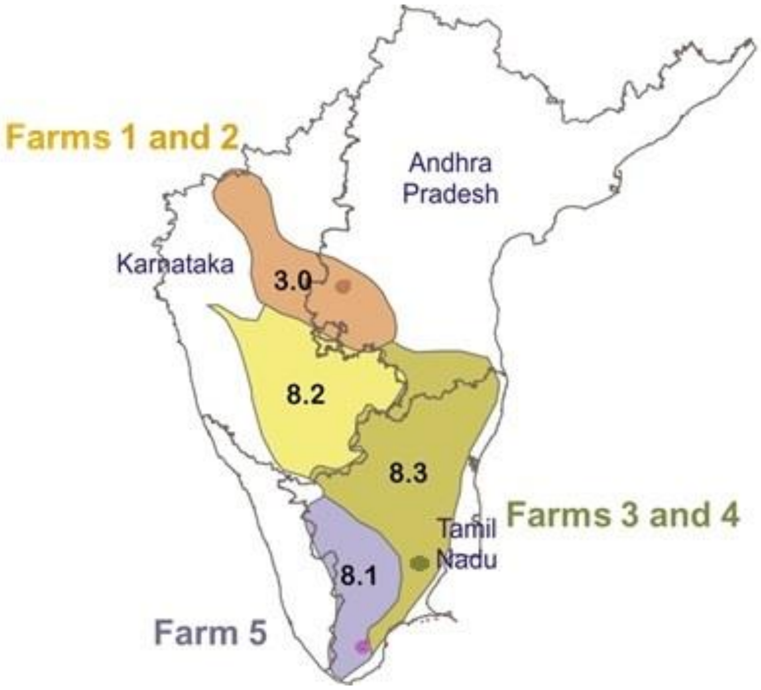


Fig. S2: Approximate locations of experimental farms (see dots) and the Indian agro-ecological regions (AER) included in this study. *Farms 1 and 2 as well as Farms 3 and 4 are very close to each other. The exact GPS location of each farm is presented in SI Table S2.*

See next fourteen pages for Figs S3-S8 and S9-14

Figs. S3-S8: Temporal variation in N_2O at all farms. *The X-axis on these graphs indicates the day after transplantation. The primary Y-axis presents GHG emissions in units of mg m^{-2} h^{-1} (in black closed circles). The secondary Y-axis presents water levels (in blue) in the field water tube installed next to the sampling chamber used to measure the GHG emission rate for each treatment (BP and AP stand for baseline and alternative practices), and for the replicate chamber (R1, R2 and R3 denote three different replicates). When there was no water level data available for a given day, white gaps can be seen in the water level dataset. The sampling frequency for water level measurements in presented in Table S2.* **(Red lines show N input)**

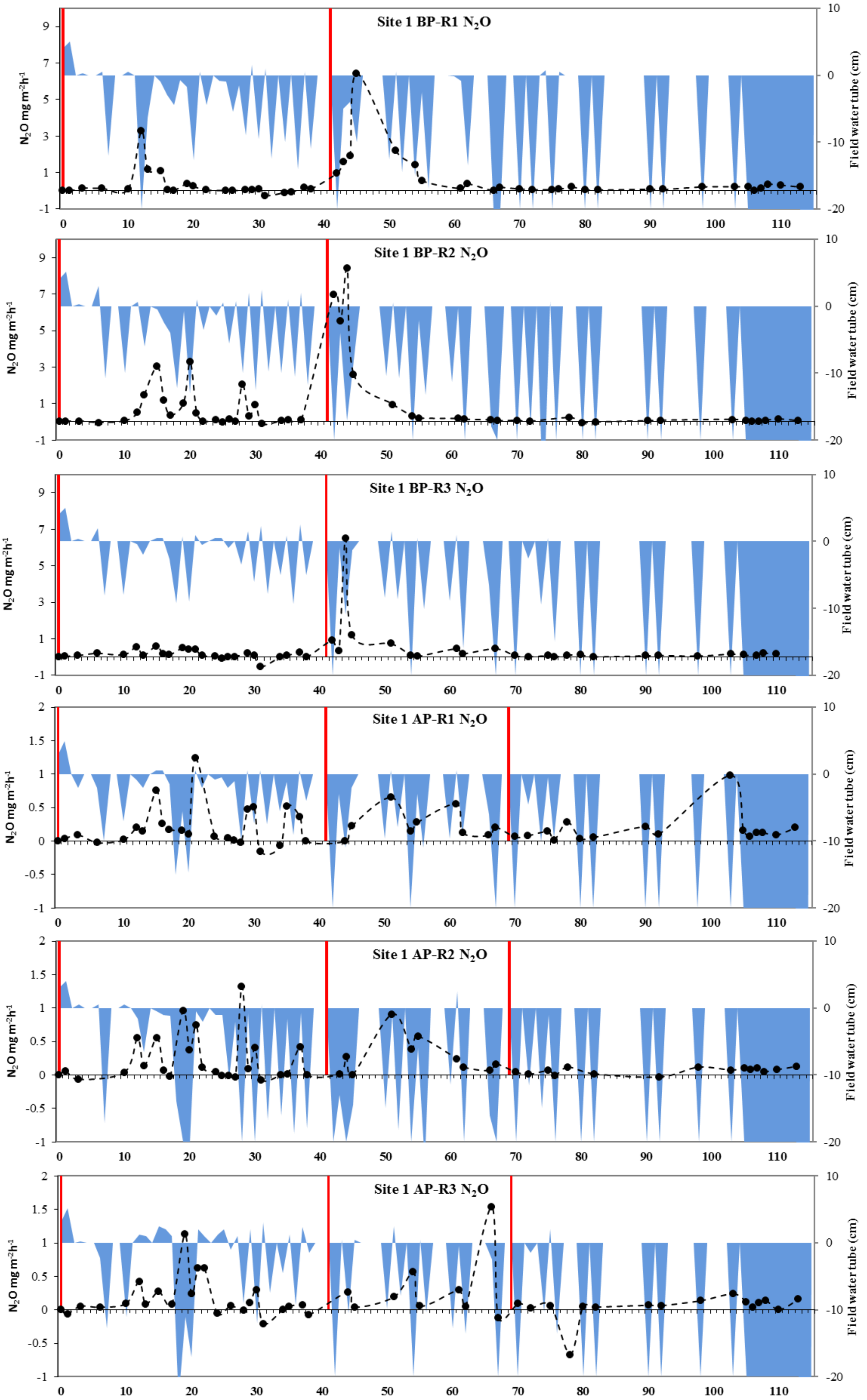

Site 1 BP-R1 N$_2$O
Site 1 BP-R2 N$_2$O
Site 1 BP-R3 N$_2$O
Site 1 AP-R1 N$_2$O
Site 1 AP-R2 N$_2$O
Site 1 AP-R3 N$_2$O
N$_2$O mg m^{-2}h^{-1}
Field water tube (cm)
-1
1
3
5
7
9
-1
-0.5
0
0.5
1
1.5
2
-20
-10
0
10
0
10
20
30
40
50
60
70
80
90
100
110

Fig. S3 - Farm 1

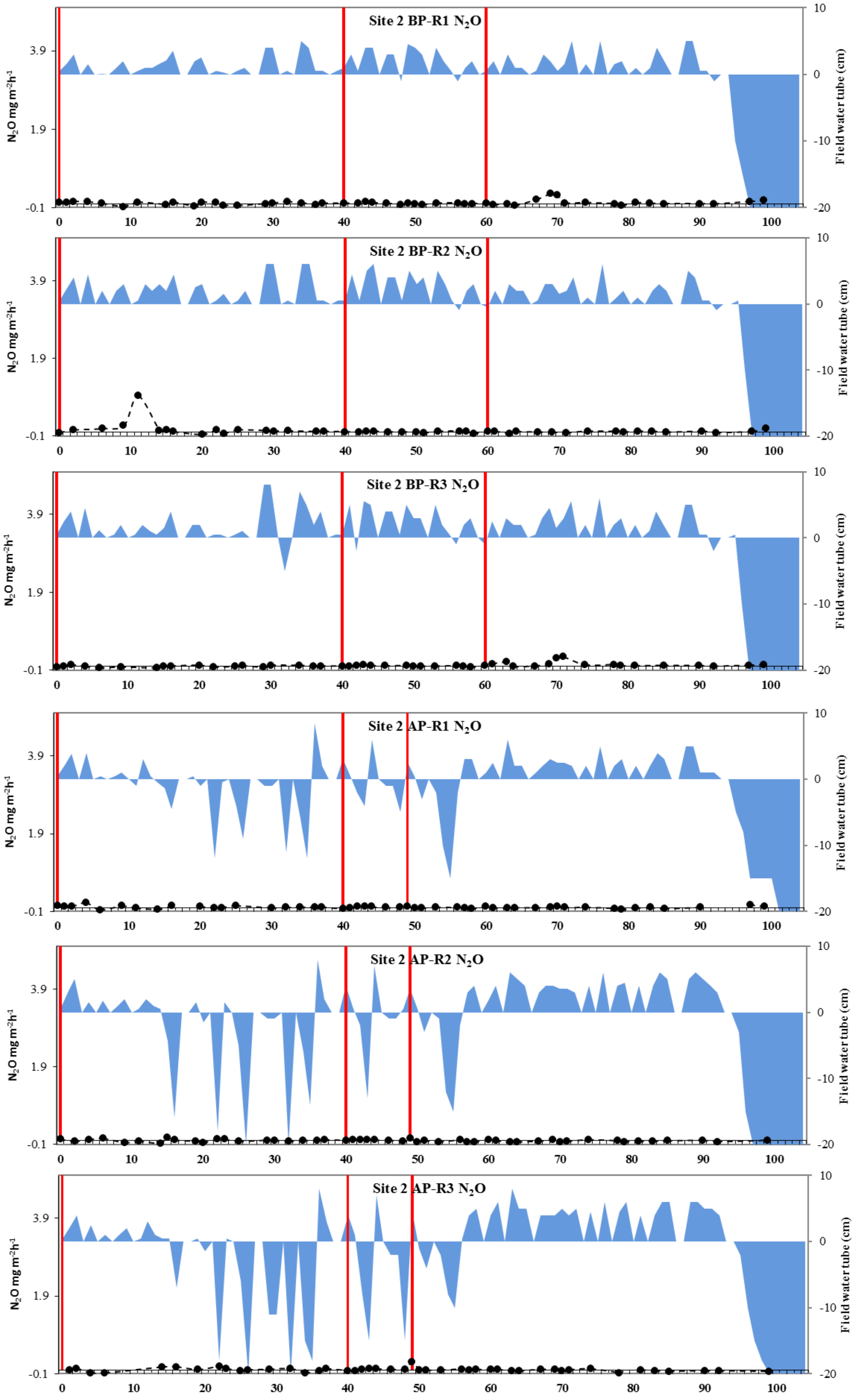

Site 2 BP-R1 N_2O
Site 2 BP-R2 N_2O
Site 2 BP-R3 N_2O
Site 2 AP-R1 N_2O
Site 2 AP-R2 N_2O
Site 2 AP-R3 N_2O
N_2O mg m^{-2}h^{-1}
Field water tube (cm)
3.9
1.9
-0.1
10
0
-10
-20
0
10
20
30
40
50
60
70
80
90
100

Fig. S4 - Farm 2

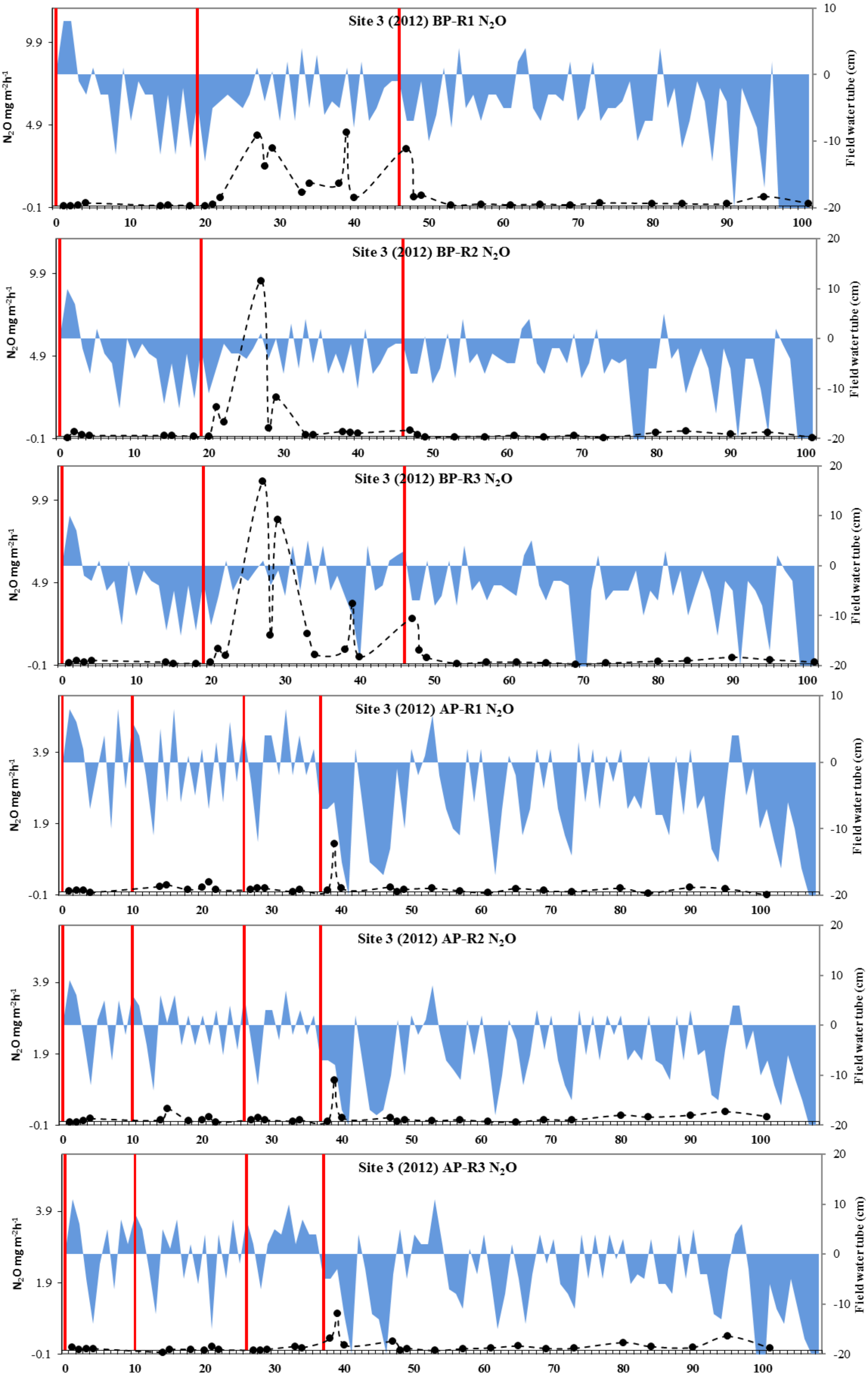


Fig. S5 - Farm 3 (2012)

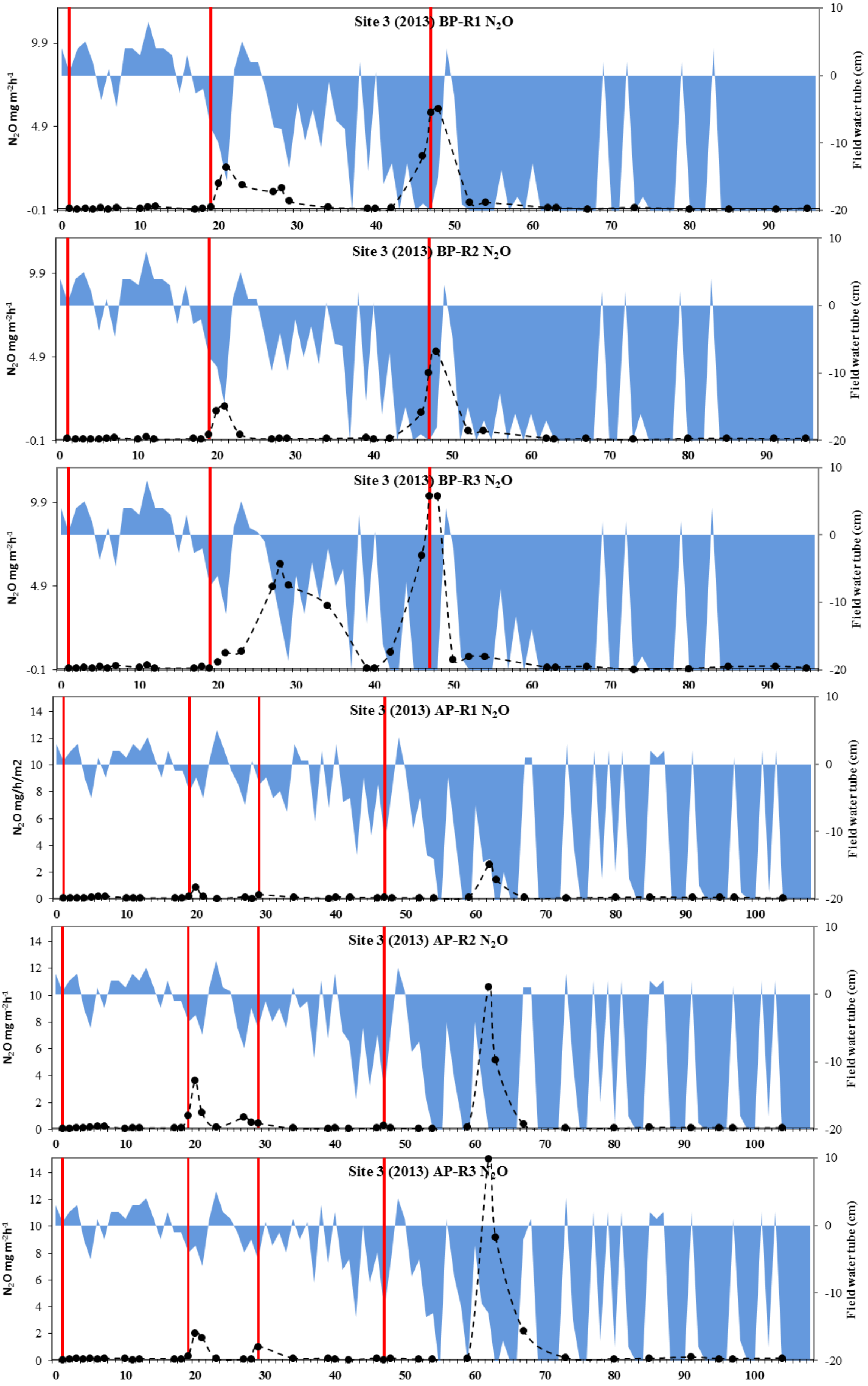


Fig. S6 - Farm 3 (2013)

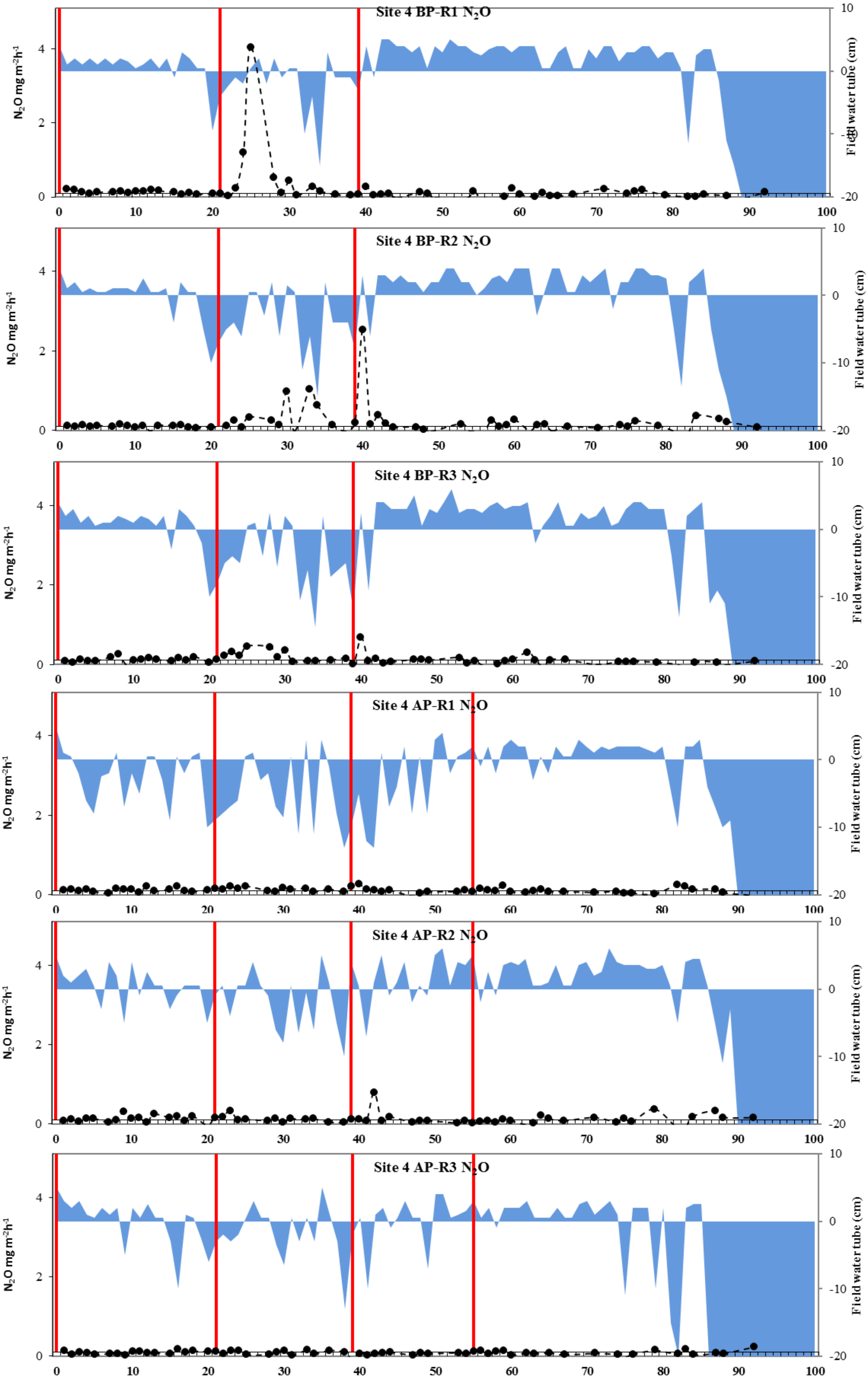

Site 4 BP-R1 N$_2$O
Site 4 BP-R2 N$_2$O
Site 4 BP-R3 N$_2$O
Site 4 AP-R1 N$_2$O
Site 4 AP-R2 N$_2$O
Site 4 AP-R3 N$_2$O
N$_2$O mg m^{-2}h^{-1}
Field water tube (cm)
0
2
4
10
0
-10
-20
0
10
20
30
40
50
60
70
80
90
100

Fig. S7 – Farm 4

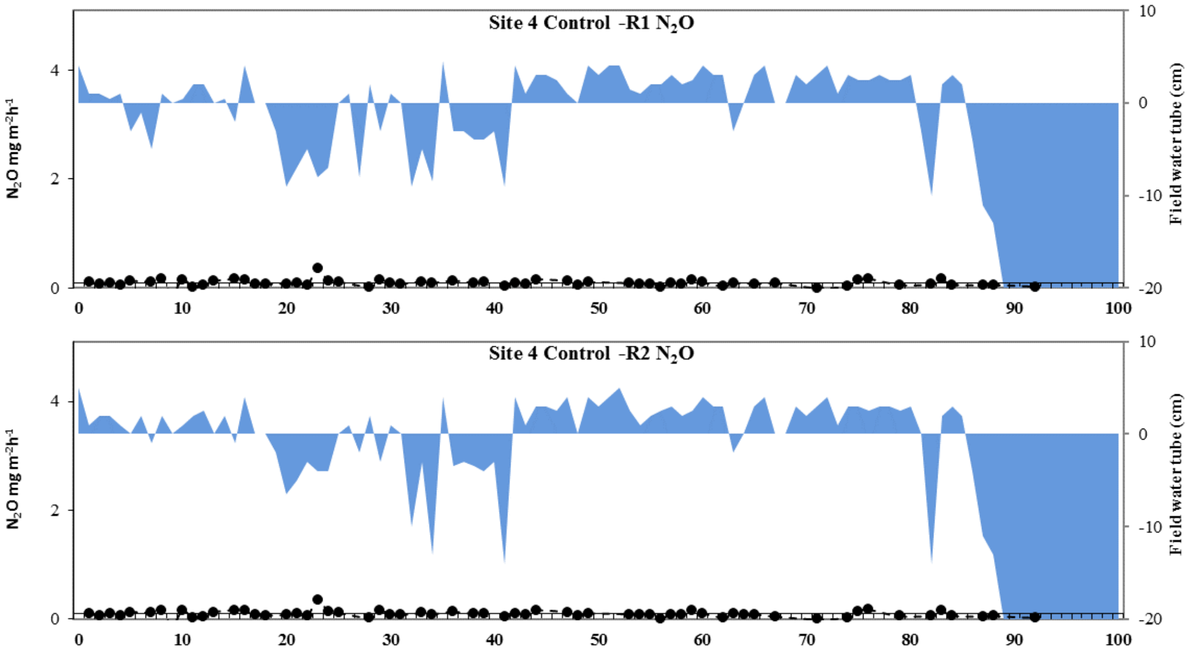


Fig. S7 – Farm 4 (Controls)

