Nonlinear responses of agri soil NH_3 and N_2O emissions to N input: model and implications

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Content

- Motivation
- BRRT v2 algorithm
- Model performance
- Discussion and implications
- Next step

N2O—China, completed, 2013

NH3-China, completed, 2014

N2O/NH3--World, ongoing

Impacts, next step

1. Motivation: Linear vs nonlinear?

IPCC (2006) Tier 1 and most inventories----

N2O EF = 1% with [0.3%, 3%] as CI95% for Upland crops

= 0.3% with [0%, 0.6%] as CI95% for paddy rice

NH3 EF = 10% with [3%, 30%] as CI95% for all agri soils

&

Assume as linear response of N_2O and NH_3 emissions on N inputs

$$V = N \cdot EF + V^0, \text{ where } EF = \frac{dV}{dN} = C$$

V, *V*^0 -- total N2O/NH3 flux and N2O/NH3 flux with zero N rate (CK), kg N/ha/yr;

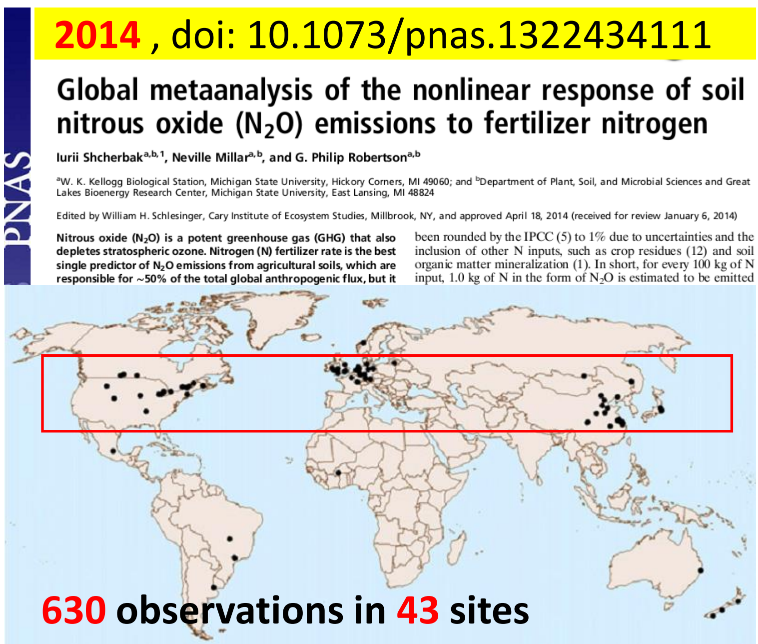
N -- N-fertilizer application rate, kgN/ha/yr;

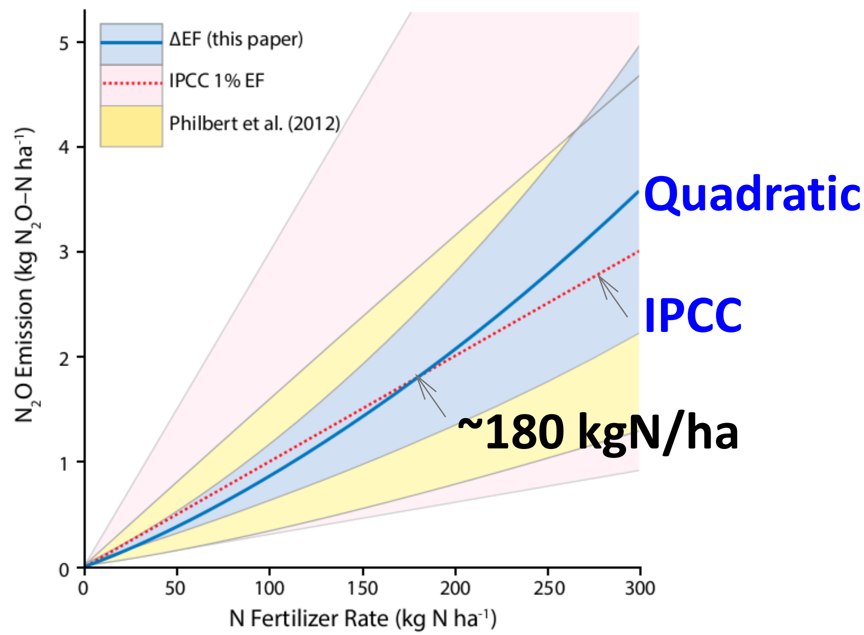
EF -- Fertilizer-induced emission factor of N2O/NH3, %;

1. Motivation: Linear vs nonlinear?

Shcherbak et al. (2014), Kim et al. (2013). etc----

$$V = N \cdot EF + V^0, \text{ where } EF = \frac{dV}{dN} \neq C$$



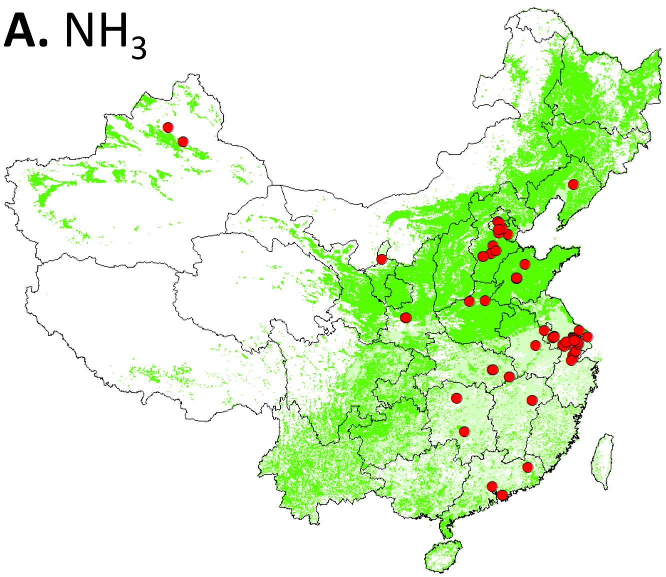


Lower R^2=0.24, higher uncertainty range

1. Motivation: Linear vs nonlinear?

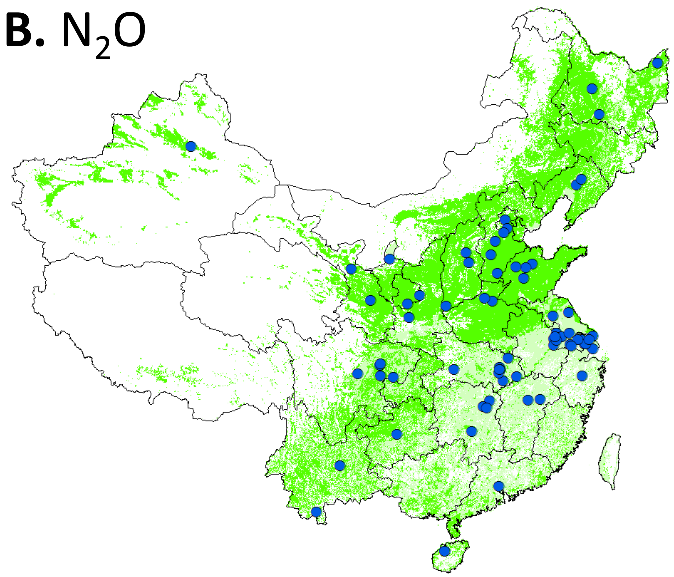
So, we test the generality of these findings in China with largest N consumption (>30% of globe)