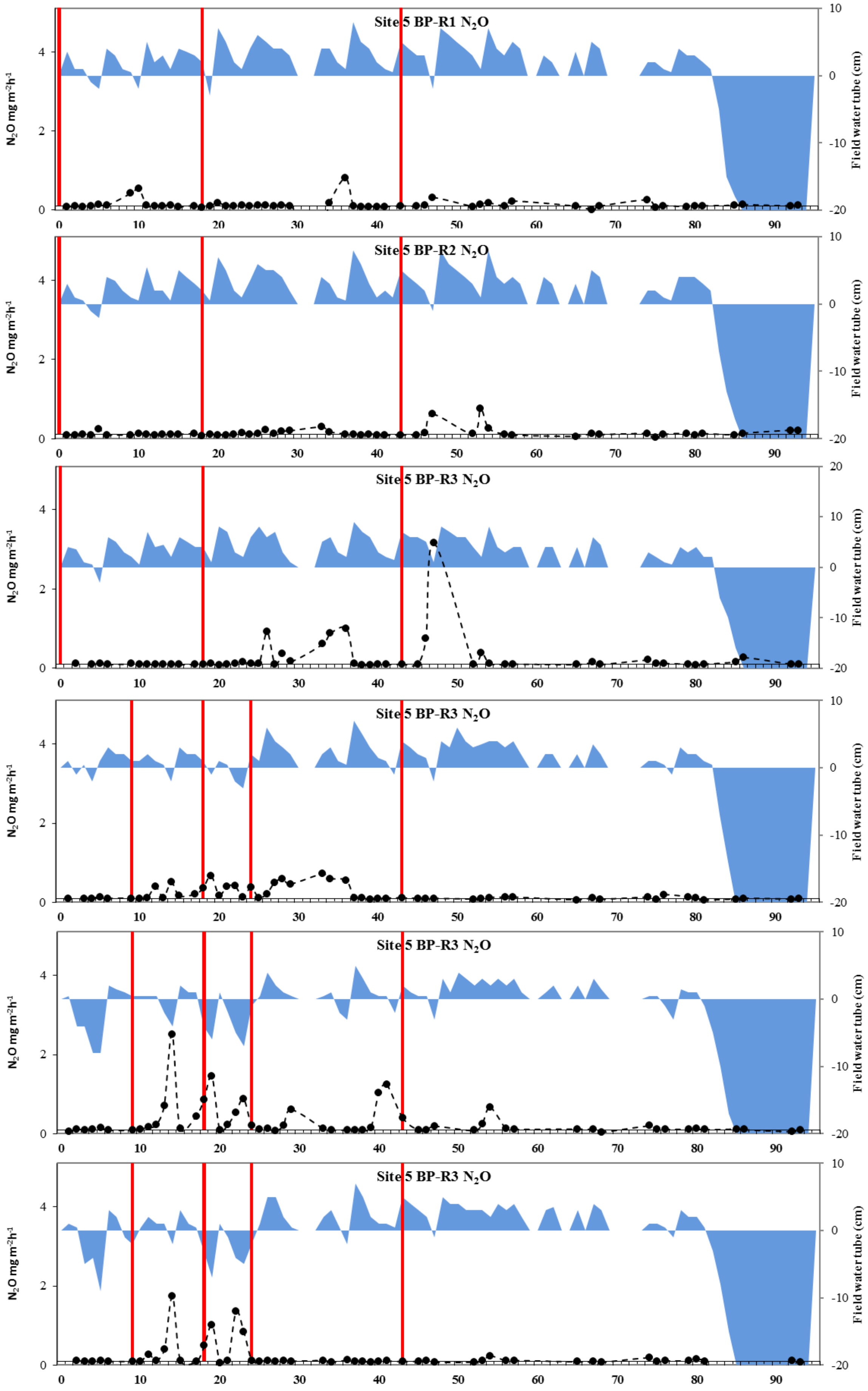

Site 5 BP-R1 N$_2$O
Site 5 BP-R2 N$_2$O
Site 5 BP-R3 N$_2$O
Site 5 BP-R3 N$_2$O
Site 5 BP-R3 N$_2$O
Site 5 BP-R3 N$_2$O
N$_2$O mg m^{-2}h^{-1}
Field water tube (cm)
0
2
4
10
0
-10
-20
20
0
10
20
30
40
50
60
70
80
90

Fig. S8 – Farm 5

***Figs. S9-S14: Temporal variation in CH_4 at all farms**. The X-axis on these graphs indicate day after transplantation. The primary Y-axis presents GHG emissions in units of mg m^{-2} h^{-1} (in black closed circles). The secondary Y-axis presents water levels (in blue) in the field water tube installed next to the sampling chamber used for measuring GHG emission rate for each treatment (BP and AP stand for baseline and alternative practices), and the replicate chamber (R1, R2 and R3 denote three different replicates). When there was no water level data available for a given day, white gaps can be seen in the water level dataset. The sampling frequency for water level measurements in presented in Table S2.*

See next seven pages.

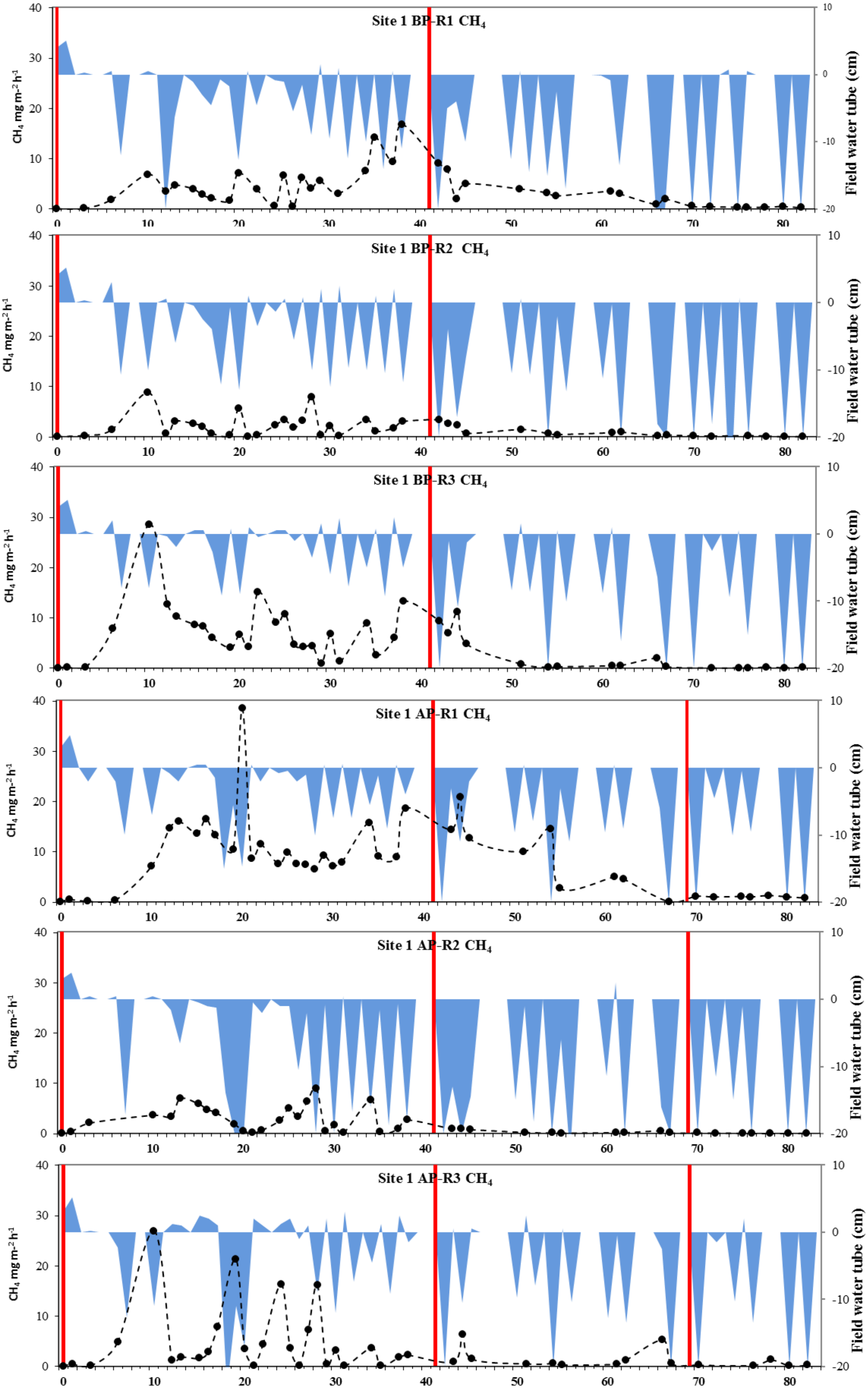

Site 1 BP-R1 CH$_4$
Site 1 BP-R2 CH$_4$
Site 1 BP-R3 CH$_4$
Site 1 AP-R1 CH$_4$
Site 1 AP-R2 CH$_4$
Site 1 AP-R3 CH$_4$
CH$_4$ mg m^{-2} h^{-1}
Field water tube (cm)
0
10
20
30
40
-20
-10
0
10
0
10
20
30
40
50
60
70
80

Fig. S9 - Farm 1

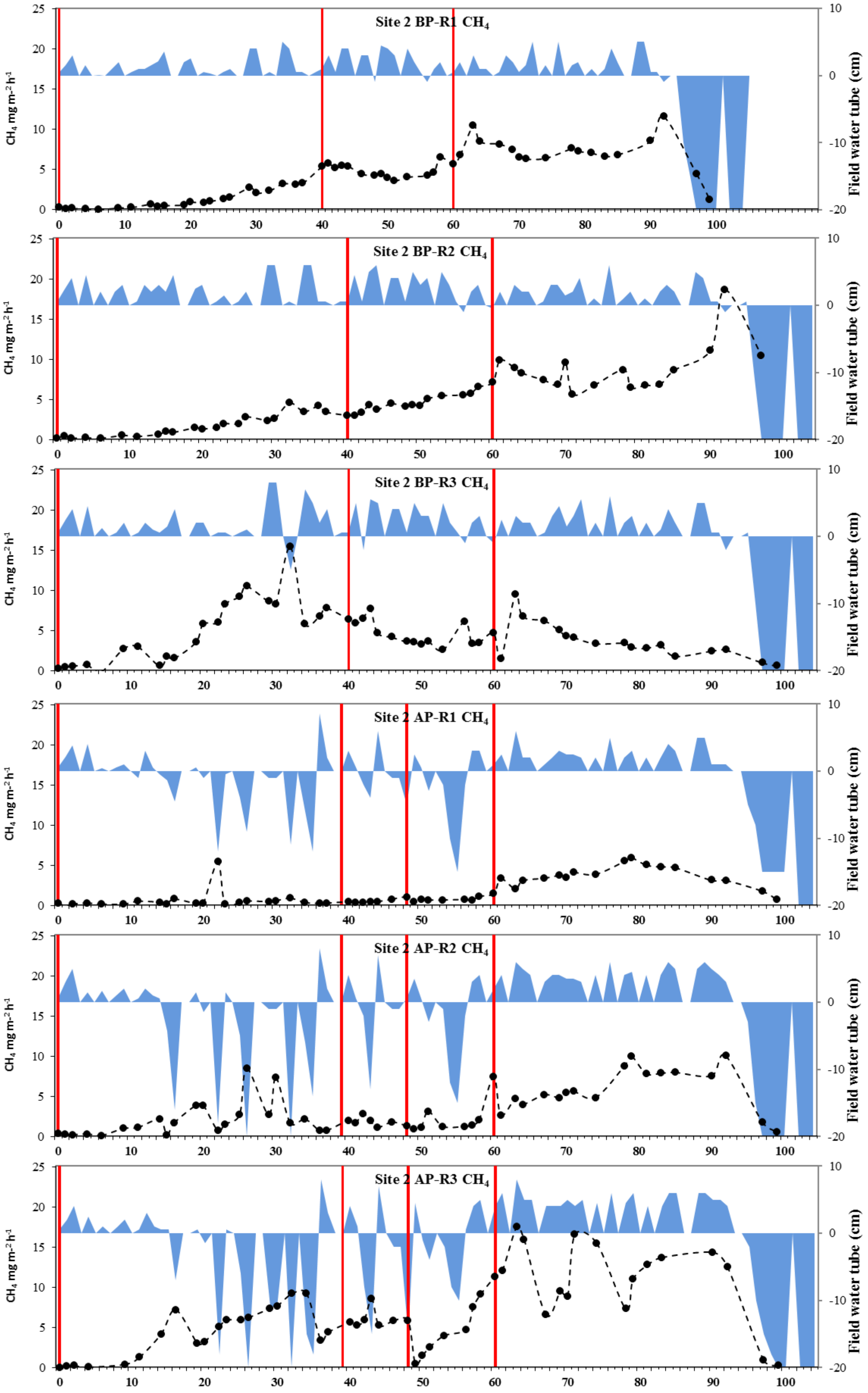
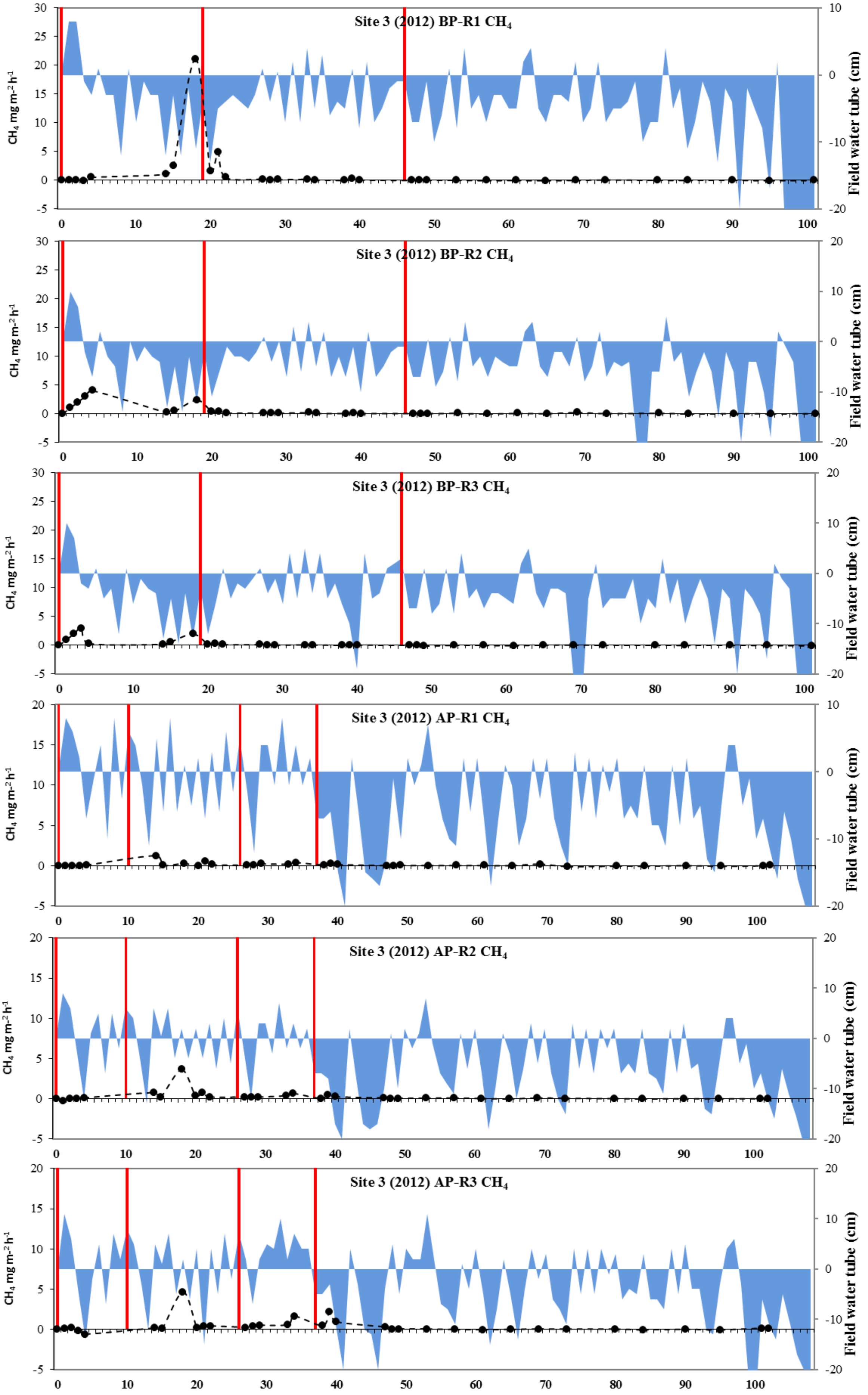


Fig S10 - Farm 2



SI Fig. S11 - Farm 3 (2012)

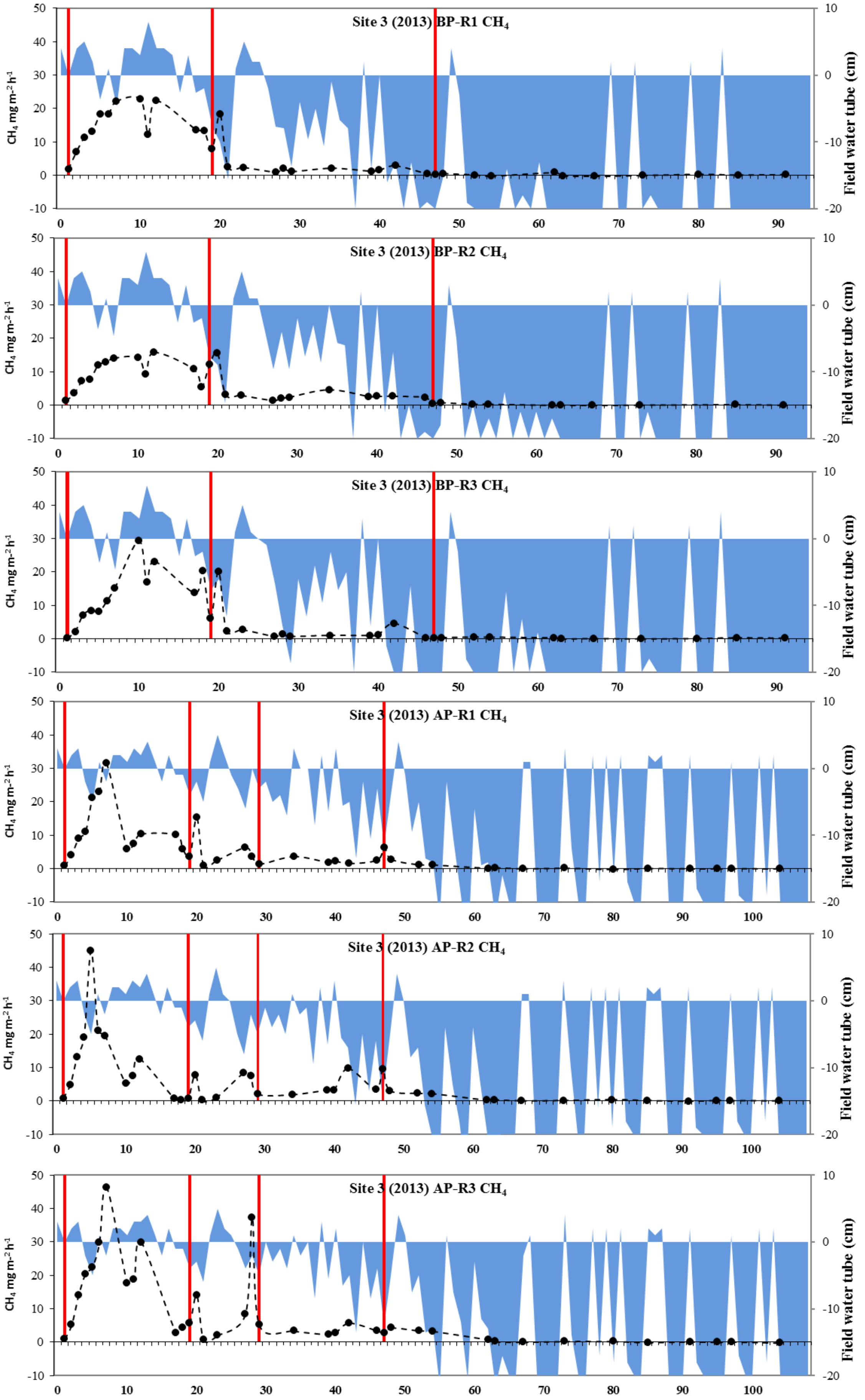
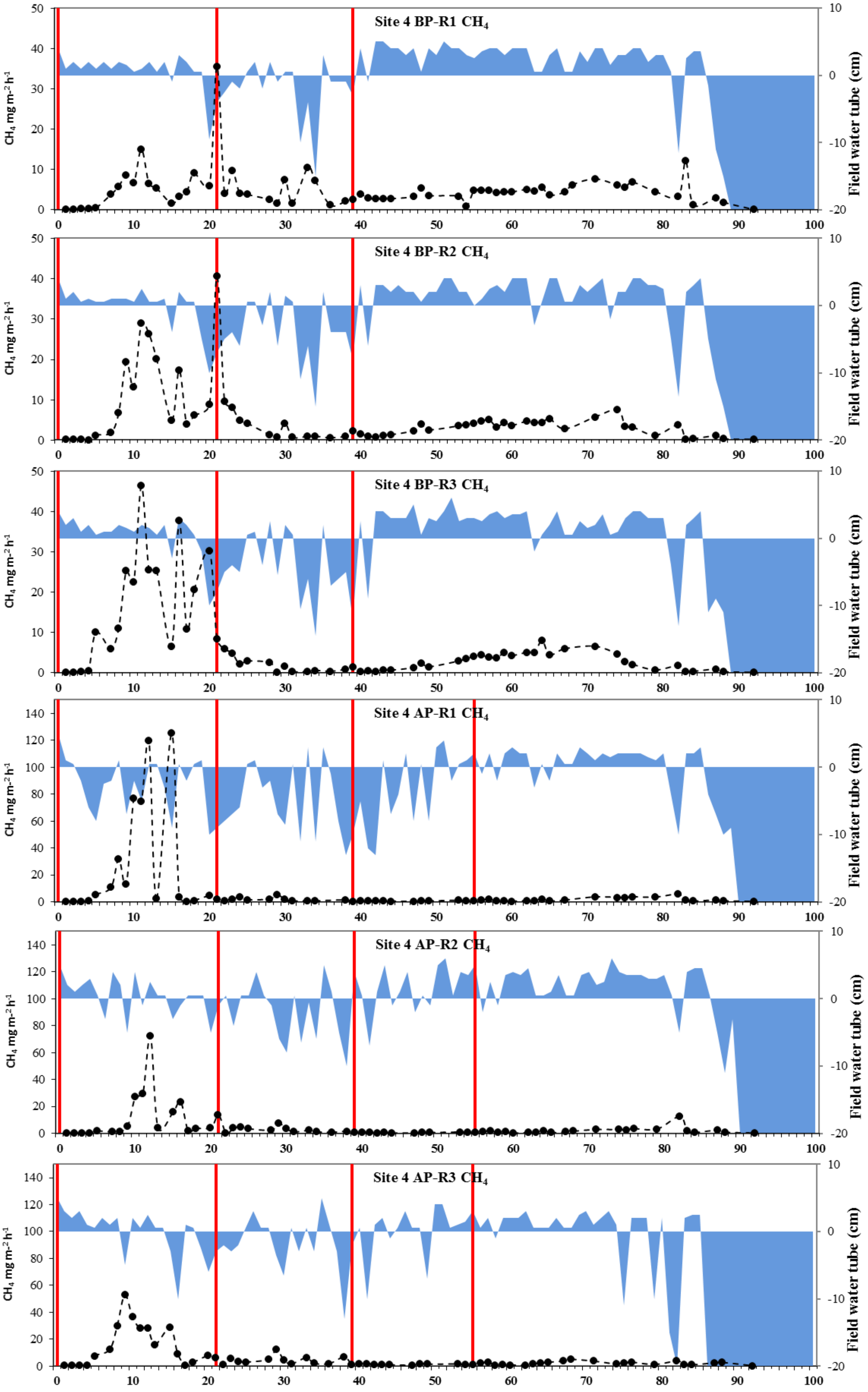
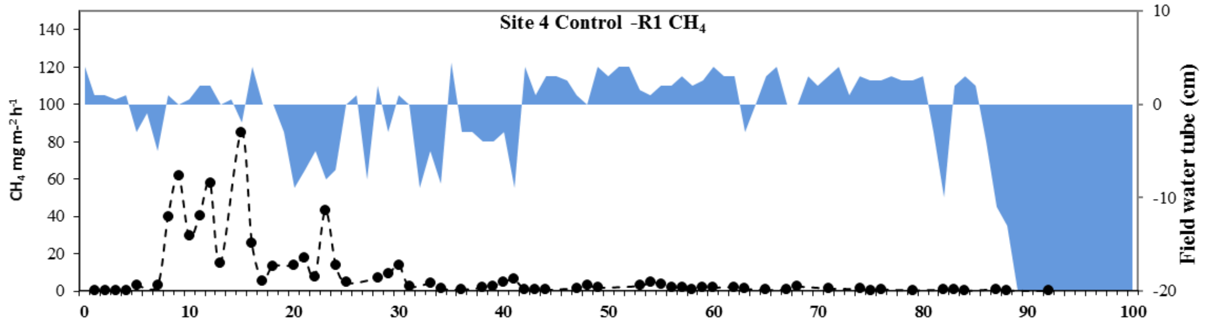