A. NH_3



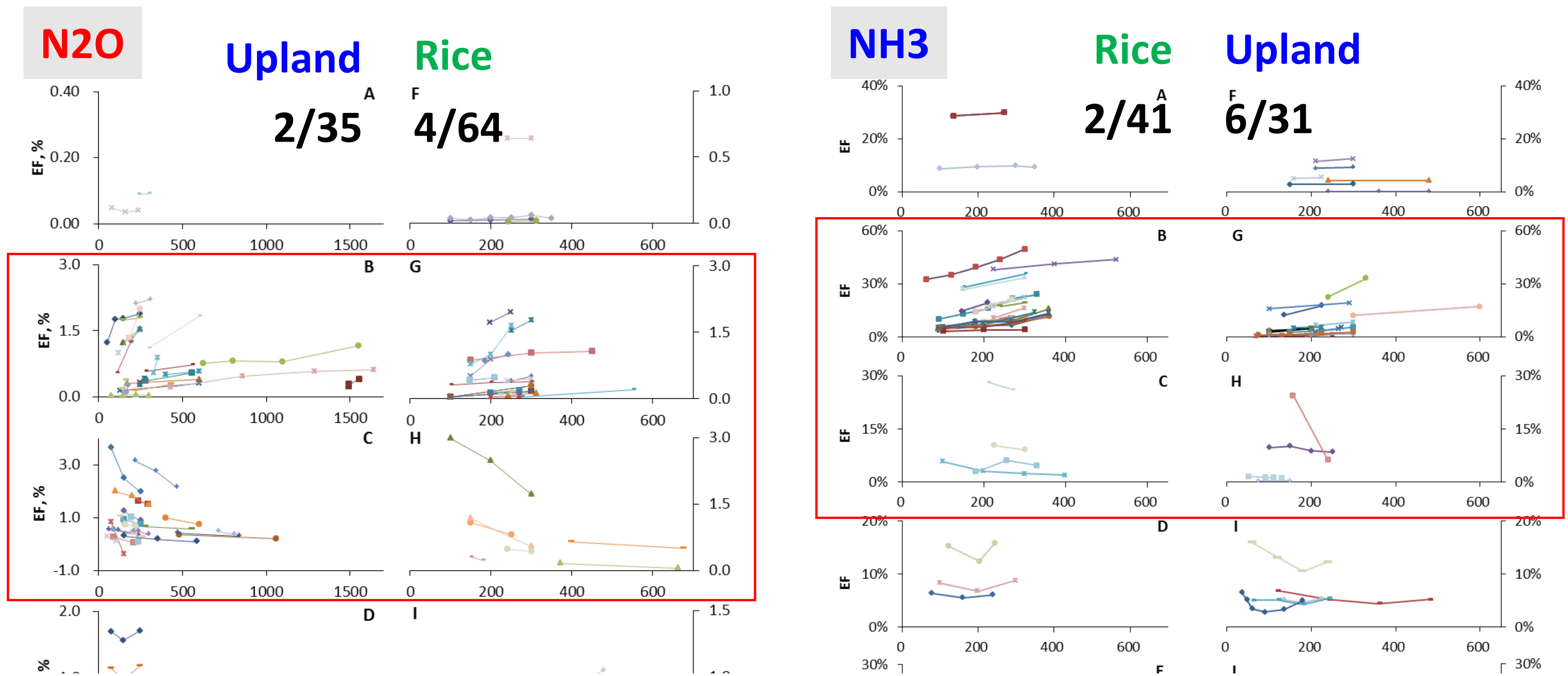
- Record: **209** (upland), **286** (rice)
  - Experimental Sites: **79**

B. N_2O

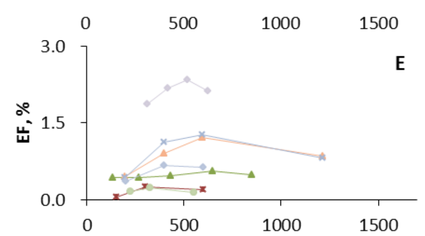


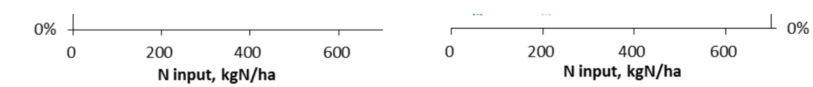
- Record: **523** (upland), **209** (rice)
  - Experimental Sites: **96**

1. Motivation: Linear vs nonlinear?



However, ΔEF and EF^0 are constant, or spatio-temporal differential?