Fig S12 - Farm 3 (2013)



SI Fig. S13 - Farm 4



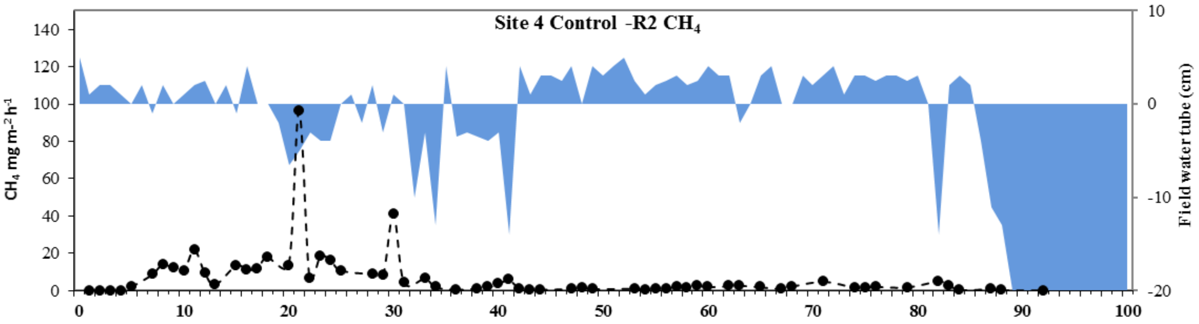
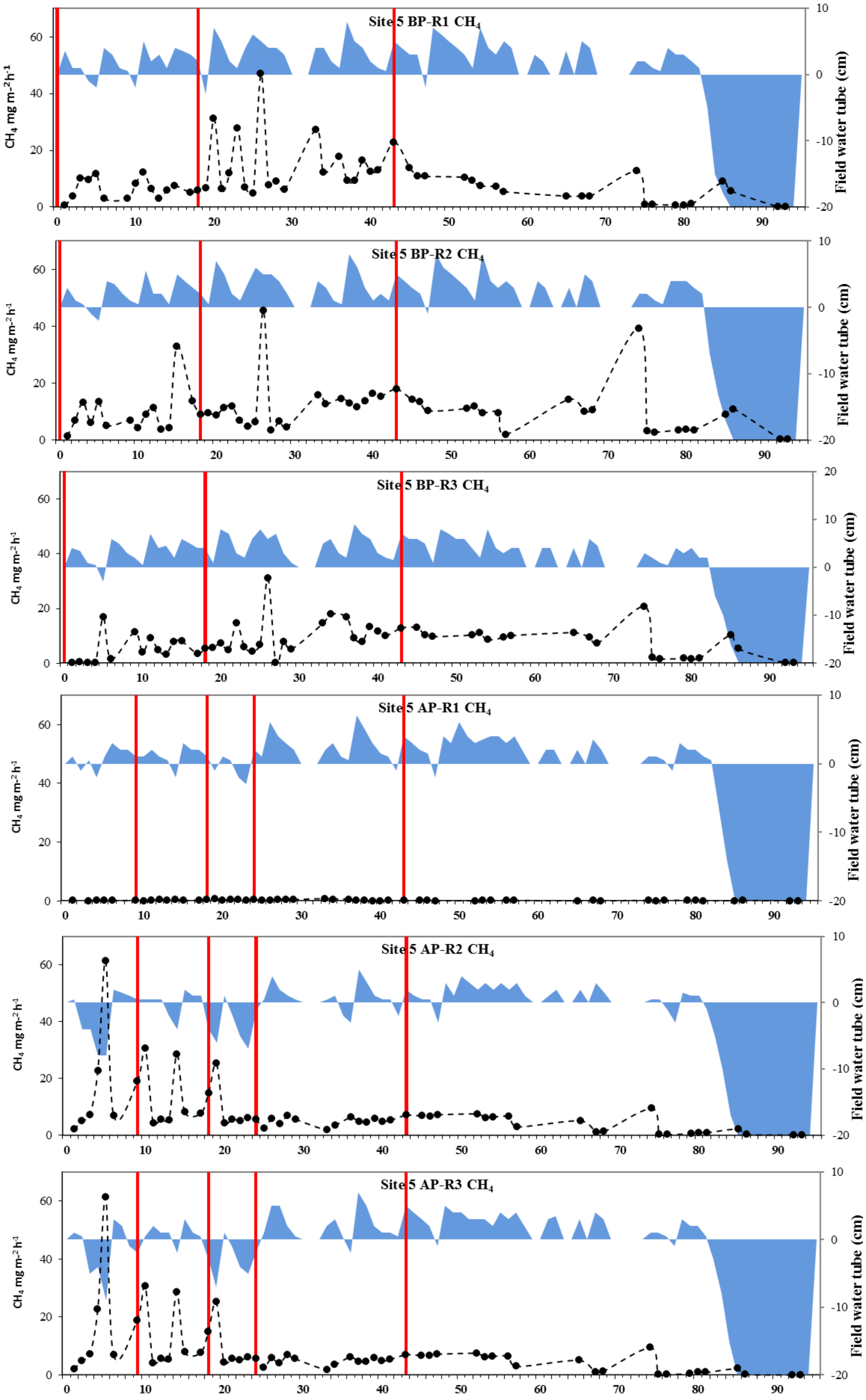


Fig. S13- Farm 4 (Controls)



SI Fig S14 - Farm 5

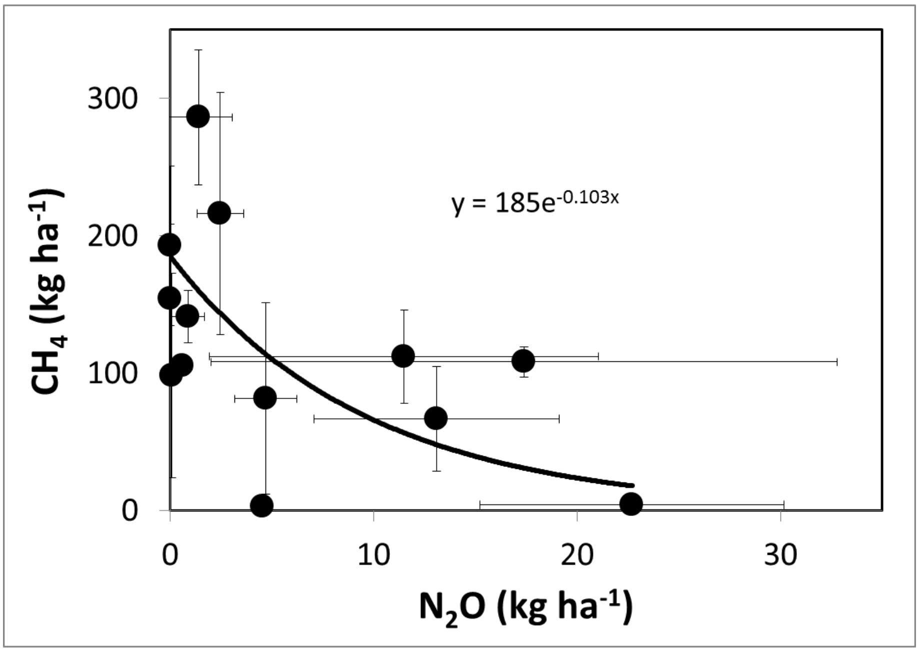


Fig. S15: Inverse relationship between N_2O and CH_4 emissions for average emissions from all thirteen treatments (6 seasons, two treatments and one control at Farm 4) *Except during two seasons, one of the two GHGs (CH_4 or N_2O) was a dominant contributor to net GWP_{100} (Figure 1). In two seasons (Farm 1 [2012] and Farm 3 [2012]), the contribution of CH_4 and N_2O fluxes to net GWP_{100} was comparable possibly because the surface was sufficiently oxidized for N_2O flux while the subsurface was simultaneously sufficiently reduced for significant CH_4 flux[49]. When average emissions from all thirteen treatments in this study are considered, there is an inverse exponential relationship between the two GHGs. Error bars represent 95% confidence intervals. High and medium water index farms (mild- or medium-intermittent flooding) show high variability in CH_4 but not much variation in N_2O. In contrast, intense-intermittent farms show a relatively high range in N_2O but not much variation in CH_4.*

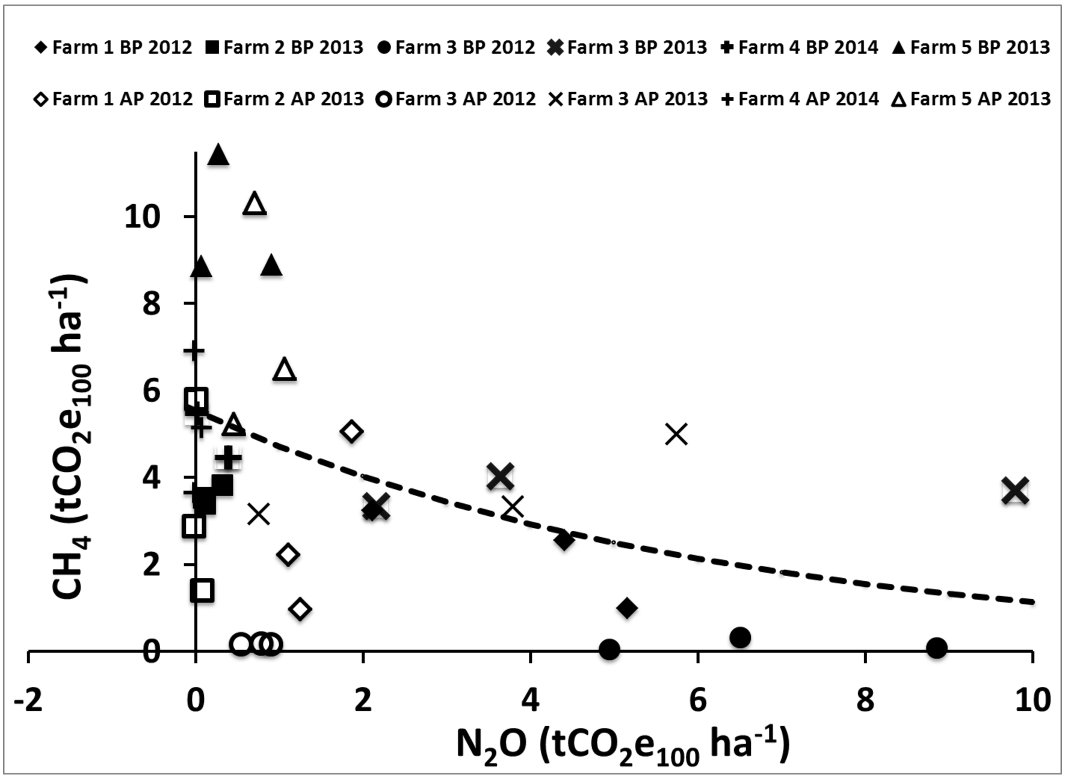


Fig. S16: Overall inverse relationship between N_2O and CH_4 emissions for individual replicates from each farm and treatment.

Figs. S17-S22: Correlation of N_2O flux for all replicates for each treatment with water index (S17), inorganic N (S18), number of flooding events$_{>3\ days}$ (S19), added organic C (S20), added total N (S21) and Clay:Sand ratio (S22) *When we consider the correlation of N_2O emissions and individual parameters, N_2O emissions were most strongly (and negatively) correlated with parameters that reflect extent of flooding at each farm (water index, maximum flooding duration, number of flooding events). See SI Table S34 for Pearson correlation coefficients between average N_2O flux for each treatment and individual parameters.*

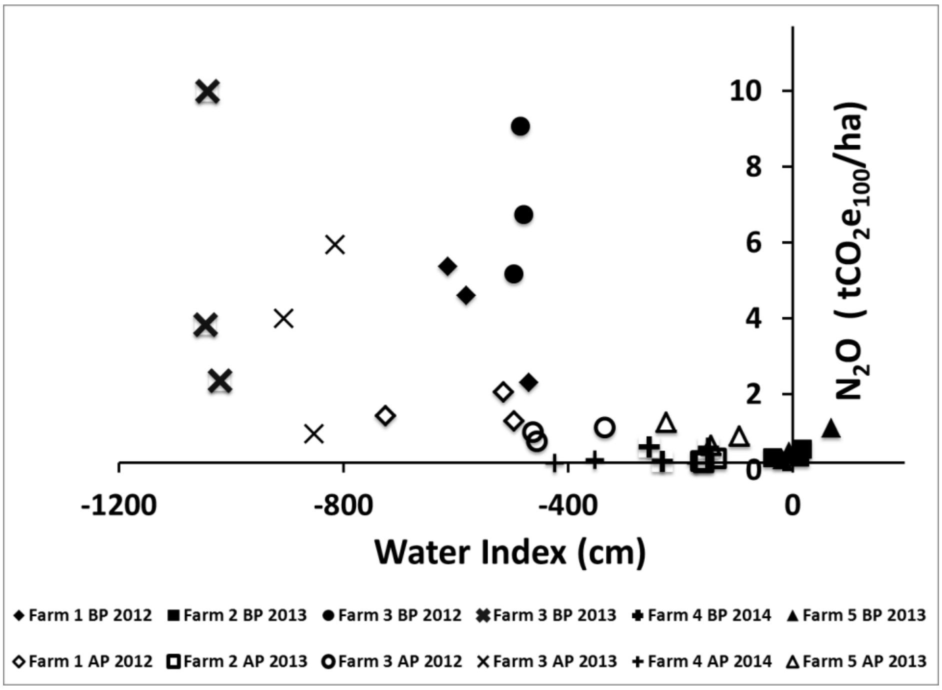


Fig. S17 N_2O *vs.* Water index

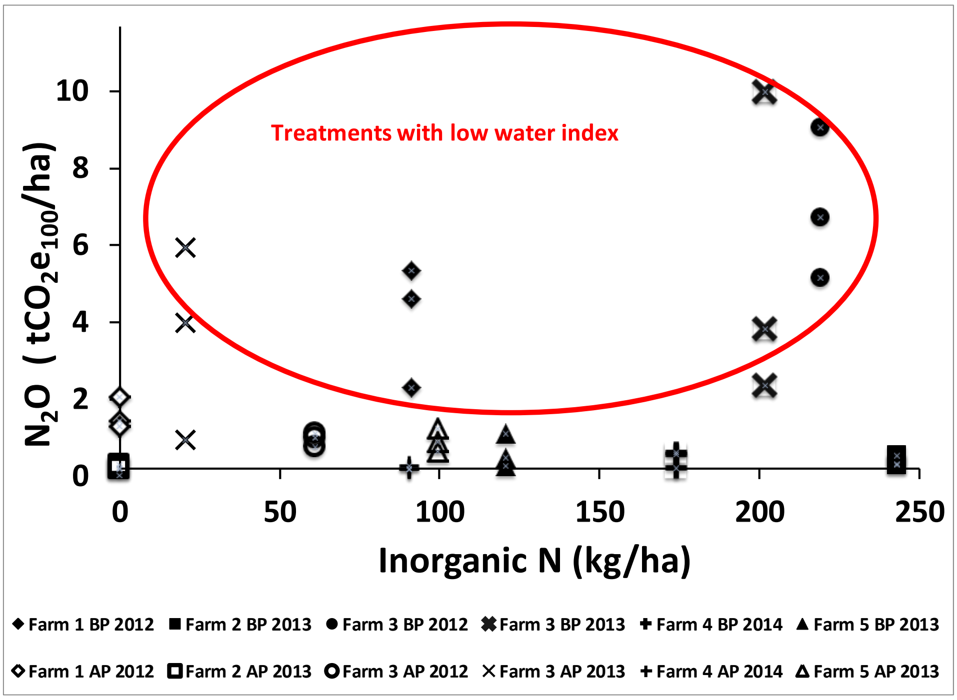


Fig. S18 N_2O *vs.* Inorganic N (all replicates)

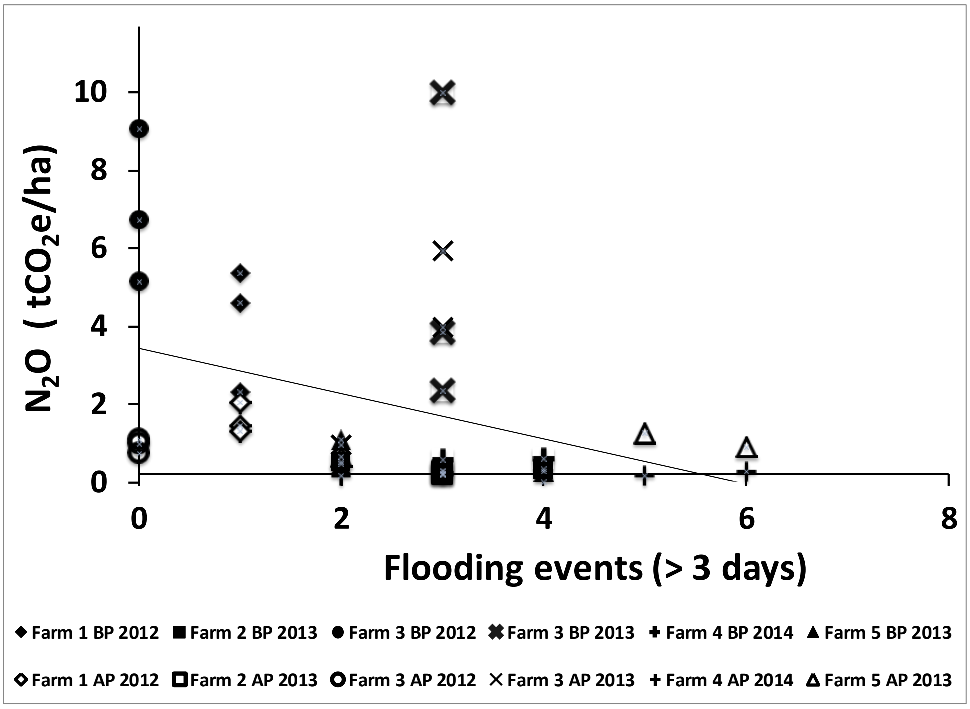


Fig. S19 N_2O *vs.* Number of Flooding events (> 3 days)

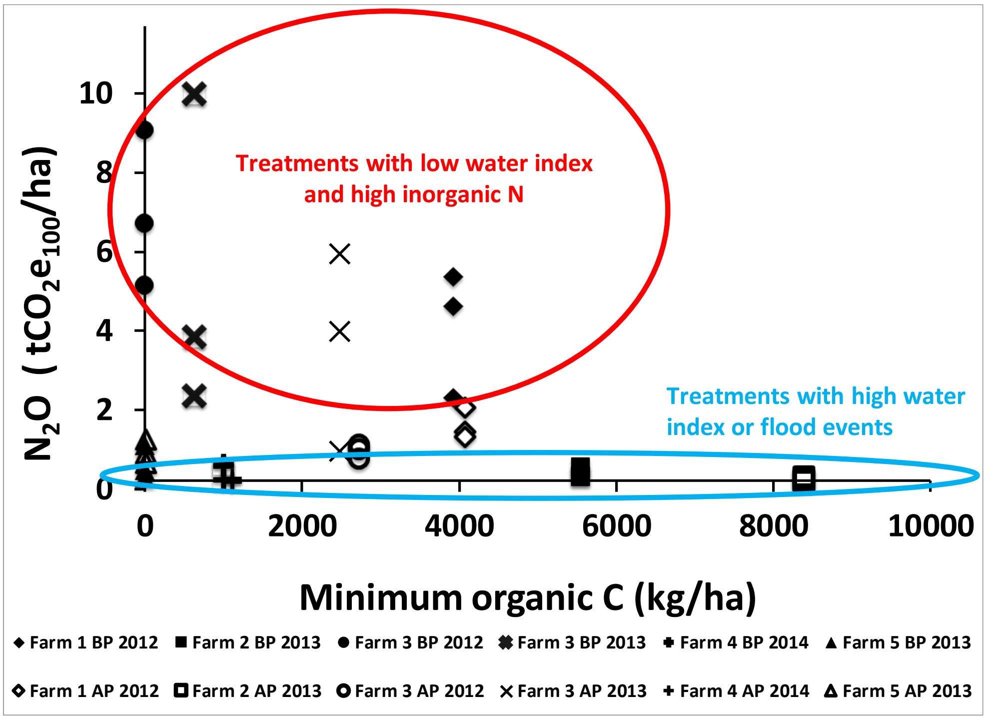


Fig. S20 N_2O *vs.* organic matter

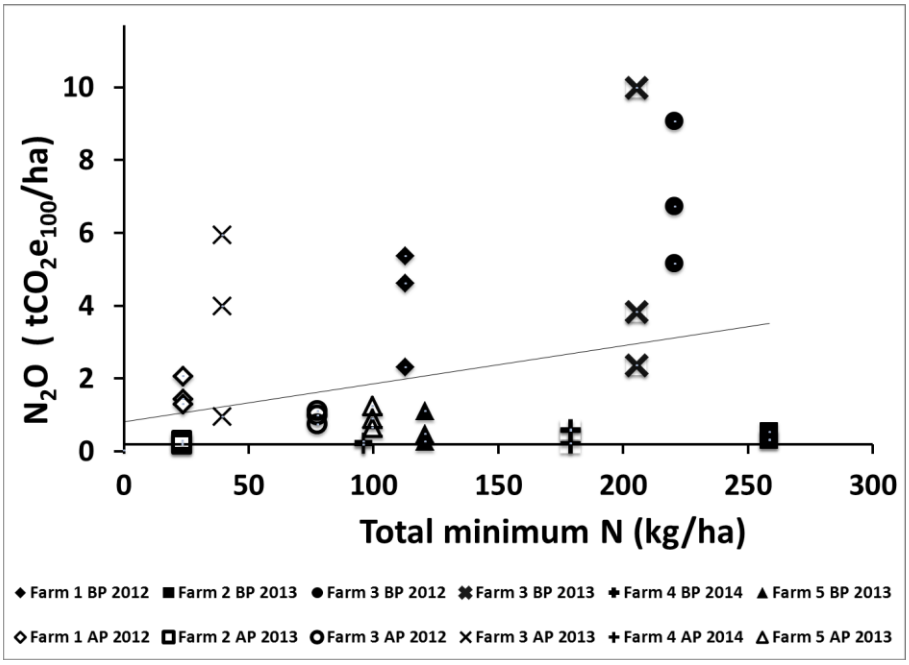


Fig. S21 N_2O *vs.* Total N (Inorganic N + minimum organic N)

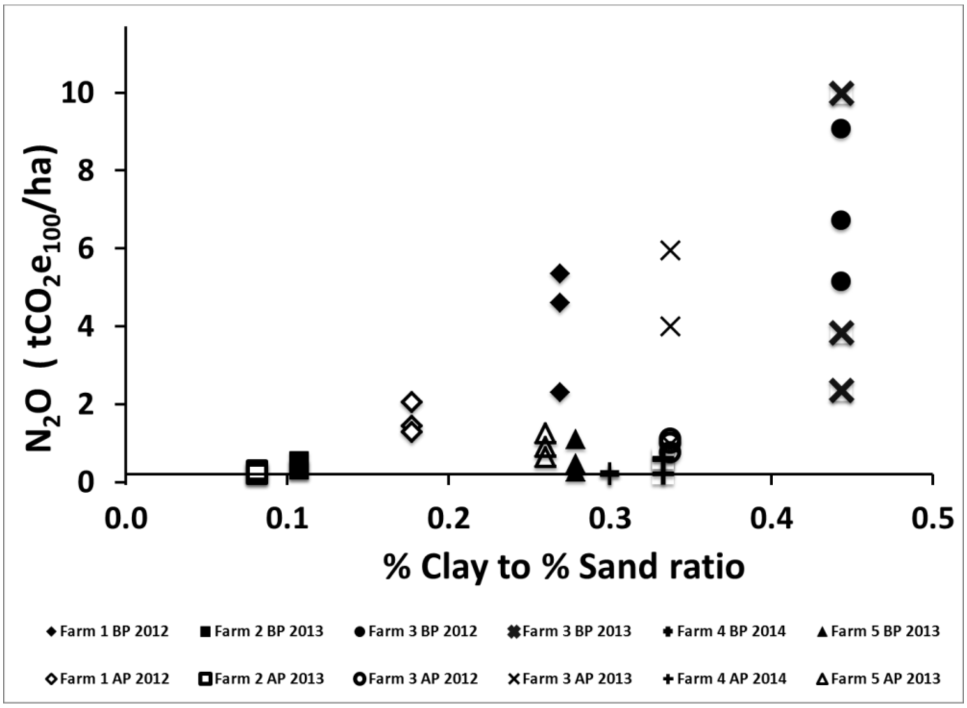


Fig. S22 N_2O *vs.* % Clay: % Sand in the soil

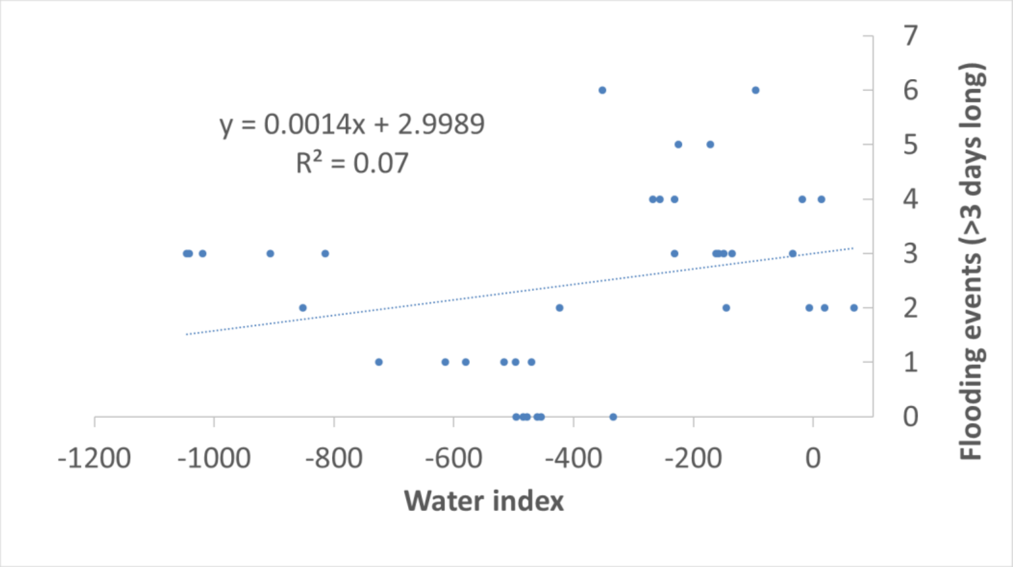


Fig S23 Number of Flooding events (> 3 days) vs water index (all replicates)

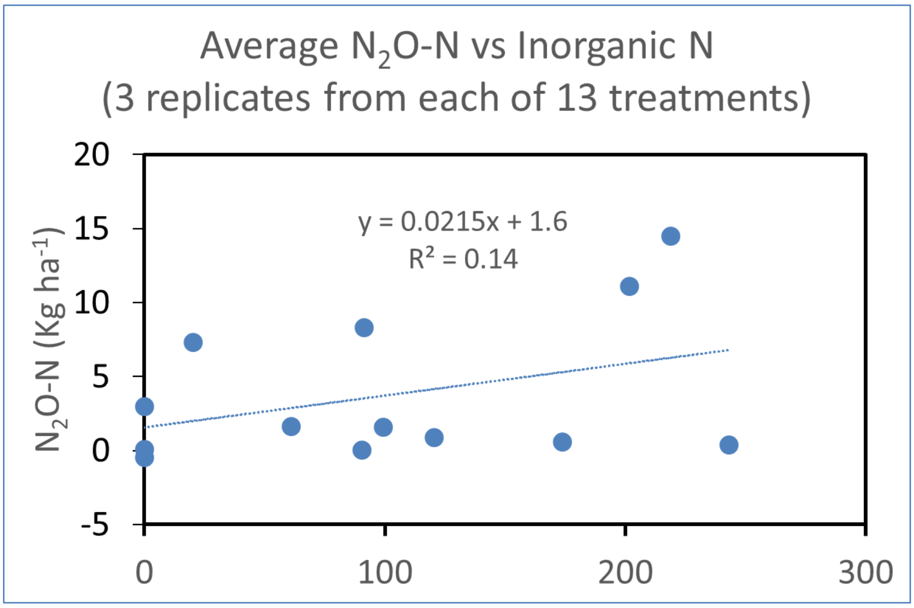


Fig. S24 Average N_2O *vs.* Average Inorganic N (n = 13 treatments with 3 replicates each)

Figs. S25-28: Correlation of average CH_4 flux in each season with water index (S25), number of flooding events$_{>3\ days}$ (S26), added organic C (S27) and SOC (S28) *When we consider the correlation of CH_4 emissions and individual parameters, CH_4 emissions were most strongly (and positively) correlated with parameters that reflect extent of flooding at each farm (water index, maximum flooding duration, number of flooding events). See SI Table S36 for Pearson correlation coefficients between average CH_4 flux for each treatment and individual parameters.*

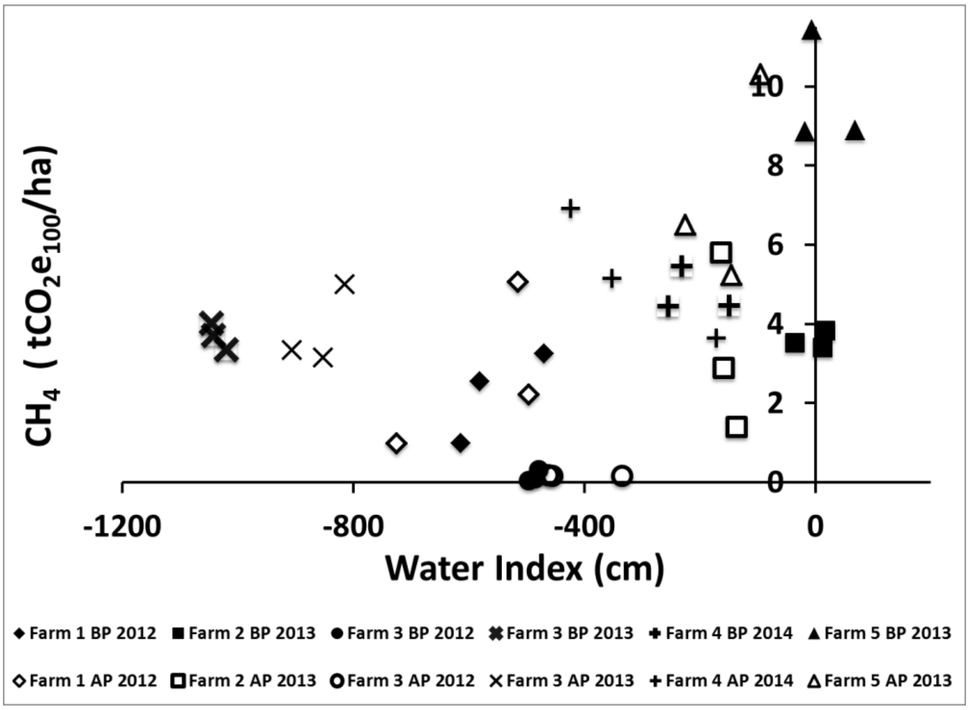


Fig. S25: CH_4 *vs.* Water index

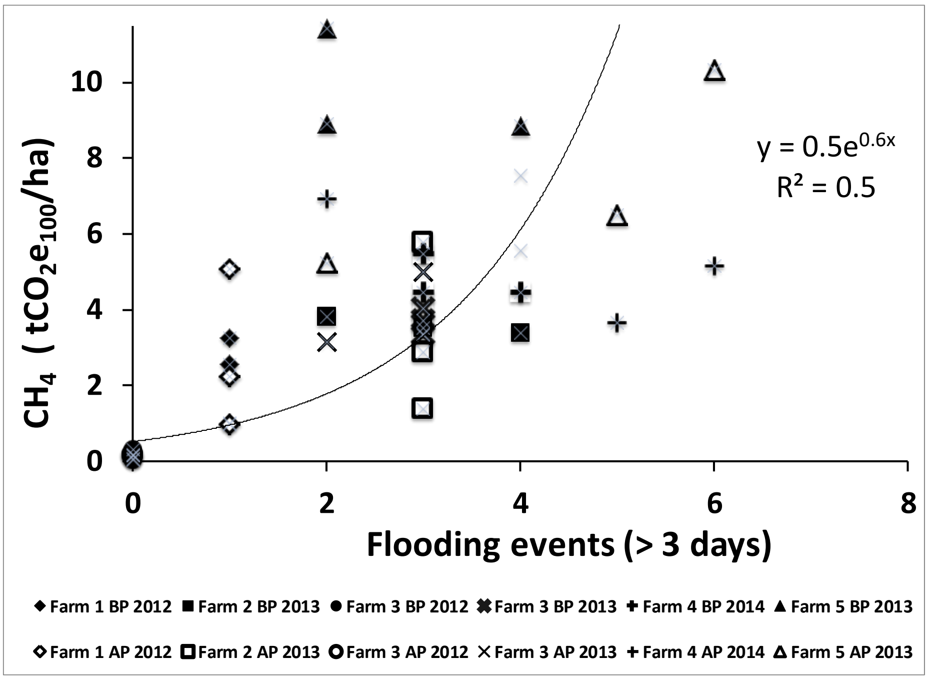


Fig. S26: CH_4 *vs.* number of flooding events (> 3 days)

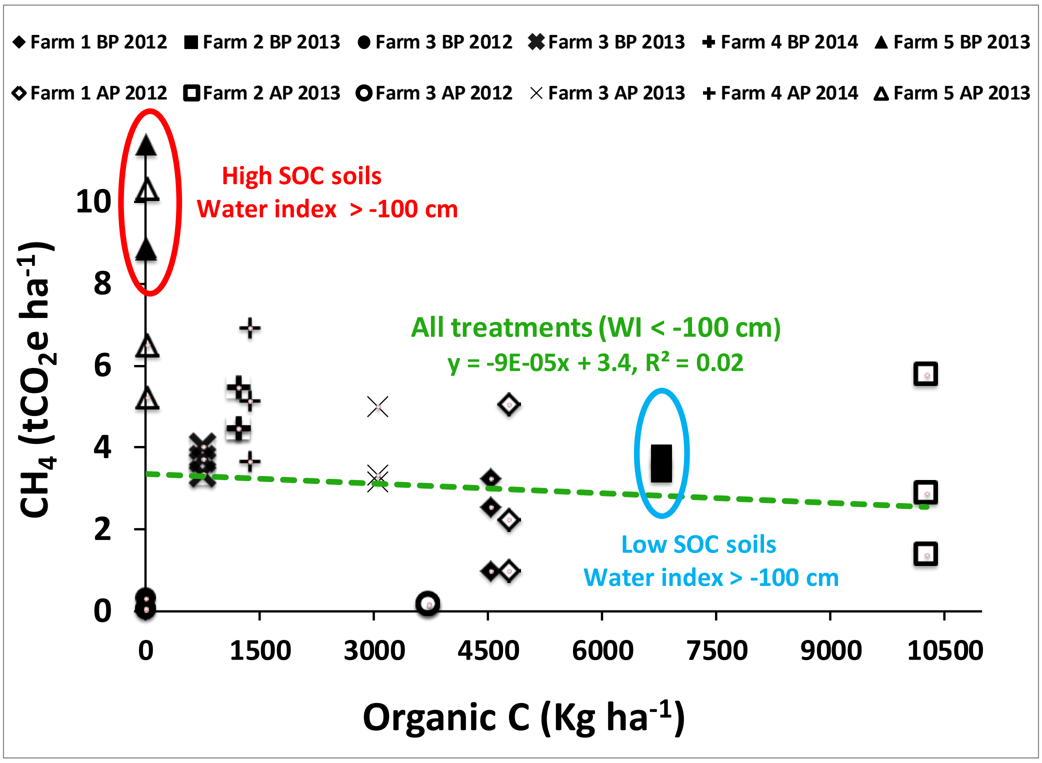


Fig. S27: CH_4 *vs.* added organic carbon *The graph plots the maximum possible organic C input on the X-axis but the trend remains the same if the minimum possible organic C is plotted instead (see SI Table S32 for maximum and minimum possible organic C inputs). The points enclosed in red and blue circles correspond to two Farms with high water indices (mild-intermittent flooding).*

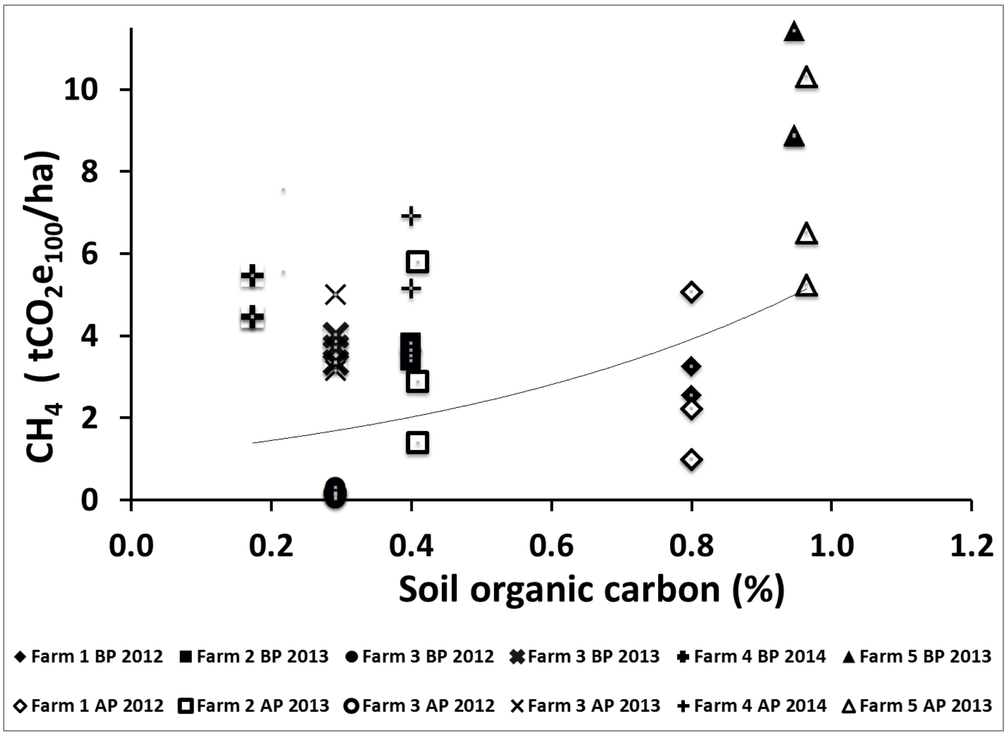


Fig. S28: CH_4 *vs.* soil organic matter (SOM)

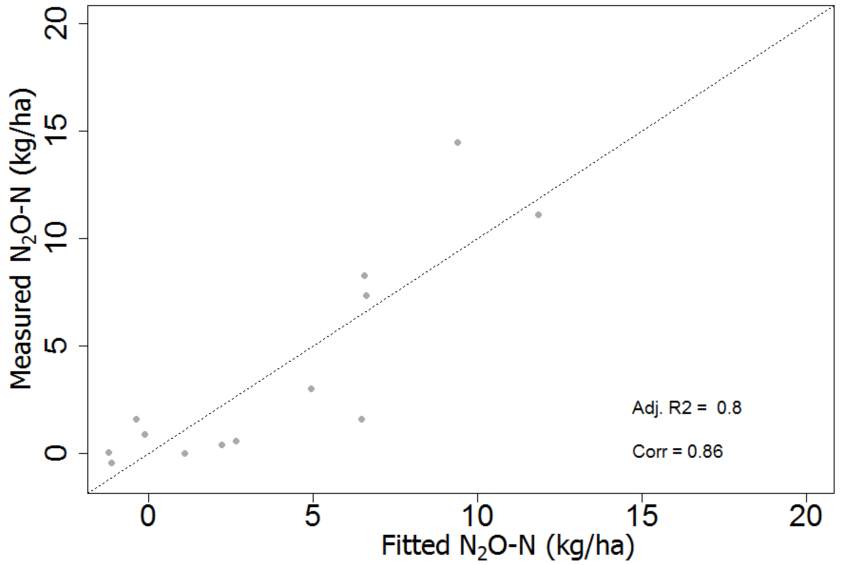


Fig. S29: Plot of fitted vs measured N_2O emissions, using the multivariate regression model that includes water index, continuous flooding events and input of inorganic N. *Notice the strong correlation between fitted and measured emissions (R = 0.86). The water index captures the cumulative flooding conditions at each Farm but the number of continuous flooding events reflects the temporal pattern that gave rise to the flooding conditions at a specific Farm. Water index, periods of continuous flooding and inorganic N explain 70%, 10% and 4% of the variance in the data, respectively. Even though periods of continuous flooding and inorganic N input explain a small fraction of the total variance when compared to water index, their addition to the model is statistically significant.*

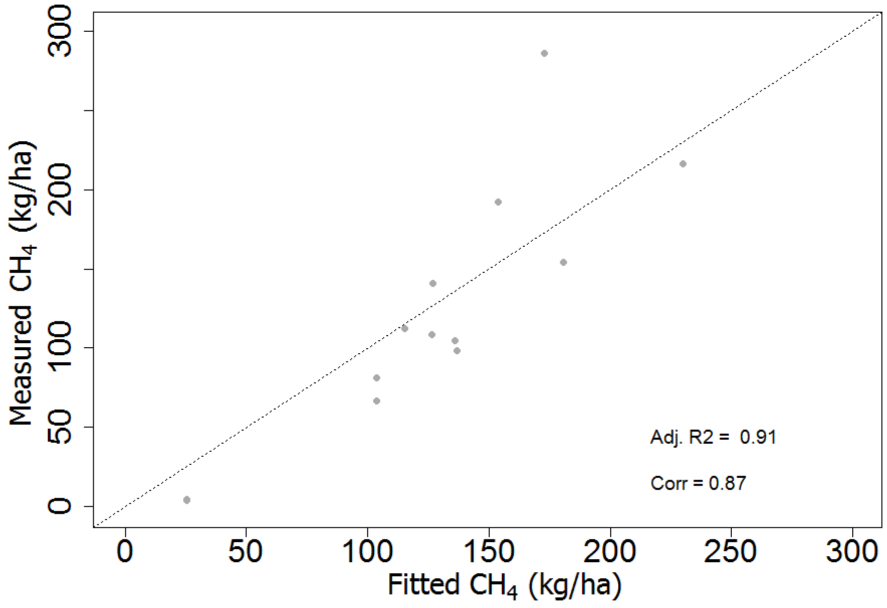


***Fig. S30**: **Plot of fitted vs measured CH_4 emissions, using the multivariate regression model that includes continuous flooding events and soil organic carbon as parameters**. Notice the strong correlation between fitted and measured emissions (R = 0.87). The number of flooding events and SOC explain 87% and 5% of the variance in the CH_4 emissions, respectively.*

Figs. S31-33 and S34-35: *We compared the two treatments (AP vs BP) from each farm to demonstrate how specific changes in important parameters trigger or suppress N_2O and/or CH_4 emissions. These examples cannot yet be generalized; however, they illustrate the potential effect of managing certain parameters. To visualize this analysis we use parallel coordinate plots*[50]*. With these plots, we can visualize how a set of parameters change among a pair of treatments. Each parallel Y-axis represents the range of one specific parameter. Solid horizontal lines connect the values between parameters for each Farm. SI Figures S31-33 and S34-35 show N_2O and CH_4 emissions as well as parameters that had the most statistically significant relationships with rice GHG emissions with respect to flooding characteristics, soil characteristics, and inputs: water index, continuous flooding events, inorganic N input, organic C input, soil organic carbon (SOC) and clay/sand ratio.*

Please see farms showing N_2O dominance in SI Figure S31-33 and farms showing dominance of CH_4 in SI Figure S34-35.

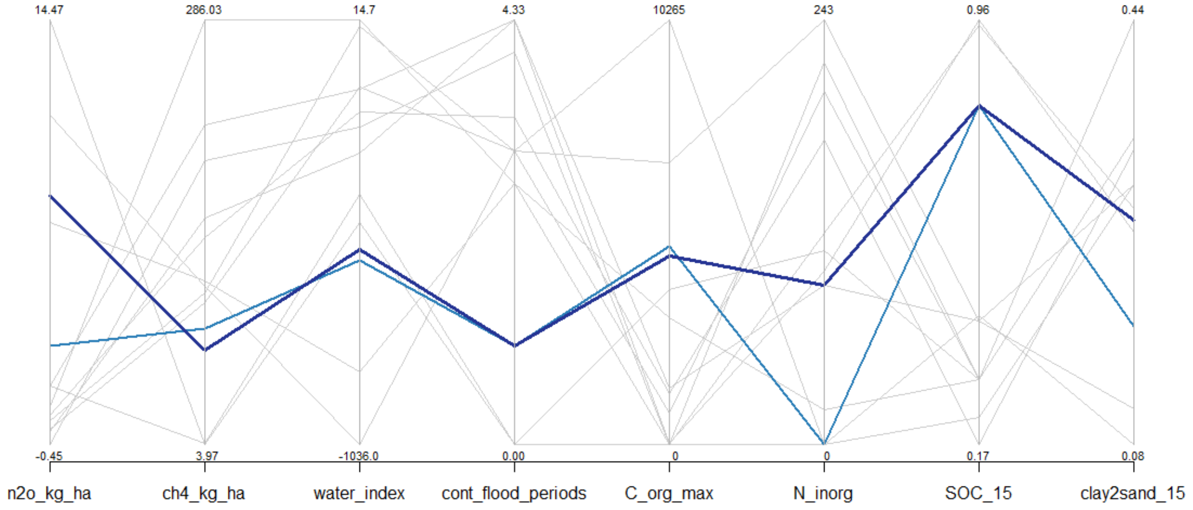


Fig. S31*:* ***Parallel coordinate plot for Farm1-2012-AP (lighter blue) and Farm1-2012-BP (darker blue).*** *The light grey lines in the background show treatments not considered in this analysis. This figure compares Farm 1 (2012) AP and BP treatments. BP treatments had higher N_2O emissions (AP = 3.0 kg N_2O ha^{-1}, BP = 8.3 kg N_2O ha^{-1}). We see the inverse relationship with CH_4 emissions, where AP had slightly higher emissions (AP = 81.1 kg CH_4 ha^{-1}, BP = 66.5 kg CH_4 ha^{-1}). These Farms had similar flooding characteristics: both had comparable water index values (close to the median of all the Farms) and the same number of continuous flooding events. One of the main differences is the inorganic N input (AP = 0 kg N ha^{-1}, BP = 91 kg N ha^{-1}). As shown in Equation 1, a higher inorganic N input is related to higher N_2O emissions. This example also shows a positive correlation between clay/sand ratio and N_2O emissions. BP had a 50% higher clay/sand ratio (AP = 0.18, BP = 0.27) and even though this soil characteristic parameter did not show up in the multivariate regression model (Equation 1), this example qualitatively shows difference in clay/sand ratio between BP and AP as a potential cause of difference in N_2O emissions under similar flooding characteristics.*

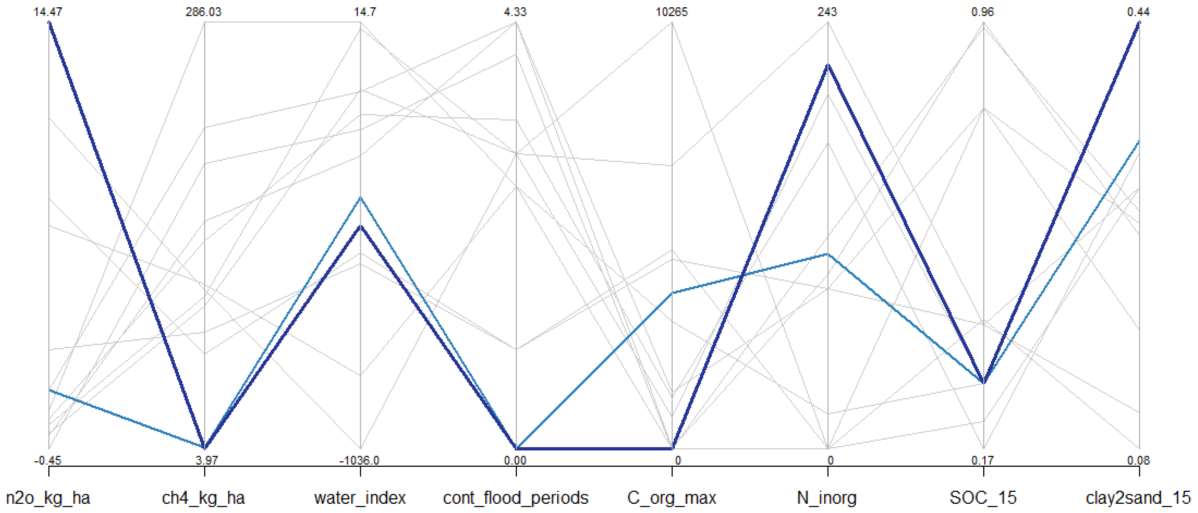


Fig. S32**: **Parallel coordinate plot for Farm3-2012-AP (lighter blue) and Farm3-2012-BP (darker blue). *The light grey lines in the background show treatments not considered in this analysis. This figure compares Farm 3 (2012) AP and BP treatments. BP treatments had significantly higher average* N_2O *emissions (14.5 kg* N_2O ha^{-1}*; maximum* N_2O *emissions among all 13 treatments) and very similar* CH_4 *emissions. These sites had similar water indices (close to the median of all sites) and similar continuous flooding events (minimum from all sites). For both sites, inorganic N input is above 100 kg* ha^{-1}*, however, site BP had almost twice the inorganic N input and higher* N_2O *emissions than AP. As with Farm 1, similar flooding characteristics and changes in the inorganic nitrogen input affect* N_2O *emissions without having a significant effect on* CH_4 *emissions.*

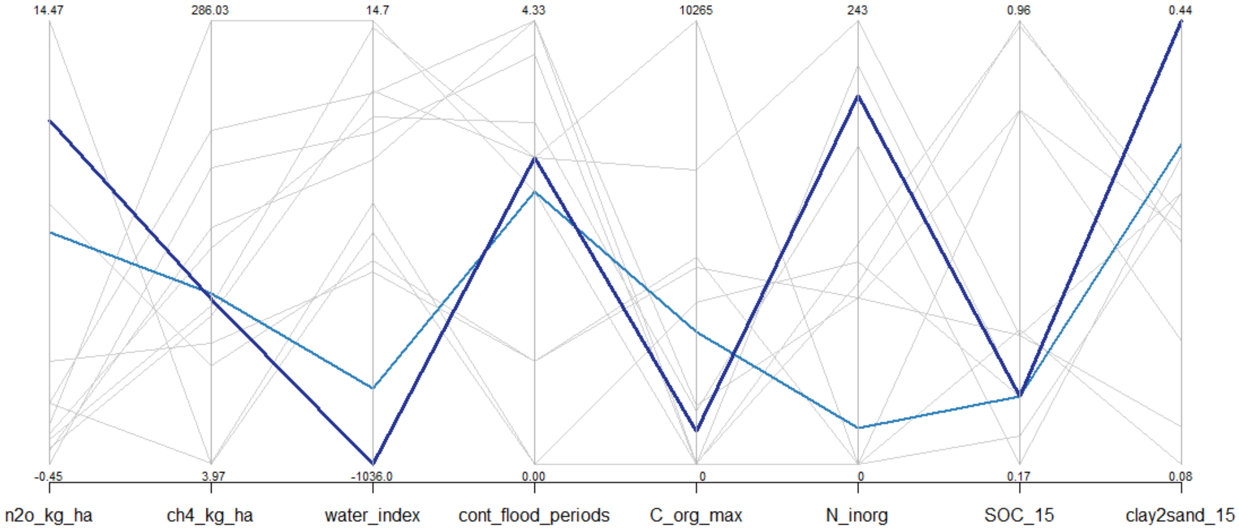


Fig. S33: Parallel coordinate plot for Farm3-2013-AP (lighter blue) and Farm3-2013-BP (darker blue). *The light grey lines in the background show treatments not considered in this analysis. This figure compares AP and BP treatments at Farm 3 (2013). In this case, BP treatment had higher* N_2O *emissions (AP = 7.3 kg* N_2O ha^{-1}*, BP = 11. kg* N_2O ha^{-1}*) and similar* CH_4 *emissions. BP had a lower water index, higher inorganic N input and higher clay to sand ratio. The difference in water index (AP = -858 vs BP = -1,036) was the main driver of* N_2O *emissions.*

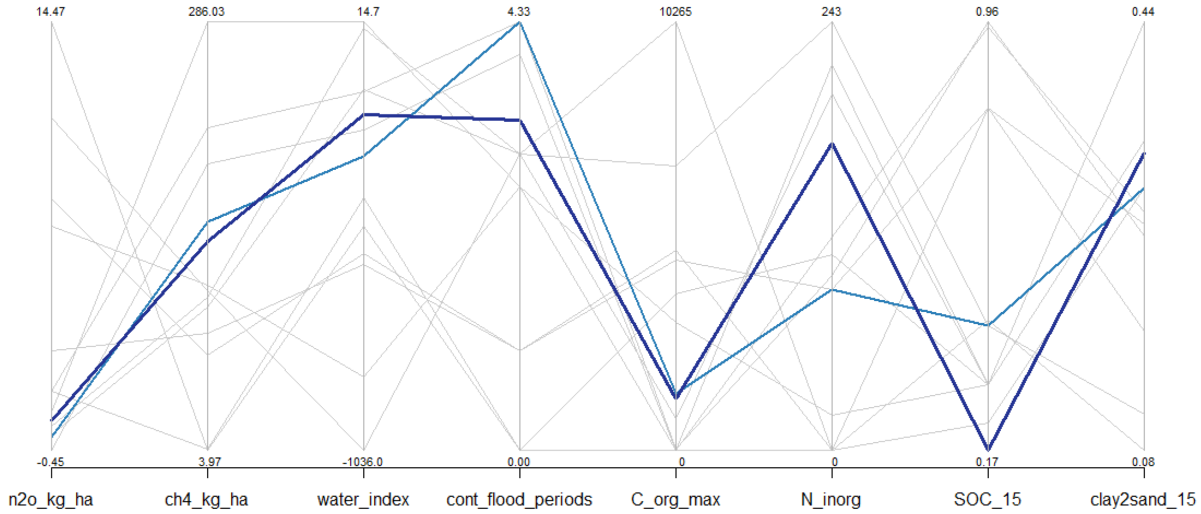


Fig. S34: Parallel coordinate plot for Farm4-2014-AP (lighter blue) and Farm4-2014-BP (darker blue). *The light grey lines in the background show treatments not considered in this analysis. This figure compares Farm 4 AP and BP treatments.* N_2O *emissions for these two treatments are close to the lower end of all treatments, although slightly higher for BP treatments (AP = 0 kg* N_2O ha^{-1}*, BP = 0.57 kg* N_2O ha^{-1}*).* CH_4 *emissions are slightly higher for Farm AP (AP = 154 kg* CH_4 ha^{-1}*, BP = 141 kg* CH_4 ha^{-1}*). High water index and an elevated number of continuous flooding events suppress* N_2O *emissions for both AP and BP. Conversely, these high flooding conditions trigger* CH_4 *emissions and in particular the relatively higher number of continuous flooding events in AP corresponds to the higher* CH_4 *emissions at that farm.*

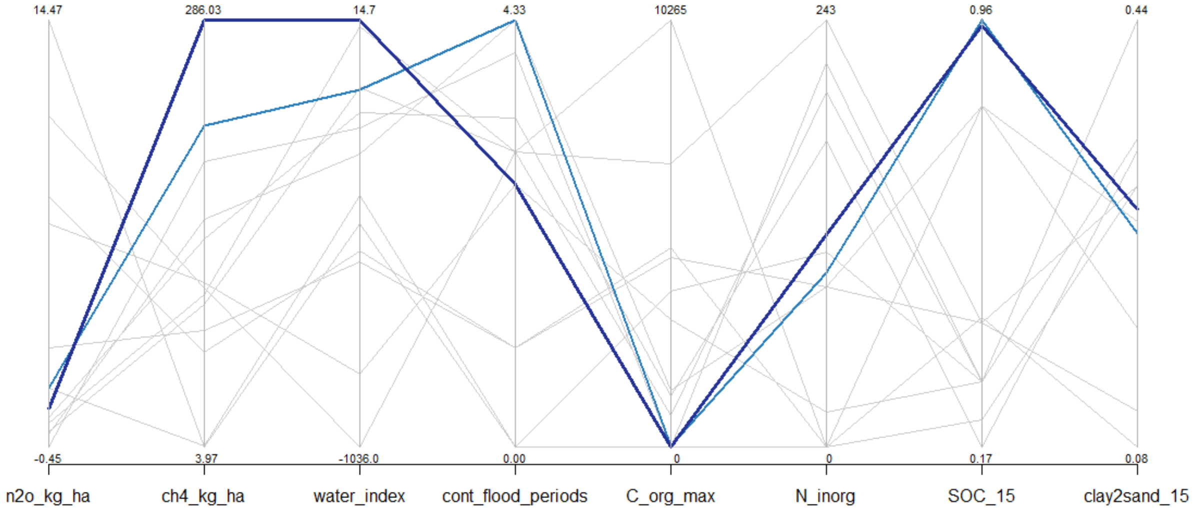


Fig. S35*:* ***Parallel coordinate plot for Farm 5-2013-BP (darker blue) and Farm 5-2013-AP (lighter blue).*** *The light grey lines in the background show treatments not considered in this analysis. This figure compares Farm 5 AP and BP treatments. In this case, both AP and BP had similar and low* N_2O *emissions. However, both treatments had significantly high* CH_4 *emissions (where AP = 216 kg* CH_4 ha^{-1}*, BP = 286 kg* CH_4 ha^{-1}*), the maximum measured in this study. These two treatments had similar inputs and soil characteristics (clay/sand ratio), but different flooding characteristics with overall high water index values. The soil organic C from both AP and BP treatments are at the maximum observed in this study, and as shown in Equation 2, this high soil organic C content supports the high* CH_4 *emissions.*

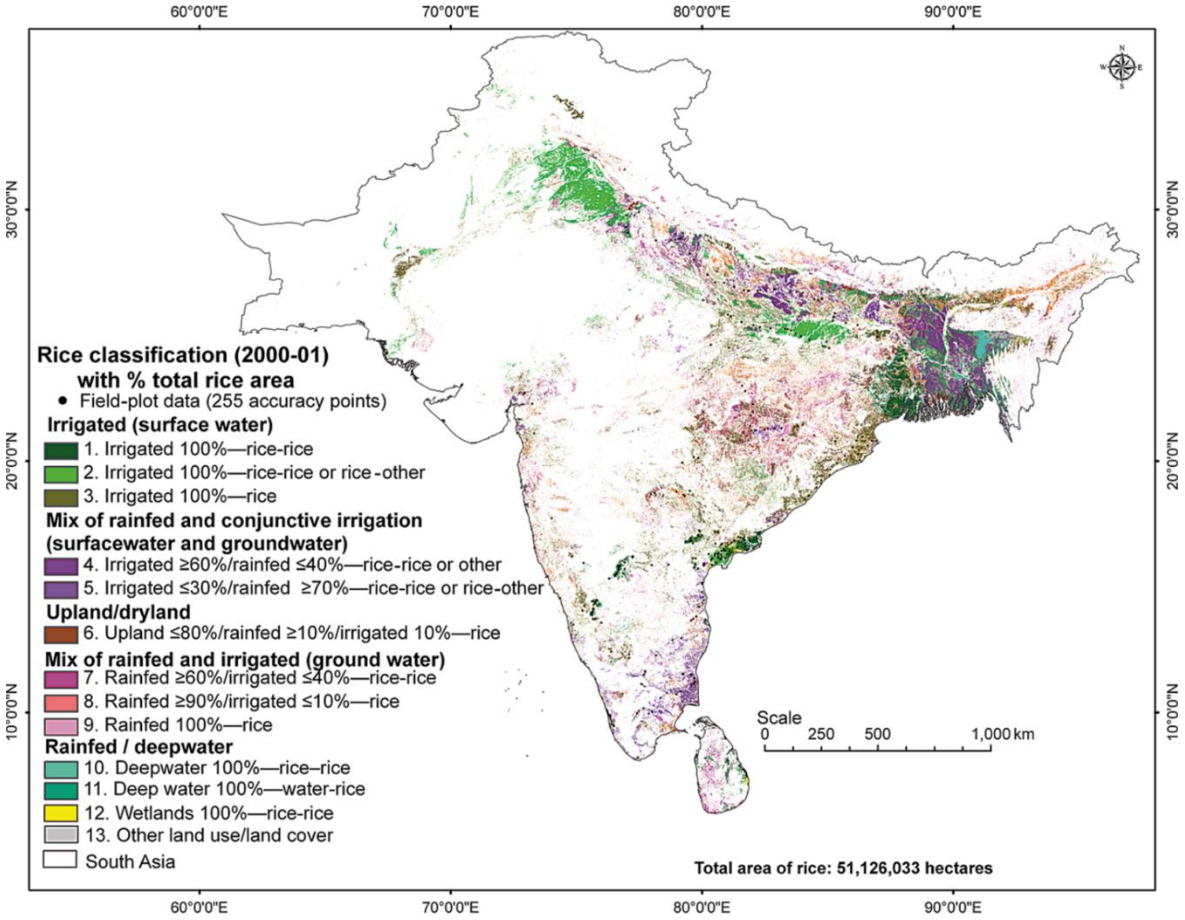


Fig. S36: Indian subcontinent rice management classes *The spatial layout of water management classes for rice farms in the Indian subcontinent (Image from Gumma et al. 2011)*[51].

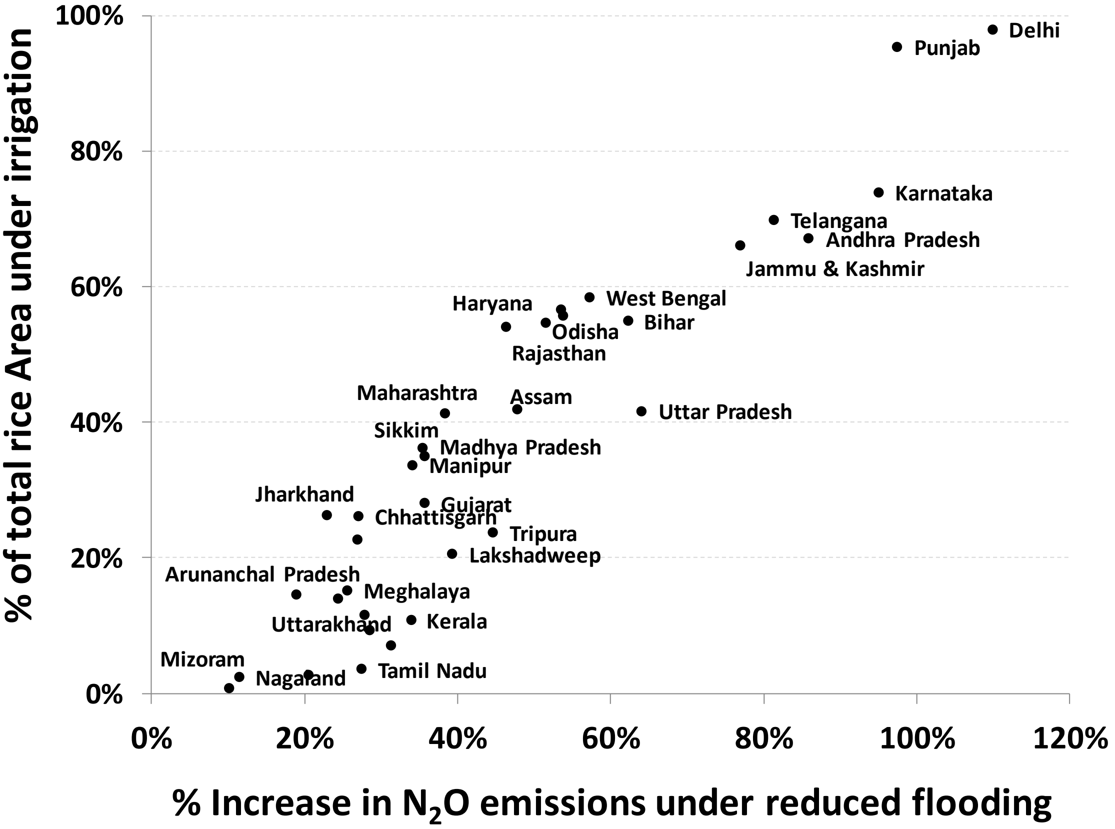


Figure S37: Relationship between rice area under irrigation vs. potential for high N_2O emissions. *If different states move from medium to intense intermittent flooding (or from minimum water index and maximum flooding events to minimum water index and minimum flooding events scenarios), the net susceptibility of different states in India to increased N_2O emissions as calculated by Equation 1 (See SI Table S42) will depend on the percentage of area under irrigation[51]. States in India that have higher percentage rice under irrigation (e.g., Delhi, Punjab or Karnataka are more susceptible to high N_2O emissions under reduced flooding (i.e., intense intermittent flooding) simply because higher area under irrigation implies that with reduced flooding more total rice area will have lower water indices and hence higher N_2O emissions based on Equation 1 (SI Table S42). Irrigated area for each state was estimated by aggregating results from all twelve categories (SI Table S38) and classifying each pixel from the Gumma et al. (2011) dataset as irrigated or non-irrigated pixel.*

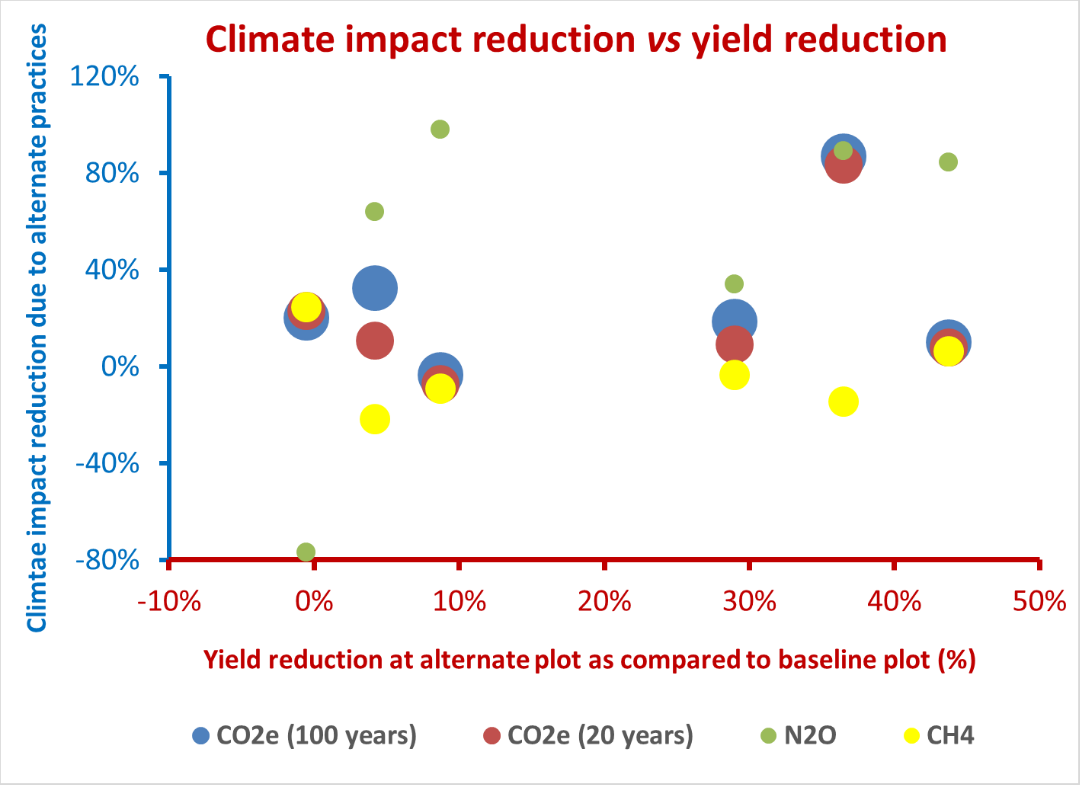


Fig. S38 Reduction in climate impacts vs reduction in yields *Comparison of alternate treatments with corresponding baseline treatments at five farms. There is no direct correlation between reduction in yields and reduction in climate impacts which implies that we should be able to optimize management practices such that yields are maximized but climate impacts are minimized.*

Supporting Tables

(All supporting tables are available as Dataset S1)

Supporting Table S1 Indian studies

(Too large to be pasted as an image, available only as an Excel spreadsheet, includes 39 studies on rice GHG emissions from India)

Table S2 General site description: Soil, weather, seed variety, transplantation and sampling intensity details

	Farm 1 (2012)	Farm 2 (2013)	Farm 3 (2012)	Farm 3 (2013)	Farm 4 (2014)	Farm 5 (2013)
Agro-ecological region (AER)	3	3	8.3	8.3	8.3	8.1
Measured SOC (0-15 cm) (%)	0.8	0.4	0.3	0.3	0.3	0.95
Water holding capacity (0-15) (% v/v)	57-62	51-57	54	54	65-71	61
Measured Sand, Silt, Clay (0-15 cm) (w/w)	65-71, 18-17,17-13	75-77, 17-17,8-6	63-64, 13-13,25-23	63-64, 13-13,25-23	63-62,17-20,21-19	65,17-18,18-17
Season description (w.r.t monsoon)	Southwest	Southwest	Southwest	Southwest	Southwest	Northeast
Local name of the season	*Kharif*	*Kharif*	Delayed *Samba* #	*Samba*	Delayed *Samba* #	*Pisanam*
Season duration BP (Days)	113 (Sep 6-Dec 28)	104 (Oct 31- Feb 12)	101 (Dec 1 - Mar 12)	96 (Oct 26-Jan 30)	99 (Dec 2- Mar 10)*	94 (Dec 15-Mar 22)
Season duration AP (Days)	113 (Sep 6-Dec 28)	104 (Oct 31- Feb 12)	108 (Dec 1 - Mar 19)	108 (Oct 26- Feb 11)	100 (Dec 2- Mar 11)*	94 (Dec 15-Mar 22)
Measured Seasonal Rainfall (mm)	105.3	45.8	83.5	67.4	52	99.6
Measured Seasonal Temp (Max/min)	13°C/38°C	13°C/37°C	20°C/36°C	18°C/34°C	14°C/39°C	23°C/32°C
Farm size (m^2)	667	320	552	552	580	660
Latitude and Longitude	N 14.655° E77.640°	N 14.644° E77.627°	N 10.303° E78.485°	N 10.303° E78.485°	N 10.477° E78.836°	N 08.676° E77.605°
Location (Village, District)	Upparapalli, Anantapur	Upparapalli, Anantapur	Thirumalairayapuram Pudukkotai	Thirumalairayapuram Pudukkotai	Sembattur, Pudukkotai	Melacheval, Tirunelveli
Seed variety	BPT 5204	BPT 5204	ADT 39	ADT 39	ADT 39	ASD 16
Seed quantity BP|AP (kg/ha)	61 | 61	61 | 61	148 | 49	148 | 49	124 | 49	88 |32
Seedling age BP | AP (Days)	30 | 30	30 | 30	42 | 22**	36 | 22**	34 | 34*	34 | 27
Transplantation density (# of seedlings/hill, distance between hills(cm))	4-5, 14-15	4-5, 14-15	4-5, 13-15	4-5, 13-15	4-5, 13-15	3-5, 14-15
GHG Sampling Intensity (% of season length)	44	49	33	41	64	60
Water level sampling intensity (% of season length)	55	73	99	94	100	86
Water use estimated BP | AP(mm)	1289 | 1302	9543 | 5553	3510 | 1777	2228 | 2038	4410 | 2600	Canal Irrigation
% readings below MDL (N_2O | CH_4)	36 | 11	99 | 25	21 | 57	50 | 17	38 | 25	117 | 14
% Negative values N_2O	12%	34%	13%	29%	47%	24%
% Negative values CH_4	4%	1%	18%	8%	1%	1%

* For the two control plots, the seedling age was 34 days and the season duration was 100 days

\# Sowing and transplantation delayed because of water scarcity

** Lower seedling age was recommended by local experts

Table S3 Summary of survey results from all farms in comparison with actual BP inputs

	Farm 1 (2012)		Farm 2 (2013)		Farm 3 (2012)		Farm 3 (2013)		Farm 4 (2014)		Farm 5 (2013)	
Number of surveys (villages covered)	150 (36)		90 (24)		60 (34)		70 (28)		300 (82)		78 (31)	
Major seed variety	BPT 5204		BPT 5204		ADT 39		ADT 39		ADT 39		ASD 16	
(% using this variety)	100		52		88		60		43		44	
% Farmers using organic input	58		41		30		71		44		0	
Seed rate and variety	***Survey vs BP input***		***Survey vs BP input***		***Survey vs BP input***		***Survey vs BP input***		***Survey vs BP input***		***Survey vs BP input***	
Seed rate (kg/ha)	96±33	61	70±30	61	123±26	148	125±42	148	125±42	124	82±23	88
Seedling age (days)	36±7	30	36±12	30	35±6	42	123±4	36	32±3	34	29±5	
Organic Inputs and quantity												
Organic Input 1 (t/ha) (±SD)	11 ±12	10.2 + 9.7	4.5±3.2	31*	3.8±0.5	0	3.5±1.2	3.5	5.5±3.2	5.6	0	0
Inorganic Inputs and quantity												
Preferred basal fertilizer	DAP		DAP		DAP		17:17:17		DAP		17:17:17	
Quantity (kg/ha)(±SD)	212±115	190	248±80	469*	219±60	217	207±40	208	188±61	185	208±43	195
Preferred 2nd dose N fertilizer	Urea		Urea		Urea		Urea		Urea		Urea	
Quantity (kg/ha)(±SD)	127±63	128	187±185	185	210±57	207	211±53	210	179±72	185	111±48	111
Preferred 2nd dose K fertilizer					MoP		MoP		MoP		MoP	
Quantity (kg/ha) (±SD)					123±32	124	121±29	121	105±33	134	68±33	62
Preferred 3rd dose N fertilizer			Urea		Urea		Urea		Urea		Urea	
Quantity (kg/ha)(±SD)			163±87	167	190±56	188	152±51	153	127±56	124	81±45	79
Preferred 3rd dose K fertilizer					MoP				MoP		MoP	
Quantity (kg/ha) (±SD)					122±21	124			103±36	124	52±25	62
N applied to BP (kg/ha)		206		396		219		219.6		201.5		120.55
P applied to BP (kg/ha)		154		370		100		53		113		33
K applied to BP (kg/ha)		303		463		124		112		207		95
N:P:K (applied to BP)		206:154:303		396:370:463		219:100:124		219:53:112		202:113:207		120:33:95
N:P:K (recommended)		201:57:59		201:57:59		150:50:50		150:50:50		150:50:50		150:50:50

* Farm 2 was fallow for 10 years before this experiment and had never been used for rice cultivation before. In line with recommendation of local experts, much higher organic matter was added to improve soil fertility. Inorganic N added to this site was equal to the average amount used by the top 10% highest inorganic N using farmers in the survey.

Table S4 Farm 1 (2012) Baseline and alternate practices

Time (DAT)[1]	Parameters	Baseline Practices (BP)		Alternate practices (AP)	
			Chemical[9] N (kg/ha)		Chemical[9] N (kg/ha)
0	Seed Rate[2] (kg/ha)	61		61	
-15	Farm Yard Manure (t/ha)[3]	10.5		10.5	
-2	Green leaves (kg/ha)[4]	9.7		9.7	
0	Basal Dose (kg/ha)	DAP[5] (190)	33.3	*GJWM*[6] (494) Neem cake[7] (247)	
41	Second dose	Urea[5] (128)	58	*Jeewamrutha*[8] (5 L)	0
69	Third dose (kg/ha)	NA		*Jeewamrutha*[8] (5 L)	0
	Total inorganic N input (kg/ha)		91.3		0.0

[1] DAT Days after transplantation

[2] For baseline seed rate survey results see SI Table S10 To have uniform seed rate across all treatments, a seed rate of 61kg/ha, which is within the range seen in baseline surveys, was used.

[3] For close survey based FYM results, supporting Table S11. Total % O.C assumed ranged from 18 to 22% (Tennakoon & Hemamala-Bandara,

[4] *Gliricidia Sp*. For baseline survey results, see Table S11. Higher rate was applied to have uniform application across all treatments. Total %C was assumed to range from 21 to 23 (Tennakoon and Hemamala-Bandara, 2003).

[5] For matching survey results see SI Table S11

[6] Mixture of 200kg dry cowdung, 10L cow urine, 2kg jaggery,2kg pulse powder, handful of anthill soil after being left in a cool dry place for 7 days. Total N% of GJWM assumed to be 0.75% (Kritee et.al.2015). Because dung was the major ingredient, total %C assumed ranged from 18

[7] Organic C content of neem cake was assumed to be between 25 to 50%.

[8] Local liquid biofertilizer. 10kg cowdung, 10L cow urine, 2kg jaggery,2kg pulse powder, handful of anthill soil in 200L water, mixed regularly for 2 days. Total N% of Jeewamrutha assumed to be 0.2% (Kritee et.al. 2015).

[9] For total organic N calculations, refer to SI Table S24

Table S5 Farm 2 (2013) Baseline and alternate practices

Time (DAT)[1]	Parameters	Baseline Practices (BP)		Alternate practices (AP)	
			Chemical[9] N (kg/ha)		Chemical[9] N (kg/ha)
0	Seed Rate[2] (kg/ha)	61		61	
-2	Farm Yard Manure (t/ha)[3]	30.9		46.3	
0	Basal Dose (kg/ha)[4]	DAP[4] (469)	82	*GJWM*[6] (494)	
40	Second dose (kg/ha)	Urea[5] (185)	84	*Jeewamrutha*[7] (20 L)	
48				Sheep manure[8] (192)	
60	Third dose (kg/ha)	Urea[5] (167)	77	*Jeewamrutha*[7] (20 L)	
	Total inorganic N input (kg/ha)		243.1		0.0

[1] DAT Days after transplantation

[2] For baseline seed rate survey results see SI Table S12. To have uniform seed rate across all treatments, a seed rate of 61kg/ha, which is within the range seen in baseline surveys, was used.

[3] For baseline survey results see SI Table S13. A higher rate of FYM was added across all treatments as recommended by local experts because this farm was a new rice plot which had been left fallow for several years. See SI Table 2.1 for %C content.

[4] For baseline survey results, see SI Tables S3 and S13. Because this was a new rice plot, inorganic N added to this farm was equal to the average amount used by the top 10% highest inorganic N using farmers in the survey.

[5] For matching survey results see SI Table S13

[6] Mixture of 200kg dry cowdung, 10L cow urine, 2kg jaggery,2kg pulse powder, handful of anthill soil after being left in a cool dry place for 7 days. %C and %N were assumed to be similar to FYM. See SI Table S25.

[7] Local liquid biofertilizer. 10kg cowdung, 10L cow urine, 2kg jaggery,2kg pulse powder, handful of anthill soil in 200L water, mixed regularly for 2 days. Total N% of Jeewamrutha assumed to be 0.2% (Kritee et.al. 2015)

[8] The range of %C in sheep manure was assumed to vary from 30 to 40% (Gibert et al, 2004)

[9] For total organic N calculations, refer to SI Table S25

Table S6 Farm 3 (2012) Baseline and alternate practices

Time (DAT)[1]	Parameters	Baseline Practices (BP)		Alternate practices (AP)	
			Chemical[7] N (kg/ha)		Chemical[7] N (kg/ha)
0	Seed rate[2] (kg/ha)	148		49	
0	Farm Yard Manure[3] (t/ha)			12.3	
0	Basal Dose	DAP[4] (217)	38	Azolla[5] (247) SSP (247)	
10 to 19*	Second dose	Urea[4] (207.5) MoP[4] (124)	95	Urea (44.5) Neem Cake[6] (17) MoP (24.7)	20
26	Third dose (AP)			Urea (44.5) Neem cake[6] (17.3) Zinc Sulphate (12.4)	20
37	Fourth dose (AP)			Urea (44.5) Potash (24.7)	20
46	Third dose (BP)	Urea[4](188) Mop[4] (124)	86		
	Total inorganic N input (kg/ha)		219.0		61.1

[1] DAT Days after transplantation

[2] For matching survey seed rate, see SI Table S14. Because of large difference between survey results for seed rate and AP seed rate recommended by local stakeholders. Seed rates were kept different for AP and BP treatment

[3] Since FYM application was not a mainstream practice as evident from the surveys, BP plots were not treated with FYM. For AP plot, total N% in FYM was assumed to be 0.5%. Total % O.C assumed ranged from 18 to 22% (Tennakoon and Hemamala-Bandara, 2003).

[4] See matching survey results in SI Table S15. MoP stands for Muriate of Potash and SSP stands for Single Superphosphate.

[5] See SI Table S26

[6] Total % N in neem cake is assumed to be 5 and C% varies between 25 and 50.

[7] For total organic N calculations, refer to SI Table S26

* For actual application dates, refer to SI Fig. S5.

Table S7 Farm 3 (2013) Baseline and alternate practices

Time (DAT)[1]	Parameters	Baseline Practices (BP)		Alternate practices (AP)	
			Chemical[9] N (kg/ha)		Chemical[9] N (kg/ha)
0	Seed rate[2]	148		49	
-5	Farm Yard Manure[3] (t/ha)	3.5		12.4	
0	Basal dose	Complex (208)[4]	35	Enriched FYM[5] (1236)	
15		-		Green growth (2.5 L)[6]	
18	Second dose	Urea (210)[4] MoP (121)[4]	96	Urea (44) Neem cake (17)[7] MoP (25)	20
28 to 35*	Third dose (AP)	- - - -		*Amudha Karaisal* (500L)[8] Groundnut cake (49.5)[7] Green growth (2.5 L)[8] MoP (25)	
46	Third dose (BP)	Urea (153)[4]	70	-	
46	Fourth dose (AP)	-		Groundnut cake (49.5)[7] *Themore karaisal* (25 L)[8]	
	Total inorganic N input (kg/ha)		202		20

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[1] DAT Days after transplantation

[2] For matching survey seed rate, see SI Table S16. Because of large difference between survey results for seed rate and AP seed rate recommended by local stakeholders. Seed rates were kept different for AP and BP treatment. For BP, seed rate which is within the range of survey results were used.

[3] FYM was added by 71% farmers as per 2013 surveys, see SI Table S17.

[4] See matching survey results in SI Table S18. Complex 17:17:17.

[5] Enriched FYM has 500kg FYM, 1kg Pseudomonas, 1kg Phospho bacteria, 1 kg *Trichoderma viride*, 1 kg *Metarhizium Sp.*, 250ml *Verticelium lecanni*, 250ml *Azospirillum*, 250ml Potash mobilizer, 1litre sea weed, 200ml Humic acid, 1litre green growth and 200 litres Amudhakaraisal. Because of small quantities of other mostly liquid ingredients, total N% and C% of enriched FYM was assumed to be similar to FYM.

[6] Local liquid biofertilizers. Amudha Karaisal is mixture of 1 kg of fresh cow dung, urine and Ipomoea Cornea leaves each and 25 gm of jaggery in 10 litres of water which is stirred (3X/day) and used after 24 hrs by diluting in 10 L water. Green Growth is 1:20 dilution of 1 kg of jaggery is dissolved in 20 L of water and 1 L of "mother culture". Themore karaisal is a mixture of 6 grated coconut, 2 L of butter milk, 0.5 kg jaggery, 10 bananas incubated for 15 days and spraye at 1: 20 ratio (Chandra, 2005),

[8] Total %C in groundnut and neem cake is assumed to be between 25 and 50% (Chong, 2005).

[9] For total organic N calculations, refer to SI Table S27

[*] For actual application dates, refer to SI Fig. S6

Table S8 Farm 4 (2014) Baseline and alternate practices

Time (DAT)[1]	Parameters	Baseline Practices (BP)		Alternate practices (AP)	
			Chemical[7] N (kg/ha)		Chemical[7] N (kg/ha)
-1	FYM[2]	5580		4940	
0	Basal Dose	DAP (185)[3]	32	Enriched FYM (1235)[4] SSP (247)	
21	Second dose	Urea (185)[5] MoP (124)[5]	85	Urea (74) Neem cake (12)[6]	34
39	Third dose	Urea (124)[3] MoP (124)[5]	57	Urea (49)	23
55	Fourth dose (AP)			Urea (74)	34
	Total inroganic N input (kg/ha)		174		91

[1] DAT Days after transplantation

[2] 44% of survey respondents used FYM, see SI Table S20 for matching input quantity.

[3] For matching survey results, see SI Table S21

[4] Enriched FYM has 500kg FYM, 1kg Pseudomonas, 1kg Phospho bacteria, 1 kg *Trichoderma viride*, 1 kg *Metarhizium Sp.*, 250ml *Verticelium lecanni*, 250ml *Azospirillum*, 250ml Potash mobilizer, 1litre sea weed, 200ml Humic acid, 1litre green growth and 200 litres *Amudhakaraisal.* Because of small quantities of other mostly liquid ingredients, total N% and C% of enriched FYM was assumed to be similar to FYM.

[5] For survey results see SI Table S21. BP inputs were slightly higher than average but within the range found in the survey results.

[6] Total %C in neem cake is assumed to vary between 25 and 50% (Chong, 2005)

[7] For total organic N calculations, refer to SI Table S28

Table S9 Farm 5 (2013) Baseline and alternate practices

Time (DAT)[1]	Parameters	Baseline Practices (BP)		Alternate practices (AP)	
			Chemical[8] N (kg/ha)		Chemical[8] N (kg/ha)
0	Seed rate[2]	88		32	
0-9*	Basal dose	Complex[3] (195)	33	SSP (124)	
				Urea (54)	25
				Neem cake (17)[4]	
18-24*	Second dose	Urea (111)[5]	51	Urea (54)	25
		MoP (62)[5]		Neem cake (17.3)	
		-		MoP (49.4)	
34-36	Third dose (AP)	-		Urea (54)	25
		-		Moistened sand (54)[6]	
		-		$ZnSO_4$ (2.47) in 250 L water	
43	Third dose (BP)	Urea (79)[5]	36	-	
		MoP (62)[7]		-	
51	Fourth dose (AP)	-		Urea (54)	25
		-		MoP (49.4)	
	Total inorganic N input (kg/ha)		120.0		99.4

[1] DAT Days after transplantation

[2] For baseline seed rate survey results see SI Table S22. Because of large difference between survey seed rate and AP treatment seed rate as suggested by local stakeholders. Seed rates were kept different for AP and BP treatment. For BP, seed rate which is within the range of survey results were used.

[3] For survey results see SI Table S23. Comples 17:17:17 was applied at a slightly lower rate within the range of survey results

[4] Total %C in neem cake is assumed to be between 25 and 50%.

[5] For matching survey results, see SI Table S23

[6] In times of cold weather, Urea uncubated overnight with moist soil helps to release N quickly during panicle initiation stage and protects rice plant from yield loss.

[7] For survey results see SI Table S23. As compared to surveys, a slightly higher rate that was within 1 SD of the average was applied.

[8] For total organic N calculations, refer to SI Table S29

SI Table S10 Farm 1: Seed rate survey results

Seed variety	Farmers (%)	Average seed rate (kg/ha)	SD	Earliest date of nursery sowing	Average Seedling age	SD seedling age (days)
BPT 5204	100%	96	33	01/04/11	36	7
Grand Total	**100%**	**96**	**33**	**01/04/11**	**36**	**7**

Table S11 Farm 1: Organic & Inorganic fertilizer use survey results

Events and type of input	Average rate(kg/ha)	SD	Farmer %
1	**5212**	**9666**	
Castor cake	368	283	2%
Complex 10:26:26	148	23	1%
Complex 17:17:17	2265	5822	5%
Complex 19:19:19	134	58	2%
Complex 20:20:00	124		1%
DAP	212	115	21%
FYM	11231	11890	57%
Green leaves	1096	1162	3%
Gromor	124	0	1%
Neem cake	535	311	2%
Sulphate	165		1%
Urea	143	95	16%
Zinc Sulphate	43	48	8%
Potash	145	81	7%
SSP	216	118	3%
2			
Biozyme	82		1%
Complex 13:00:25	82		1%
Complex 17:17:17	135	56	17%
Complex 19:19:19	100	34	3%
Complex 20:20:0:13	126	4	2%
Complex 20:20:00	215	137	5%
DAP	213	234	38%
FYM	7410		1%
Green leaves	1833	1622	4%
Gromor	134	18	2%
Neem cake	153	68	3%
Sulphate	206	71	2%
Urea	127	63	55%
Zinc Sulphate	53	55	11%
Potash	142	81	9%
SSP	193	130	7%
3			
Biozyme	20		1%
Castor cake	494		1%
Complex 10:26:26	132		1%
Complex 14:35:14	189	82	1%
Complex 17:17:17	138	113	10%
Complex 19:19:19	226	179	3%
DAP	159	94	17%
Neem cake	103	29	1%
Pirodan	12		1%
Sulphate	110	48	3%
Urea	133	64	40%
Zinc Sulphate	31		1%
Potash	168	63	13%
4			
Ammomium sulphate	132		1%
Biozyme	30		1%
Complex 17:17:17	139	78	3%
Complex 20:20:00	62		1%
DAP	124	0	3%
Sulphate	130	72	6%
Urea	135	55	18%
Zinc Sulphate	16		1%
Potash	113	30	4%

SI Table S12 Farm 2: Seed rate survey results

Seed variety	Farmer (%)	Average seed rate (kg/ha)	SD	Earliest Date of nursery sowing	Average seedling age	SD seedling age (days)
BPT 5204	52.00	70	30	25/05/12	36	12
IR 64	4.00	83	19	20/05/12	40	3
MTU 1010	6.00	44	52	04/06/12	32	3
NLR masura	10.00	115	49	25/05/12	43	16
R.N.R	6.00	82	20	10/06/12	33	4
Grand Total	**78.00**	**75**	**37**	**20/05/12**	**36**	**11**

SI Table S13 Farm 2: Organic & Inorganic fertilizer use survey results

Row Labels	Average of Quantity (kg/ha)	SD	Farmer %
0	**4412**	**3272**	41.1%
FYM	4526	3239	41.1%
Neem cake	165		1.1%
1			
Ammonia sulphate	124	0	2.2%
Castor Cake	124	87	5.6%
complex 12:00:20	165		1.1%
complex 17:17:17	263	134	14.4%
complex 17:17:17	154		1.1%
complex 20:20:00	207	158	6.7%
complex 20:20:20	103	29	2.2%
DAP	248	80	46.7%
Gravils	40		1.1%
Neem cake	185	87	2.2%
Potash	171	107	14.4%
SSP	136	39	11.1%
Thimet capsule	6		1.1%
Urea	226	135	41.1%
2			
Castor Cake	103	29	2.2%
complex 10:26:26	247	0	2.2%
complex 17:17:17	124	0	3.3%
complex 19:19:19	165		1.1%
complex 20:20:00	247	0	2.2%
complex 20:20:20	82		1.1%
DAP	216	93	14.4%
Gravils	20		1.1%
Potash	124	0	2.2%
Urea	187	185	24.4%
Zip gold	309		1.1%
3			
Ammonia sulphate	124		1.1%
Castor Cake	82		1.1%
complex 17:17:17	124		2.2%
complex 19:19:19	124		1.1%
complex 20:20:20	124		1.1%
DAP	124		1.1%
florite capsule	5		1.1%
Potash	93		1.1%
SSP	41	0	3.3%
Urea	163	87	10.0%
4			
Ammonia sulphate	82		1.1%
Potash	98		1.1%

SI Table S14 Farm 3 (2012): Seed rate survey results

Seed variety	Farmer (%)	Average seed rate kg/ha	SD	Earliest Date of nursery sowing	Average seedling age	SD seedling age (days)
CR	8%			10/08/11	33	19
Ponni	2%			10/08/11	41	
ADT39	88%	145	56	10/08/11	35	6
BPT	2%			05/09/11	40	
Grand Total	**100%**	**145**	**56**	**40765**	**35**	**7**

SI Table S15 Farm 3 (2012): Organic & Inorganic fertilizer use survey results

Events and type of input	Average rate (kg/ha)	StdDev of Quantity (kg/ha)2	% of farmers
1	**190**	**85**	
Complex 17:17:17	235	73	28%
Complex 20:20:0	256	55	22%
Complex 20:20:20	232	64	12%
DAP	219	60	45%
MoP	77	32	7%
SSP	137	24	5%
Urea	107	33	32%
Zinc Sulphate	20	10	5%
2	**162**	**70**	193%
Complex 17:17:17	74		
Complex 20:20:0	124		2%
MoP	123	32	82%
Neem cake	39	9	5%
Urea	210	57	98%
Valarchi kurunai	20		2%
Zinc Sulphate	7	1	3%
3	**150**	**62**	195%
Ammonium Sulphate	135	63	12%
MoP	122	21	78%
Neem cake	37	21	5%
Urea	190	56	93%
Valarchi kurunai	21	24	5%
Zinc Sulphate	62		2%
4	**124**	**35**	17%
Ammonium Sulphate	124	29	8%
MoP	103	36	5%
Urea	154	44	3%
Grand Total			

SI Table S16 Farm 3 (2013): Seed rate survey results

Seed variety	Farmer (%)	Average seed rate (kg/ha)	SD	Earliest date of nursery sowing	Average seedling age	SD seedling age (days)
ADT 37	1%	148		15/09/12	35	
ADT 39	60%	123	26	01/09/12	34	4
ADT 45	1%	148		05/09/12	35	
CR	6%	140	29	25/08/12	39	15
PPT	31%	132	28	20/08/12	38	5
Grand Total	**100%**	**128**	**27**	**20/08/12**	**35**	**6**

SI Table S17 Farm 3 (2013): Organic fertilizer use survey results

Row Labels	Average of Quantity applied (kg/ha)	SD	% of farmers
1	**3445**	**1245**	
FYM	3445	1245	71
	3445	**1245**	

SI Table S18 Farm 3 (2013): Inorganic fertilizer use survey results

Events and type of input	**Average rate (kg/ha)**	**SD**	**% of farmers**
1	**175**	**64**	141%
Complex 17:17:17	207	40	59%
Complex 20:20:0	239	18	7%
DAP	190	47	36%
SSP	124		1%
Urea	105	57	39%
2	**134**	**90**	221%
Alvin wonder	7		1%
Alwin gold	10	3	9%
Kurunaimaranthu	8	4	39%
MoP	121	29	66%
Neem cake	19	9	3%
Urea	211	53	101%
Zinc sulphate	4	2	3%
3	**122**	**55**	201%
Ammonium sulphate	93	31	4%
Kurunaimaranthu	11	9	9%
MoP	105	31	87%
Neem cake	30		1%
Urea	152	51	97%
Zinc sulphate	28	4	3%
4	**92**	**35**	60%
Alwin top	0		1%
Ammonium sulphate	104	29	33%
MoP	66	27	10%
Urea	97	31	14%
Zinc sulphate	49		1%
Grand Total			

SI Table S19 Farm 4: Seed rate survey results

Seed variety	Farmer (%)	Average seed rate (kg/ha)	SD	Earliest date of nursery sowing	Average seedling age	SD seedling age (days)
Andhra ponni	13%	97	28	07/08/13	32	3
BPT	10%	126	44	21/08/13	35	4
CR	12%	131	43	13/08/13	39	6
Ponni	10%	108	33	13/08/13	36	6
ADT36	4%	130	23	20/01/13	32	3
ADT37	6%	104	35	05/02/13	33	3
ADT39	46%	125	42	20/08/13	32	3
Grand Total	**100%**	**120**	**40**	**20/01/13**	**34**	**5**

SI Table S20 Farm 4 Organic fertilizer use survey results

	Average rate (kg/ha)	SD	% of farmers
1	**5460**	**3274**	
FYM	5473	3283	44%
Mill manure	3705		0%
Thakkai poondu			0%
Grand Total			

SI Table S21 Farm 4 Inorganic fertilizer use survey results

	Average rate (kg/ha)	SD	% of farmers
1	**177**	**74**	
Urea	114	48	26%
MoP	124		0%
Complex 17:17:17	212	67	35%
DAP	188	61	47%
Complex 20:20:20	165	74	3%
Complex 20:20:0	143	29	1%
SSP	593		0%
Complex	145	74	4%
2			
Urea	179	72	90%
MoP	105	33	43%
Kuranamarunthu	29	51	3%
Complex 17:17:17	158	108	2%
Energy nutrients	19	13	2%
Ammonium sulphate	107	23	2%
Neem cake	111	17	1%
Sulphate	185		0%
3			
Urea	127	56	76%
MoP	103	36	64%
Energy nutrients	12		0%
Ammonium sulphate	86	27	2%
Sulphate	89	33	2%
Ammonium chloride	93	44	1%
Grand Total			

SI Table S22 Farm 5 Seed rate survey results

Seed variety	Farmer (%)	Average seed rate (kg/ha)	SD	Earliest date of nursery sowing	Average seedling age	SD seedling age (days)
ADT 39	14%	81	31	17/10/12	24	5
ADT 45	22%	80	16	26/10/12	28	3
ASD 16	44%	82	23	19/10/12	29	5
BPT 5124	8%	71	7	13/10/12	29	3
CO 45	13%	91	25	21/10/12	29	2
Grand Total	**100%**	**81**	**23**	**41195**	**28**	**4**

SI Table S23 Farm 5: Inorganic fertilizer use by BP farmers based on survey

Row Labels	Average input Quantity (kg/ha)	SD	% of farmers
1	**157**	**75**	
Complex 17:17:17	208	43	47%
Complex 20:20:0:13	197	40	8%
DAP	166	44	46%
Urea	73	71	37%
2			
Ammonium sulphate	52	20	17%
DAP	62		1%
MoP	68	33	46%
Neem Cake	35	19	23%
Urea	111	48	100%
Zinc sulphate	22		1%
3			
Ammonium sulphate	52	29	50%
MoP	52	25	79%
Neem Cake	21	11	6%
Urea	81	45	60%
4			
Ammonium sulphate	62		1%
MoP	25		1%
Urea	37		1%
Grand Total			

Table S24 Cumulative mineralized N input during the cropping season at Farm 1 (2012)

	Baseline Practices						***Alternate practices****					
	Input name	**Amount (kg/ha)**	**Total %N**	**Set 1[#]**	**Set 2[##]**	**Set 3[###]**	**Input name**	**Amount (kg/ha)**	**Total %N**	**Set 1[#]**	**Set 2[##]**	**Set 3[###]**
2012	FYM**	10478	0.5	5.2	6.8	23.6	FYM	10478	0.5	5.2	6.8	23.6
	Green Leaves***	9730	0.64	6.2	8.1	28.0	Green leaves	9730	0.64	6.2	8.1	28.0
							*GJWM***	494	0.75	0.4	0.5	1.7
							Neem Cake **	247	5	1.2	1.6	5.6
2011	FYM	10478	0.5	21.0	3.7	10.5	FYM	10478	0.5	21.0	3.7	10.5
2010	FYM	10478	0.5	7.9	2.9	5.2	FYM	10478	0.5	7.9	2.9	5.2
Total mineralized org N available in 2012				40.3	21.5	67.3				41.9	23.5	74.5

[#] Set 1 corresponds to mineralization of 10, 40,15% of the total N in 1st, 2nd and 3rd year after application of organic matter

[##] Set 2 corresponds to mineralization of 13, 7,5.5% of the total N in 1st, 2nd and 3rd year after application of organic matter

[###] Set 3 corresponds to mineralization of 45, 20,10% of the total N in 1st, 2nd and 3rd year after application of organic matter

**Jeevamrutha* is a local liquid biofertilizer. It contains negligible amount of N (Kritee et al. 2015) and therefore its contribution was not added in this table

**Total N% in FYM, Neem cake and GJWM is 0.5%, 5% and 0.75% respectively (Kritee et al, 2015).

*** Total N% in green leaves (Gliricidia) was assumed to be 0.64% based on a regional study (Kundu et al, 1993, IRRI)

Table S25 Cumulative mineralized N input during the cropping season at Farm 2 (2013)

	Baseline Practices						***Alternate practices****					
	Input name	**Amount (kg/ha)**	**Total %N**	**Set 1$^{\#}$**	**Set 2$^{\#\#}$**	**Set 3$^{\#\#\#}$**	**Input name**	**Amount (kg/ha)**	**Total %N**	**Set 1$^{\#}$**	**Set 2$^{\#\#}$**	**Set 3$^{\#\#\#}$**
2013	FYM	30875	0.5	15.4	20.1	69.5	FYM	46312	0.5	23.2	30.1	104.2
							Sheep manure**	192	1.98	0.4	0.5	1.7
2012	Land was fallow in 2012							Land was fallow in 2012				
2011	Land was fallow in 2011							Land was fallow in 2011				
Total mineralized org N available in 2013				15.4	20.1	69.5				23.5	30.6	105.9

Set 1 corresponds to mineralization of 10, 40,15% of the total N in 1st, 2nd and 3rd year after application of organic matter

Set 2 corresponds to mineralization of 13, 7,5.5% of the total N in 1st, 2nd and 3rd year after application of organic matter

Set 3 corresponds to mineralization of 45, 20,10% of the total N in 1st, 2nd and 3rd year after application of organic matter

* *Jeevamrutha* is a local liquid biofertilizer. It contains negligible amount of N (Kritee et al. 2015) and therefore its contribution was not added in this table

** Sheep manure was assumed to have 1.98% N (Gibert, 2004)

Table S26 Cumulative mineralized N input during the cropping season at Farm 3 (2012)

	Baseline Practices						*Alternate practices*					
	Input name	**Amount (kg/ha)**	**Total %N**	**Set 1[#]**	**Set 2[##]**	**Set 3[###]**	**Input name**	**Amount (kg/ha)**	**Total %N**	**Set 1[#]**	**Set 2[##]**	**Set 3[###]**
2012	FYM	0	0.5	0.0	0.0	0.0	FYM	12350	0.5	6.2	8.0	27.8
							Azolla*			5.0	6.5	22.5
							Neem Cake	34.58	5	0.2	0.2	0.8
2011	FYM	5000	0.5	10.0	1.8	5.0	FYM	5000	0.5	10.0	1.8	5.0
2010	FYM		Farmer add FYM on alternate years. No FYM was added in 2010 in this farm				FYM		Farmer add FYM on alternate years. No FYM was added in 2010 in this farm			
Total mineralized org N available in 2012				10.0	1.8	5.0				21.3	16.5	56.1

Set 1 corresponds to mineralization of 10, 40,15% of the total N in 1st, 2nd and 3rd year after application of organic matter

Set 2 corresponds to mineralization of 13, 7,5.5% of the total N in 1st, 2nd and 3rd year after application of organic matter

Set 3 corresponds to mineralization of 45, 20,10% of the total N in 1st, 2nd and 3rd year after application of organic matter

*Heterosporous free-floating freshwater ferns that live symbiotically with Anabaena azollae, a nitrogen-fixing blue-green algae. The estimates of N fixed by azolla can fix vary from 53 to 1000 kg/ha N, with dry matter production between 39 and 390 tons/ha, in crop cycles of 40–365 days {FAO, 2009 #357}. At Farm 3, Azolla dried up ~30 days after inoculation and we assume that a total of 50 Kg N/ha was fixed in azolla which matches the estimates used earlier {Akiyama, 2005 #190}. Using a C:N ratio of 10 {Ferentinos, 2002 #356}, the minimum organic C from azolla was estimated to be 500 and based on the range of dry matter production{Ferentinos, 2002 #356}, the maximum estimate was placed at 1000 Kg C/ha.

Table S27 Cumulative mineralized N input during the cropping season at Farm 3 (2013)

	Baseline Practices						***Alternate practices***					
	Input name	**Amount (kg/ha)**	**Total %N**	**Set 1**[#]	**Set 2**[##]	**Set 3**[###]	**Input name**	**Amount (kg/ha)**	**Total %N**	**Set 1**[#]	**Set 2**[##]	**Set 3**[###]
2013	FYM	3459	0.5	1.7	2.2	7.8	FYM	12355	0.5	6.2	8.0	27.8
							Enriched FYM	1236	0.5	0.6	0.8	2.8
							Groundnut cake*	98	4	0.4	0.5	1.8
							Neem Cake	17	5	0.1	0.1	0.4
2012	FYM		Farmer add FYM on alternate years. No FYM was added in 2012 in this farm				FYM	12350	0.5	24.7	4.3	12.4
							Azolla**			19.2	3.4	9.6
							Neem Cake	34.58	5	0.7	0.1	0.3
2011	FYM	5000	0.5	3.8	1.4	2.5	FYM	5000	0.5	3.8	1.4	2.5
Total mineralized org N available in 2013				5.5	3.6	10.3				55.6	18.6	57.5

Set 1 corresponds to mineralization of 10, 40,15% of the total N in 1st, 2nd and 3rd year after application of organic matter

Set 2 corresponds to mineralization of 13, 7,5.5% of the total N in 1st, 2nd and 3rd year after application of organic matter

Set 3 corresponds to mineralization of 45, 20,10% of the total N in 1st, 2nd and 3rd year after application of organic matter

*Total % N in Groundnut cake assumed to be 7 (Average of Chong, 2005)

** See SI Table 4.3

Table S28 Cumulative mineralized N input during the cropping season at Farm 4 (2014)

	Baseline Practices						***Alternate practices***					
	Input name	**Amount (kg/ha)**	**Total %N**	**Set 1[#]**	**Set 2[##]**	**Set 3[###]**	**Input name**	**Amount (kg/ha)**	**Total %N**	**Set 1[#]**	**Set 2[##]**	**Set 3[###]**
2014	FYM	5580	0.5	2.8	3.6	12.6	FYM	4940	0.5	2.5	3.2	11.1
							Enriched FYM	1235	0.5	0.6	0.8	2.8
							Neem Cake	12	5	0.1	0.1	0.3
2013	FYM		*Farmer add FYM on alternate years. No FYM was added in 2013*				FYM		*Farmer add FYM on alternate years. No FYM was added in 2013*			
2012	FYM	5000	0.5	3.8	1.4	2.5	FYM	5000	0.5	3.8	1.4	2.5
Total mineralized org N available in 2014				6.5	5.0	15.1				6.9	5.5	16.7

[#] Set 1 corresponds to mineralization of 10, 40,15% of the total N in 1st, 2nd and 3rd year after application of organic matter

[##] Set 2 corresponds to mineralization of 13, 7,5.5% of the total N in 1st, 2nd and 3rd year after application of organic matter

[###] Set 3 corresponds to mineralization of 45, 20,10% of the total N in 1st, 2nd and 3rd year after application of organic matter

Table S29 Cumulative mineralized N input during the cropping season at Farm 5 (2013)

	Baseline Practices						Alternate practices					
	Input name	Amount (kg/ha)	Total %N	Set 1#	Set 2##	Set 3###	Input name	Amount (kg/ha)	Total %N	Set 1#	Set 2##	Set 3###
2013	*Baseline farmers do not use any organic inputs in this region*						FYM Neem Cake	0 34	0.5 5	0.0 0.2	0.0 0.2	0.0 0.8
2012	*Baseline farmers do not use any organic inputs in this region*						*Baseline farmers do not use any organic inputs in this region*					
2011	*Baseline farmers do not use any organic inputs in this region*						*Baseline farmers do not use any organic inputs in this region*					
Total mineralized org N available in 2013				0.0	0.0	0.0				0.2	0.2	0.8

Set 1 corresponds to mineralization of 10, 40,15% of the total N in 1st, 2nd and 3rd year after application of organic matter

Set 2 corresponds to mineralization of 13, 7,5.5% of the total N in 1st, 2nd and 3rd year after application of organic matter

Set 3 corresponds to mineralization of 45, 20,10% of the total N in 1st, 2nd and 3rd year after application of organic matter

Table S30: Evidence of variation in nitrous oxide flux due to inorganic or organic N inputs and drainage events

Season/treatment		N_2O (Kg/ha)	N_2O-N (Kg/ha)	Inorganic N (kg/ha)	Min organic N	Max organic N	Max EF	Min EF	Nitrogen[1] input 1			Nitrogen[1] input 2			Nitrogen[1] input 3			Nitrogen[1] input 4			Clear evidence of high N_2O coinciding with drainage[2]		High N_2O 1-3 days after drainage	
									Rise	Peak	End	Rise	Peak	End	Rise	Peak	End	Rise	Peak	End		(DAT)		(DAT)
Farm 1 2012	BP 1	14.8	9.4	91	21.5	67.3	8.3%	5.9%	10	12	16	1	4	20							✓✓	12,45		
	BP2	17.3	11.0	91	21.5	67.3	9.8%	6.9%	10	20	31	1	3	13							✓✓✓✓	20,28, 42, 44	✓	15
	BP3	7.1	4.5	91	21.5	67.3	4.0%	2.8%				2	4	14							✓	45		
	AP 1	6.2	4.0	0	23.5	74.5	16.9%	5.3%	12	21	92										✓✓	30, 103	✓✓✓✓	21, 35, 51, 61
	AP2	4.2	2.7	0	23.5	74.5	11.3%	3.6%	10	28	62										✓✓✓✓	19, 28, 51, 54	✓✓✓✓	12,15, 21,37
	AP 3	3.7	2.3	0	23.5	74.5	10.0%	3.2%	6	19	67										✓✓✓	19,30,54		
Farm 2 2013	BP 1	0.3	0.2	243	15.4	69.5	0.09%	0.07%							3	9	11							
	BP2	1.1	0.7	243	15.4	69.5	0.27%	0.22%	2	11	15													
	BP3	0.4	0.3	243	15.4	69.5	0.10%	0.08%							1	10	14							
	AP 1	0.3	0.2	0	23.5	105.6	0.80%	0.18%																
	AP2	0.0	0.0	0	23.5	105.6																		
	AP 3	0.0	0.0	0	23.5	105.6	0.10%	0.02%															✓	49
Farm 3 2012	BP 1	21.9	13.9	219	1.8	10.0	6.3%	6.1%				2	8	21		1	2							
	BP2	16.6	10.6	219	1.8	10.0	4.8%	4.6%				2	8	14										
	BP3	29.7	18.9	219	1.8	10.0	8.6%	8.3%				1	8	21		1	2				✓	39		
	AP 1	1.8	1.2	61	16.5	56.1	1.5%	1.0%										1	2	3	✓	39		
	AP2	2.7	1.7	61	16.5	56.1	2.2%	1.4%										1	2	3	✓	39		
	AP 3	3.0	1.9	61	16.5	56.1	2.5%	1.7%										1	2	3	✓	39		
Farm 3 2013	BP 1	12.2	7.8	202	3.6	10.28	3.8%	3.7%				2	3	10		1	6				✓✓✓	21,47,48		
	BP2	7.2	4.6	202	3.6	10.28	2.2%	2.2%				2	3	5	1	2	6				✓✓✓	21,47, 48		
	BP3	32.8	20.9	202	3.6	10.28	10.2%	9.9%				2	9	21		1	4				✓✓✓✓✓	28,29, 46,47, 48		
	AP 1	2.5	1.6	20	19.1	58.81	4.1%	2.0%										13	16	21	✓	62		
	AP2	12.7	8.1	20	19.1	58.81	20.5%	10.2%				1	2	5				13	16	21	✓	62		
	AP 3	19.3	12.3	20	19.1	58.81	31.1%	15.5%				1	2	5	0	1	6	13	16	27	✓✓✓	62,20,29		
Farm 4 2014	BP 1	1.2	0.8	174	5.0	15.1	0.4%	0.4%				2	4	10										
	BP2	1.4	0.9	174	5.0	15.1	0.5%	0.5%				4	12	15	0	0	1				✓	33	✓	40
	BP3	0.0	0.0	174	5.0	15.1	0.0%	0.0%				1	4	10									✓	40
	AP 1	-0.1	-0.1	91	5.5	16.7																	✓	39
	AP2	-0.1	0.0	91	5.5	16.7									1	3	4							
	AP 3	0.2	0.1	91	5.5	16.7	0.14%	0.13%													✓	92		
	C1	-0.6	-0.4	0	0.0	0.0															✓	23		
	C2	-0.8	-0.5	0	0.0	0.0															✓	23		
Farm 5 2013	BP 1	0.2	0.1	121	0.0	0.0	0.11%	0.11%																
	BP2	0.9	0.6	121	0.0	0.0	0.49%	0.49%							2	4	13							
	BP3	3.0	1.9	121	0.0	0.0	1.60%	1.60%				6	8	19	3	4	9							
	AP 1	2.4	1.5	99	0.2	0.8	1.51%	1.50%	1	5	7	0	1	5	0	4	13							
	AP2	3.5	2.3	99	0.2	0.8	2.26%	2.25%	2	5	6	0	1	6	3	5	21	8	10	12	✓	40	✓✓✓	14, 19,23,41
	AP 3	1.5	1.0	99	0.2	0.8	0.96%	0.96%	3	5	6	0	4	6									✓✓✓✓	14,19,22

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[1] These columns record how many days after the addition of nitrogen did N_2O flux started increasing, when did it first peak and when did it decline back to the background levels. See supporting Figs. S3 to S8. Generally, AP plots had lower rate (but higher number) of nitrogen inputs. When high amount of organic matter is added with or without inorganic N, the entries are in red font.

[2] Each ✓implies one evidence of drainage related N2O flux for that replicate treatment. Drainage is defined as water level below -7.5 cm. When the color of ✓is red, drainage implies that the recorded water level was below 0 cm after at least 4 days of flooding.

Table S31: Evidence of variation in methane flux due to drainage events and growth stages

Season and treatment		CH_4 (Kg/ha)	CH_4 ($tCO2e_{100}$/ha)	CH_4 (tCO_2e_{20}/ha)	Water Index	Drainage[1]	Drainage related DAT	Growth stages (DAT) Tillering (5-15)	Active tillering (20-35)	Panicle initiation (35-45)	Flowering (50-65)	Grain filling
Farm 1 2012	BP 1	74.9	2.5	6.4	-581			✓		✓		
	BP2	29.1	1.0	2.5	-614			✓				
	BP3	95.4	3.2	8.2	-470	✓	10	✓		✓		
	AP 1	148.9	5.1	12.8	-516	✓	20	✓		✓	✓	
	AP2	28.8	1.0	2.5	-726							
	AP 3	65.5	2.2	5.6	-497	✓✓	10,19			✓		
Farm 2 2013	BP 1	103.3	3.5	8.9	-35	✓	92				✓	✓
	BP2	112.0	3.8	9.6	19	✓	92				✓	✓
	BP3	99.5	3.4	8.6	14	✓	32	✓	✓	✓		
	AP 1	40.5	1.4	3.5	-135	✓	22					✓
	AP2	84.3	2.9	7.3	-158	✓	26					✓
	AP 3	170.0	5.8	14.6	-162	✓✓	16, 43	✓	✓	✓	✓	✓
Farm 3 2012	BP 1	8.9	0.3	0.8	-478	✓	18					
	BP2	0.9	0.0	0.1	-496							
	BP3	2.1	0.1	0.2	-484							
	AP 1	4.2	0.1	0.4	-454							
	AP2	4.9	0.2	0.4	-461							
	AP 3	4.5	0.2	0.4	-334					✓		
Farm 3 2013	BP 1	118.4	4.0	10.2	-1046	✓	20	✓				
	BP2	98.6	3.4	8.5	-1020			✓				
	BP3	109.2	3.7	9.4	-1042	✓	20	✓				
	AP 1	92.6	3.1	8.0	-852			✓				
	AP2	97.9	3.3	8.4	-907	✓✓	5, (42-48)	✓				
	AP 3	146.9	5.0	12.6	-815	✓✓	28 ,7	✓				
Farm 4 2014	BP 1	131.3	4.5	11.3	-149	✓✓✓✓	21,33,34, 83	✓				
	BP2	131.1	4.5	11.3	-256	✓	21	✓				
	BP3	160.8	5.5	13.8	-232	✓✓	20, 21	✓				
	AP 1	203.3	6.9	17.5	-424	✓✓✓	12,15, 82,29	✓				
	AP2	107.4	3.7	9.2	-172			✓				
	AP 3	151.5	5.1	13.0	-352	✓	29	✓				
	C1	221.9	7.5	19.1	-268	✓✓	15, 23	✓	✓			
	C2	163.2	5.5	14.0	-232	✓	21	✓	✓			
Farm 5 2013	BP 1	260.4	8.9	22.4	-18	✓	20	✓	✓	✓		✓
	BP2	336.1	11.4	28.9	-7	✓	15	✓	✓	✓		✓
	BP3	261.6	8.9	22.5	69	✓	5	✓	✓	✓	✓	✓
	AP 1	303.4	10.3	26.1	-96	✓✓	5,85	✓		✓	✓	✓
	AP2	191.3	6.5	16.4	-226	✓✓✓✓	5,10,14,19	✓				
	AP 3	153.9	5.2	13.2	-146	✓✓✓✓	5,10,14,19	✓				

[1] Each ✓ implies one evidence of drainage related methane flux for that replicate treatment. Drainage is defined as water level below -7.5 cm. When the color of tick-mark is red (✓), drainage implies that the recorded water level was below 0 cm after at least 4 days of flooding.

Table S32: Variables tested for multivariate regression analysis

	Season	N_2O-N (Kg/ha)	N_2O (tCO_2e_{20}/ha)	N_2O (tCO_2e_{100}/ha)	CH_4 (Kg/ha)	CH_4 (tCO_2e_{20}/ha)	CH_4 (tCO_2e_{100}/ha)	Total GWP tCO_2e_{20}/ha	Total GWP tCO_2e_{100}/ha	N_2O % contribution to GWP_{20}	N_2O % contribution to GWP_{100}	Water Index (cm)	Maximum duration of a flooded period (days)	Continuous flooding events (> 3 days)	Cumulative flooding (days)	# water level alternations (drainage + flooding events)	Yield dry grain (kg/ha)	Organic C input MIN (kg/ha)	Organic C input MAX (kg/ha)	Inorganic N (kg/ha)	Min organic N (kg/ha)	Max organic N (kg/ha)	Season length (days)	Growing degree days	Cumulative Max Temp	Cumulative Min temp	SOC %	Sand%	Silt %	Clay%	Clay/sand	Fines	Fines/Sand	pH	EC	WHC
Farm 1 2012	BP 1	9.4	4.0	4.4	74.9	6.4	2.5	10.4	7.0	38%	63%	-581	4	1	4	18	4796	3929	4543	91	21.5	67.3	113	1869	3786	2306	0.80	64.70	17.90	17.40	0.27	35.30	0.55	7.82	0.712	64
	BP2	11.0	4.6	5.2	29.1	2.5	1.0	7.1	6.1	65%	84%	-614	4	1	4	22	4796	3929	4543	91	21.5	67.3	113	1869	3786	2306	0.80	64.70	17.90	17.40	0.27	35.30	0.55	7.82	0.712	64
	BP3	4.5	1.9	2.1	95.4	8.2	3.2	10.1	5.4	19%	39%	-470	4	1	4	27	4796	3929	4543	91	21.5	67.3	113	1869	3786	2306	0.80	64.70	17.90	17.40	0.27	35.30	0.55	7.82	0.712	64
	AP 1	4.0	1.7	1.9	148.9	12.8	5.1	14.5	6.9	12%	27%	-516	4	1	4	15	3512	4080	4785	0	23.5	74.5	113	1869	3786	2306	0.80	70.7	16.9	12.50	0.177	29.400	0.416	7.66	0.8	56
	AP2	2.7	1.1	1.2	28.8	2.5	1.0	3.6	2.2	31%	56%	-726	4	1	4	16	3512	4080	4785	0	23.5	74.5	113	1869	3786	2306	0.80	70.7	16.9	12.50	0.177	29.400	0.416	7.66	0.8	56
	AP 3	2.3	1.0	1.1	65.5	5.6	2.2	6.6	3.3	15%	33%	-497	4	1	4	25	3512	4080	4785	0	23.5	74.5	113	1869	3786	2306	0.80	70.7	16.9	12.50	0.177	29.400	0.416	7.66	0.8	56
Farm 2 2013	BP 1	0.2	0.1	0.1	103.3	8.9	3.5	9.0	3.6	1%	3%	-35	34	3	65	5	4800	5558	6793	243	15.4	69.5	104	1537.5	3267	1908	0.40	75.20	16.70	8.10	0.11	24.80	0.33	8.33	0.55	52
	BP2	0.7	0.3	0.3	112.0	9.6	3.8	9.9	4.1	3%	8%	19	41	2	63	7	4800	5558	6793	243	15.4	69.5	104	1537.5	3267	1908	0.40	75.20	16.70	8.10	0.11	24.80	0.33	8.33	0.55	52
	BP3	0.3	0.1	0.1	99.5	8.6	3.4	8.7	3.5	1%	3%	14	21	4	60	11	4800	5558	6793	243	15.4	69.5	104	1537.5	3267	1908	0.40	75.20	16.70	8.10	0.11	24.80	0.33	8.33	0.55	52
	AP 1	0.2	0.1	0.1	40.5	3.5	1.4	3.6	1.5	2%	6%	-135	26	3	37	13	2700	8394	10265	0	23.5	105.6	104	1537.5	3267	1908	0.41	77.10	16.70	6.30	0.08	23.00	0.30	8.2	0.46	55
	AP2	0.0	0.0	0.0	84.3	7.3	2.9	7.2	2.9	0%	0%	-158	26	3	41	14	2700	8394	10265	0	23.5	105.6	104	1537.5	3267	1908	0.41	77.10	16.70	6.30	0.08	23.00	0.30	8.2	0.46	55
	AP 3	0.0	0.0	0.0	170.0	14.6	5.8	14.6	5.8	0%	0%	-162	26	3	42	13	2700	8394	10265	0	23.5	105.6	104	1537.5	3267	1908	0.41	77.10	16.70	6.30	0.08	23.00	0.30	8.2	0.46	55
Farm 3 2012	BP 1	13.9	5.9	6.5	8.9	0.8	0.3	6.6	6.8	88%	96%	-478	2	0	2	29	4224	0	0	219	1.8	10.0	100	1753.5	3229	2298	0.29	60.70	12.40	26.90	0.44	39.30	0.65	7.69	0.35	59
	BP2	10.6	4.5	4.9	0.9	0.1	0.0	4.5	5.0	98%	99%	-496	2	0	2	31	4224	0	0	219	1.8	10.0	100	1753.5	3229	2298	0.29	60.70	12.40	26.90	0.44	39.30	0.65	7.69	0.35	59
	BP3	18.9	8.0	8.9	2.1	0.2	0.1	8.1	8.9	98%	99%	-484	2	0	2	27	4224	0	0	219	1.8	10.0	100	1753.5	3229	2298	0.29	60.70	12.40	26.90	0.44	39.30	0.65	7.69	0.35	59
	AP 1	1.2	0.5	0.5	4.2	0.4	0.1	0.9	0.7	58%	79%	-454	2	0	2	59	2682	2732	3735	61	16.5	56.1	107	1882	3459	2465	0.29	67.30	10.00	22.70	0.34	32.70	0.49	7.69	0.33	59
	AP2	1.7	0.7	0.8	4.9	0.4	0.2	1.1	1.0	63%	83%	-461	..	0	2	57	2682	2732	3735	61	16.5	56.1	107	1882	3459	2465	0.29	67.30	10.00	22.70	0.34	32.70	0.49	7.69	0.33	59
	AP 3	1.9	0.8	0.9	4.5	0.4	0.2	1.2	1.1	68%	86%	-334	2	0	2	47	2682	2732	3735	61	16.5	56.1	107	1882	3459	2465	0.29	67.30	10.00	22.70	0.34	32.70	0.49	7.69	0.33	59
Farm 3 2013	BP 1	7.8	3.3	3.6	118.4	10.2	4.0	13.5	7.7	24%	47%	-1046	7	3	16	23	5580	623	761	202	3.6	10.3	95	1544.5	2889	2140	0.29	60.70	12.40	26.90	0.44	39.30	0.65	7.69	0.35	59
	BP2	4.6	1.9	2.2	98.6	8.5	3.4	10.4	5.5	19%	39%	-1020	7	3	16	24	5580	623	761	202	3.6	10.3	95	1544.5	2889	2140	0.29	60.70	12.40	26.90	0.44	39.30	0.65	7.69	0.35	59
	BP3	20.9	8.8	9.8	109.2	9.4	3.7	18.2	13.5	48%	73%	-1042	7	3	16	22	5580	623	761	202	3.6	10.3	95	1544.5	2889	2140	0.29	60.70	12.40	26.90	0.44	39.30	0.65	7.69	0.35	59
	AP 1	1.6	0.7	0.8	92.6	8.0	3.1	8.6	3.9	8%	19%	-852	7	2	11	36	3964	2475	3049	20	19.1	58.8	107	1728	3261	2375	0.29	67.30	10.00	22.70	0.34	32.70	0.49	7.69	0.33	59
	AP2	8.1	3.4	3.8	97.9	8.4	3.3	11.8	7.1	29%	53%	-907	7	3	15	35	3964	2475	3049	20	19.1	58.8	107	1728	3261	2375	0.29	67.30	10.00	22.70	0.34	32.70	0.49	7.69	0.33	59
	AP 3	12.3	5.2	5.7	146.9	12.6	5.0	17.8	10.7	29%	53%	-815	7	3	15	45	3964	2475	3049	20	19.1	58.8	107	1728	3261	2375	0.29	67.30	10.00	22.70	0.34	32.70	0.49	7.69	0.33	59
Farm 4 2014	BP 1	0.8	0.3	0.4	131.3	11.3	4.5	11.6	4.8	3%	8%	-149	40	3	59	17	1288	1004	1228	174	5.0	15.1	98	1618	3156	2080	0.17	62.50	16.80	20.80	0.33	37.60	0.60	7.8	0.38	75
	BP2	0.9	0.4	0.4	131.1	11.3	4.5	11.6	4.9	3%	8%	-256	21	4	51	19	1288	1004	1228	174	5.0	15.1	98	1618	3156	2080	0.17	62.50	16.80	20.80	0.33	37.60	0.60	7.8	0.38	75
	BP3	0.0	0.01	0.013	160.8	13.8	5.5	13.8	5.5	0%	0%	-232	21	3	53	19	3477	1004	1228	174	5.0	15.1	98	1618	3156	2080	0.17	62.50	16.80	20.80	0.33	37.60	0.60	7.8	0.38	75
	AP 1	-0.1	-0.02	-0.025	203.3	17.5	6.9	17.5	6.9	0%	0%	-424	15	2	19	32	3477	1115	1365	91	5.5	16.7	97	1637	3193	2101	0.40	61.70	19.70	18.50	0.30	38.20	0.62	7.9	0.36	75
	AP2	0.0	-0.02	-0.022	107.4	9.2	3.7	9.2	3.6	0%	-1%	-172	23	5	43	32	3477	1115	1365	91	5.5	16.7	97	1637	3193	2101	0.40	61.70	19.70	18.50	0.30	38.20	0.62	7.9	0.36	75
	AP 3	0.1	0.1	0.1	151.5	13.0	5.1	13.1	5.2	0%	1%	-352	16	6	47	27	3174	1115	1365	91	5.5	16.7	97	1637	3193	2101	0.40	61.70	19.70	18.50	0.30	38.20	0.62	7.9	0.36	75
	C1	-0.4	-0.2	-0.2	221.9	19.1	7.5	18.9	7.4	-1%	-2%	-268	21	4	50	20	3174	0	0	0	0.0	0.0	97	1637	3193	2101	0.22	61.70	19.70	18.50	0.30	38.20	0.62	7.9	0.2	75
	C2	-0.5	-0.2	-0.2	163.2	14.0	5.5	13.8	5.3	-2%	-5%	-232	21	4	46	19	3174	0	0	0	0.0	0.0	97	1637	3193	2101	0.22	61.70	19.70	18.50	0.30	38.20	0.62	7.9	0.2	75
Farm 5 2013	BP 1	0.1	0.1	0.1	260.4	22.4	8.9	22.5	8.9	0%	1%	-18	25	4	62	9	6484	0	0	121	0.0	0.0	108	1672.8	2964	2317	0.95	64.70	17.30	18.02	0.28	35.32	0.55	7.9	0.2	64
	BP2	0.6	0.2	0.3	336.1	28.9	11.4	29.2	11.7	1%	2%	-7	38	2	63	5	6484	0	0	121	0.0	0.0	108	1672.8	2964	2317	0.95	64.70	17.30	18.02	0.28	35.32	0.55	7.9	0.2	64
	BP3	1.9	0.8	0.9	261.6	22.5	8.9	23.3	9.8	3%	9%	69	64	2	68	3	6484	0	0	121	0.0	0.0	108	1672.8	2964	2317	0.95	64.70	17.30	18.02	0.28	35.32	0.55	7.9	0.2	64
	AP 1	1.5	0.6	0.7	303.4	26.1	10.3	26.7	11.0	2%	6%	-96	19	6	55	16	6519	9	17	99	0.2	0.8	108	1672.8	2964	2317	0.96	64.90	18.20	16.85	0.26	35.05	0.54	7.9	0.2	64
	AP2	2.3	0.9	1.1	191.3	16.4	6.5	17.4	7.6	5%	14%	-226	18	5	40	17	6519	9	17	99	0.2	0.8	108	1672.8	2964	2317	0.96	64.90	18.20	16.85	0.26	35.05	0.54	7.9	0.2	64
	AP 3	1.0	0.4	0.4	153.9	13.2	5.2	13.6	5.7	3%	8%	-146	30	2	38	16	6519	9	17	99	0.2	0.8	108	1672.8	2964	2317	0.96	64.90	18.20	16.85	0.26	35.05	0.54	7.9	0.2	64

Table S33 Difference in climate impacts of farm-specific baseline and alternate practices

	Season	N_2O-N (kg/ha)	CH_4 (kg/ha)	Average N_2O-N (kg/ha)	Average CH_4 (kg/ha)	Total average climate impact (tCO_2e_{100}/ha)	Total average climate impact (tCO_2e_{20}/ha)	N_2O-N reduction (kg/ha)	CH_4 reduction (kg/ha)	N_2O reduction (tCO_2e_{100}/ha)	CH_4 reduction (tCO_2e_{100}/ha)	Total long-term mitigation (tCO_2e_{100}/ha)	Total short-term mitigation (tCO_2e_{20}/ha)	Reduction in inorganic N (kg/ha)	Reduction in yield (t/ha)	Reduction in yield (%)	Reduction in CO_2e_{100} (%)	Reduction in CO_2e_{20} (%)	Reduction in N_2O-N (%)	Reduction in CH_4 (%)
Farm 1 2012	BP 1	9.4	74.9	8.3	66.5	6.2	9.2													
	BP2	11.0	29.1																	
	BP3	4.5	95.4																	
	AP 1	4.0	148.9	3.0	81.1	4.2	8.2													
	AP2	2.7	28.8																	
	AP 3	2.3	65.5																	
Average BP - Average AP								5.3	-14.6	2.5	-0.5	2.0	**1.0**	91	0.20	4%	32%	11%	64%	-22%
Farm 2 2013	BP 1	0.2	103.3	0.4	104.9	3.8	9.2													
	BP2	0.7	112.0																	
	BP3	0.3	99.5																	
	AP 1	0.2	40.5	0.1	98.3	3.4	8.5													
	AP2	0.0	84.3																	
	AP 3	0.0	170.0																	
Average BP - Average AP								0.3	6.6	0.2	0.2	0.4	**0.7**	243	2.10	44%	10%	8%	84%	6%
Farm 3 2012	BP 1	13.9	8.9	14.5	4.0	6.9	6.4													
	BP2	10.6	0.9																	
	BP3	18.9	2.1																	
	AP 1	1.2	4.2	1.6	4.6	0.9	1.1													
	AP2	1.7	4.9																	
	AP 3	1.9	4.5																	
Average BP - Average AP								12.9	-0.6	6.0	0.0	6.0	**5.4**	158	1.50	37%	87%	83%	89%	-15%
Farm 3 2013	BP 1	7.8	118.4	11.1	108.7	8.9	14.0													
	BP2	4.6	98.6																	
	BP3	20.9	109.2																	
	AP 1	1.6	92.6	7.3	112.5	7.3	12.8													
	AP2	8.1	97.9																	
	AP 3	12.3	146.9																	
Average BP - Average AP								3.8	-3.8	1.8	-0.1	1.6	**1.3**	182	1.60	29%	18%	9%	34%	-3%
Farm 4 2014	BP 1	0.8	131.3	0.6	141.1	5.1	12.4													
	BP2	0.9	131.1																	
	BP3	0.0	160.8																	
	AP 1	-0.1	203.3	0.0	154.0	5.2	13.3													
	AP2	0.0	107.4																	
	AP 3	0.1	151.5																	
	C1	-0.4	221.9																	
	C2	-0.5	163.2																	
Average BP - Average AP								0.5	-13.0	0.3	-0.4	-0.2	**-0.9**	83	0.30	9%	-4%	-7%	98%	-9%
Farm 5 2013	BP 1	0.1	260.4	0.9	286.1	10.1	25.0													
	BP2	0.6	336.1																	
	BP3	1.9	261.6																	
	AP 1	1.5	303.4	1.6	216.2	8.1	19.3													
	AP2	2.3	191.3																	
	AP 3	1.0	153.9																	
Average BP - Average AP								-0.7	69.9	-0.3	2.4	2.1	**5.7**	22	0.00	-0.5%	20%	23%	-77%	24%

Table S34 Correlation coefficients between N_2O emissions and measured parameters.

Parameter	R
Water index	-0.72
Cumulative flooding (days)	-0.68
Maximum duration of flooding	-0.66
Clay/sand	0.63
Percent clay	0.63
Percent silt	-0.56
Continuous flooding events (>3 days)	-0.52
pH	-0.52
Fines/sand	0.41
Percent sand	-0.4
Cumulative temperature (min)	0.36
Inorganic nitrogen input	0.36
Percent fines	0.33
Water holding capacity	-0.31
Yield (dry grain)	0.29
Number of water level fluctuations	0.27
growing_deg_days	0.25
Organic carbon input (max)	-0.24
Organic carbon input (min)	-0.23
SOM	-0.12
Electric conductivity	0.11
Organic nitrogen input (max)	-0.1
Cumulative temperature (max)	0.05
Season length (days)	-0.04
Organic nitrogen (min)	-0.03

Table S35 Multivariate regression model that explains N_2O emissions by the combination of water index, flooding events and inorganic nitrogen. All parameters have a p-value< 0.05.

Parameters		Coefficients	SE	t value	Pr (> |t|)
Water index	β_1	-0.01	0.002	-4.99	0.0005
Continuous flooding events (>3 days)	β_2	-0.915	0.359	-2.55	0.029
Inorganic Nitrogen	β_3	0.02	0.008	2.61	0.026

Table S36 Correlation coefficient between CH_4 emissions and measured parameters.

Parameter	R
Maximum duration of flooding	0.79
Cumulative flooding (days)	0.78
Continuous flooding events	0.75
Number of water level fluctuations	-0.6
Percent silt	0.58
Cumulative temperature (max)	-0.57
Organic nitrogen (min)	-0.54
Organic nitrogen input (max)	-0.51
Electric conductivity	-0.46
Water index	0.45
Water holding capacity	0.45
Growing_deg_days	-0.43
SOM	0.43
Organic carbon input (max)	-0.39
Organic carbon input (min)	-0.38
Yield (dry grain)	0.36
pH	0.23
Percent fines	0.22
Percent clay	-0.18
Inorganic nitrogen input	-0.17
Percent sand	-0.16
Fines/sand	0.15
Clay/sand	-0.15
Cumulative temperature (min)	-0.14
Season length (days)	-0.08

Table S37 Multivariate regression model that explains CH_4 emissions by the combination of water index, flooding events and inorganic nitrogen. Note that the three parameters have a p-value< 0.05.

Parameters		Coefficients	Std. error	t value	Pr (> |t|)
Flooding events (> 3 days)	β_1	33.6	6.33	5.31	0.0002
Soil organic matter	β_2	87.8	32.8	2.67	0.022

Table S38 Assumed water Index & flooding events (> 3 days) for different water management classes in the Indian subcontinent.

	Total range for water Index (cm)		Total range of number of flood events		Continuous flooding		Mild Intermittent flooding scenario		Medium Intermittent flooding		Intense Intermittent flooding	
	Min	Max	Min	Max	Water index	Flood events	Water index	Flood events	Water index	Flood events	Water index	Flood events
01. Irrigated 100% - Rice/Rice	-800	400	2	8	400	8	-100	3	-800	8	-800	2
02. Irrigated 100% - Rice/Rice or Rice/Other	-1000	300	1	8	300	8	-200	2	-1000	8	-1000	1
03. Irrigated 100% - Rice	-750	200	1	8	200	8	-100	2	-750	8	-750	1
04. Irrigated 60% / Rainfed 40% - Rice/Rice	-1200	200	1	7	200	7	-250	2	-1200	7	-1200	1
05. Irrigated 30% / Rainfed 70% - Rice/Rice or Rice/Other	-1500	-200	1	5	-200	5	-200	2	-1500	5	-1500	1
06. Upland 80% / Rainfed 10% / Irrigated 10% - Rice	-1800	-1300	0	3	-1300	3	-1300	1	-1800	3	-1800	0
07. Rainfed 60% / Irrigated 40% - Rice/Rice	-1300	-400	1	4	-400	4	-400	2	-1300	4	-1300	1
08. Rainfed 90% / Irrigated 10% - Rice	-1600	-700	0	3	-700	3	-700	1	-1600	3	-1600	0
09. Rainfed 100% - Rice	-1800	-800	0	2	-800	2	-800	1	-1800	2	-1800	0
10.Deepwater 100% - Rice/Rice	200	500	1	1	500	1	200	1	200	1	200	1
11.Deepwater 100% - water/Rice	200	500	1	1	500	1	200	1	200	1	200	1
12. Wetlands 100% - Rice/Rice	300	600	1	1	600	1	300	1	300	1	300	1

Table S39 Assumed water Index & number of flooding events for all water management classes used for temporal radiative forcing analysis (High N case)

Type	Water index	Flood events	Inorganic N	SOC	N_2O-N (kg/ha) based on Eq. 1	CH_4 (kg/ha) based on Eq. 2	N_2O* (kg/ha)	CH_4* (kg/ha)	N_2O (tCO_2e_{100}/ha)	CH_4 (tCO_2e_{100}/ha)	Total GWP (tCO_2e_{100}/ha)	N_2O (tCO_2e_{20}/ha)	CH_4 (tCO_2e_{20}/ha)	Total GWP (tCO_2e_{20}/ha)
Irrigated (Continous flooding)	500	8	250	0.4	-7.3	303.9	0.0	303.9	0.0	10.3	10.3	0.0	26.1	26.1
Irrigated (Continous flooding)	500	5	250	0.4	-4.6	203.1	0.0	203.1	0.0	6.9	6.9	0.0	17.5	17.5
Irrigated (Mild-intermittant)	-100	6	250	0.4	0.5	236.7	0.8	236.7	0.2	8.0	8.3	0.2	20.4	20.6
Irrigated (Mild-intermittant)	-100	2	250	0.4	4.2	102.3	6.6	102.3	2.0	3.5	5.4	1.8	8.8	10.6
Irrigated (Medium-intermittant)	-600	5	250	0.4	6.4	203.1	10.1	203.1	3.0	6.9	9.9	2.7	17.5	20.2
Irrigated (Medium-intermittant)	-600	0	250	0.4	11.0	35.1	17.3	35.1	5.2	1.2	6.3	4.6	3.0	7.7
Irrigated (Intense-intermittant)	-1200	3	250	0.4	14.3	135.9	22.4	135.9	6.7	4.6	11.3	6.0	11.7	17.7
Irrigated (Intense-intermittant)	-1200	0	250	0.4	17.0	35.1	26.7	35.1	8.0	1.2	9.2	7.2	3.0	10.2
Upland	-1500	0	250	0.4	20.0	35.1	31.4	35.1	9.4	1.2	10.6	8.4	3.0	11.4
Wetland/Deepwater	800	12	250	0.4	-14.0	438.3	0.0	438.3	0.0	14.9	14.9	0.0	37.7	37.7

** Neglecting negative nitrous oxide emissions. Values used in Figure 3*

Table S40 Assumed water Index & number of flooding events for all water management classes used for temporal radiative forcing analysis (Low N case)

Type	Water index	Flood events	Inorganic N	SOC	N_2O-N (kg/ha) based on Eq. 1	CH_4 (kg/ha) based on Eq. 2	N_2O* (kg/ha)	CH_4* (kg/ha)	N_2O (tCO_2e_{100}/ha)	CH_4 (tCO_2e_{100}/ha)	Total GWP (tCO_2e_{100}/ha)	N_2O (tCO_2e_{20}/ha)	CH_4 (tCO_2e_{20}/ha)	Total GWP (tCO_2e_{20}/ha)
Irrigated (Continous flooding)	500	8	150	0.4	-9.3	303.9	0.0	303.9	0.0	10.3	10.3	0.0	26.1	26.1
Irrigated (Continous flooding)	500	5	150	0.4	-6.6	203.1	0.0	203.1	0.0	6.9	6.9	0.0	17.5	17.5
Irrigated (Mild-intermittant)	-100	6	150	0.4	-1.5	236.7	0.0	236.7	0.0	8.0	8.0	0.0	20.4	20.4
Irrigated (Mild-intermittant)	-100	2	150	0.4	2.2	102.3	3.4	102.3	1.0	3.5	4.5	0.9	8.8	9.7
Irrigated (Medium-intermittant)	-600	5	150	0.4	4.4	203.1	7.0	203.1	2.1	6.9	9.0	1.9	17.5	19.3
Irrigated (Medium-intermittant)	-600	0	150	0.4	9.0	35.1	14.1	35.1	4.2	1.2	5.4	3.8	3.0	6.8
Irrigated (Intense-intermittant)	-1200	3	150	0.4	12.3	135.9	19.3	135.9	5.7	4.6	10.4	5.2	11.7	16.9
Irrigated (Intense-intermittant)	-1200	0	150	0.4	15.0	35.1	23.6	35.1	7.0	1.2	8.2	6.3	3.0	9.3
Upland	-1500	0	150	0.4	18.0	35.1	28.3	35.1	8.4	1.2	9.6	7.6	3.0	10.6
Wetland/Deepwater	800	12	150	0.4	-16.0	438.3	0.0	438.3	0.0	14.9	14.9	0.0	37.7	37.7

** Neglecting negative nitrous oxide emissions. Values used in Figure 3*

Table S41 Total rice-N_2O from countries of the Indian subcontinent, and Indian states (in million metric tons).

Water index and Flooding events are based on SI Table S38

	Scenario: Aggregate N_2O Emissions (MMT-N_2O)			Previous studies	
Country	**Continuous flooding** Water Index: Max Flooding Events:Max	**Medium-intermittent flooding** Water Index: Min Flooding Events:Max	**Intense-intermittent flooding** Water Index: Min Flooding Events:Min	**90% continuous flooding** Gerber (2016)	**~75% mild-intermittent flooding** EPA (2013)
India	0.00	0.53	0.79	0.0184	0.25
Bangladesh	0.00	0.08	0.13	0.0039	0.20
Pakistan	0.00	0.01	0.03	~0	0.0022
Nepal	0.00	0.02	0.03	~0	0.0009
Sri Lanka	0.00	0.01	0.01	~0	0.0017
Total subcontinent	0.0000	0.6500	0.9900	0.0223	0.4548

Indian States					
Uttar Pradesh	0.00	0.06	0.10		
Chhattisgarh	0.02	0.06	0.08		
West Bengal	0.00	0.05	0.08		
Odisha	0.00	0.05	0.07		
Bihar	0.00	0.04	0.06		
Tamil Nadu	0.00	0.04	0.05		
Punjab	0.00	0.02	0.05		
Assam	0.00	0.03	0.04		
Andhra Pradesh	0.00	0.02	0.04		
Jharkhand	0.01	0.03	0.04		
Madhya Pradesh	0.00	0.03	0.04		
Maharashtra	0.00	0.02	0.03		
Haryana	0.00	0.01	0.02		
Telangana	0.00	0.01	0.02		
Karnataka	0.00	0.01	0.02		
Gujarat	0.00	0.01	0.01		
Kerala	0.00	0.01	0.01		
Uttarakhand	0.00	0.00	0.01		

Table S42 Rice-N_2O per unit area from countries of the Indian subcontinent, and Indian States (Kg/ha).

	Scenario: Per-Hectare N_2O Emissions (kg-N_2O/ha)			
Country	**Continuous flooding** Water Index: Max Flooding Events:Max	**Medium-intermittent flooding** Water Index: Min Flooding Events:Max	**Intense-intermittent flooding** Water Index: Min Flooding Events:Min	% increase in intense- as compared to medium- intermittent flooding
Bhutan	1	16	21	33%
India	0	13	20	50%
Nepal	0	12	19	54%
Bangladesh	0	11	18	68%
Sri Lanka	0	11	16	52%
Pakistan	0	7	15	131%
Indian States				
Nagaland	13	26	29	11%
Mizoram	11	25	28	10%
Arunanchal Pradesh	8	22	27	19%
Himachal Pradesh	10	21	26	21%
Jharkhand	8	21	26	23%
Meghalaya	8	20	25	26%
Uttarakhand	3	19	24	28%
Chandigarh	4	19	24	28%
Manipur	3	18	24	34%
Daman & Diu	7	19	24	27%
Chhattisgarh	6	18	23	27%
Tamil Nadu	1	18	23	27%
Goa	5	18	23	24%
Sikkim	6	17	22	35%
Puducherry	0	16	22	31%
Gujarat	2	16	21	36%
Haryana	0	14	21	54%
Maharashtra	2	15	21	38%
Madhya Pradesh	2	15	21	36%
Kerala	0	16	21	34%
Tripura	0	14	21	45%
Dadara & Nagar Havelli	0	14	20	46%
Bihar	0	12	20	62%
Uttar Pradesh	0	12	19	64%
Odisha	0	12	19	52%
Rajasthan	0	12	19	53%
Assam	0	12	18	48%
Punjab	0	9	18	97%
West Bengal	0	11	18	57%
Jammu & Kashmir	0	10	17	77%
NCT of Delhi	0	8	17	110%
Lakshadweep	0	12	17	39%
Telangana	0	9	17	81%
Andhra Pradesh	0	8	16	86%
Karnataka	0	8	15	95%

Table S43: Example of effect of sampling frequency on N_2O and CH_4 emissions

Reduction in sampling frequency results in much larger error in estimation of N_2O fluxes than CH4, especially for BP treatments which have high inorganic N input and N_2O fluxes are higher than 0.25 tCO2e100/ha. Exact extent of the effect of sampling frequency on seasonal flux will vary from case to case (see Tiwari et al (2015) for details). In all cases, inability to capture just a few (e.g., 4-6) highest fluxes can result in a very high extent of underestimation of seasonal N_2O fluxes (Figures S3-S8).

		Treatment	Sampling frequency	N_2O (tCO_2e_{100}/ha)	CH_4 (tCO_2e_{100}/ha)	% reduction in N_2O	% reduction in CH_4
Farm 1 2012	Original	BP	44%	3.89	2.26		
		AP	44%	1.40	2.76		
	Highest 4 points removed	BP	41%	2.33	1.80	40%	20%
		AP	41%	0.85	2.20	39%	20%
	Highest 6 points removed	BP	39%	1.70	1.68	56%	26%
		AP	39%	0.73	2.05	48%	26%
	Twice weekly + 3 consecutive days after fertilization	BP	31%	3.56	1.99	49%	12%
		AP	31%	1.24	2.38	11%	14%
	Once weekly	BP	15%	4.22	2.50	53%	20%
		AP	15%	0.91	3.13	-36%	24%

Table S44 Summary of change in understanding of climate impacts of rice cultivation

	Before this study	After this study
Empirical data		
Maximum hourly flux (µg N_2O m^{-2} h^{-1})	2,100	15,000
Maximum seasonal flux (kg ha^{-1} $season^{-1}$)	9.9	32.8
Emission factor (% of added N converted to N_2O)*	0.02 to 0.7%	0.02 to 31%
Maximum rice-N_2O Mitigation potential (tCO_2e_{100} ha^{-1})	0.3#	6
General understanding		
Climate impacts of rice cultivaton	Short-term	Both short- and long-term
Greenhouse gases from rice fields reported to UNFCCC	CH_4	CH_4 and hopefully N_2O
Main recommended strategy to reduce rice GHG emissions	Reduce water & organic input (with some N use efficieny to tackle N_2O)	Co-manage water, N & organic input region-specifically with central focus on water management
Best water management strategy for irrigated farms	Alternate wetting and drying	Shallow flooding (no extended flooding or extended drainage)

* Our emission factor estimates include both inorganic N mineralized organic N in its calculation. If we didn't include organic N, emission factors would be higher. We didn't have N = 0 controls at all sites. # Based on 2007 IPCC report which doesn't give mitigation estimate for rice nitrous oxide but a range for general crop N_2O mitigation potential.

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