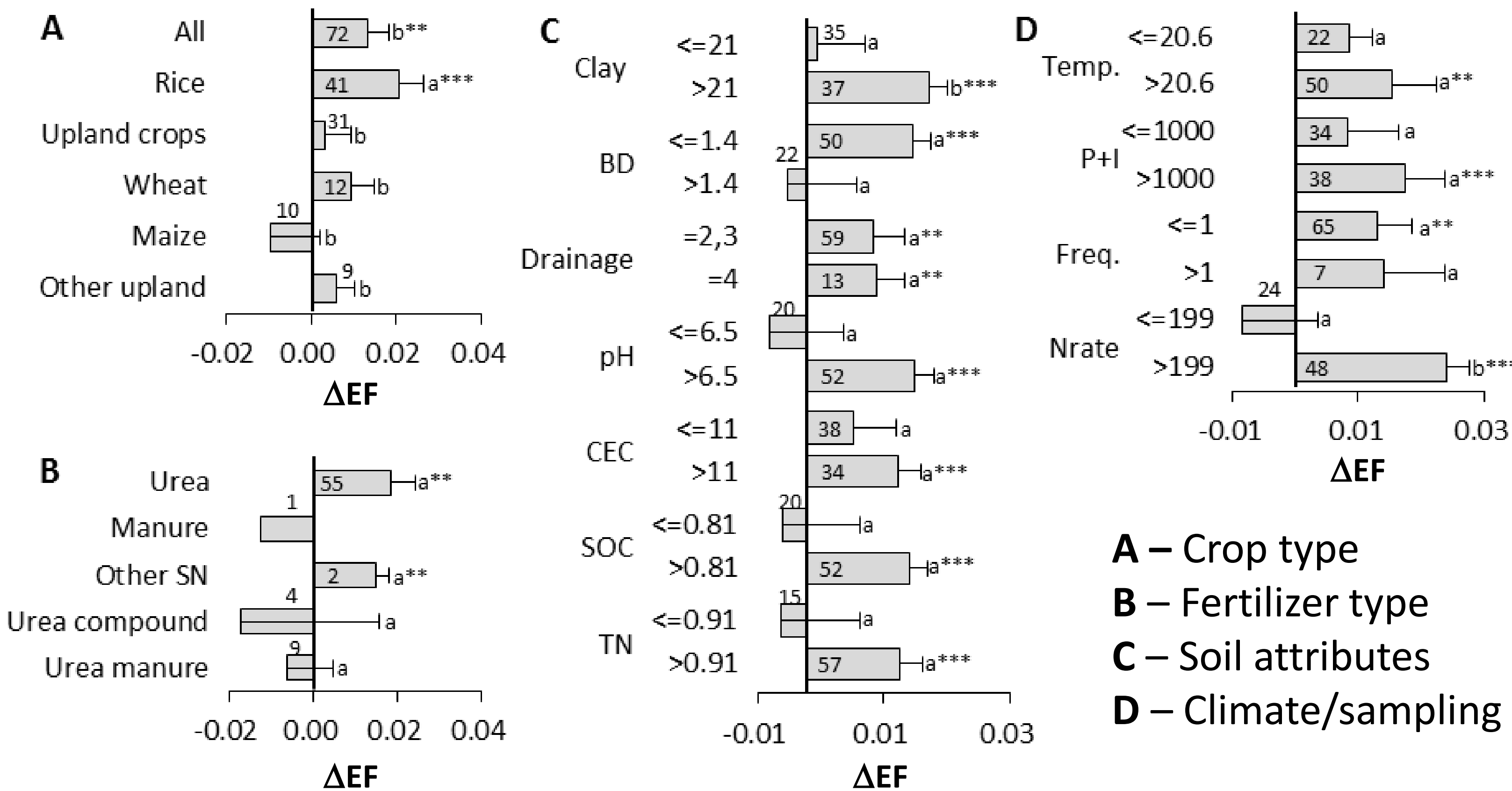




$$EF = \Delta EF \cdot N + EF^0, \text{ where } \Delta EF = \frac{dEF}{dN} = \frac{d^2V}{dN^2}$$

1. Motivation

NH$_3$ $\Delta EF, EF^0 \propto X_k \rightarrow$ **Nonlinear response is differential when X$_k$ changes**



A – Crop type
B – Fertilizer type
C – Soil attributes
D – Climate/sampling factor

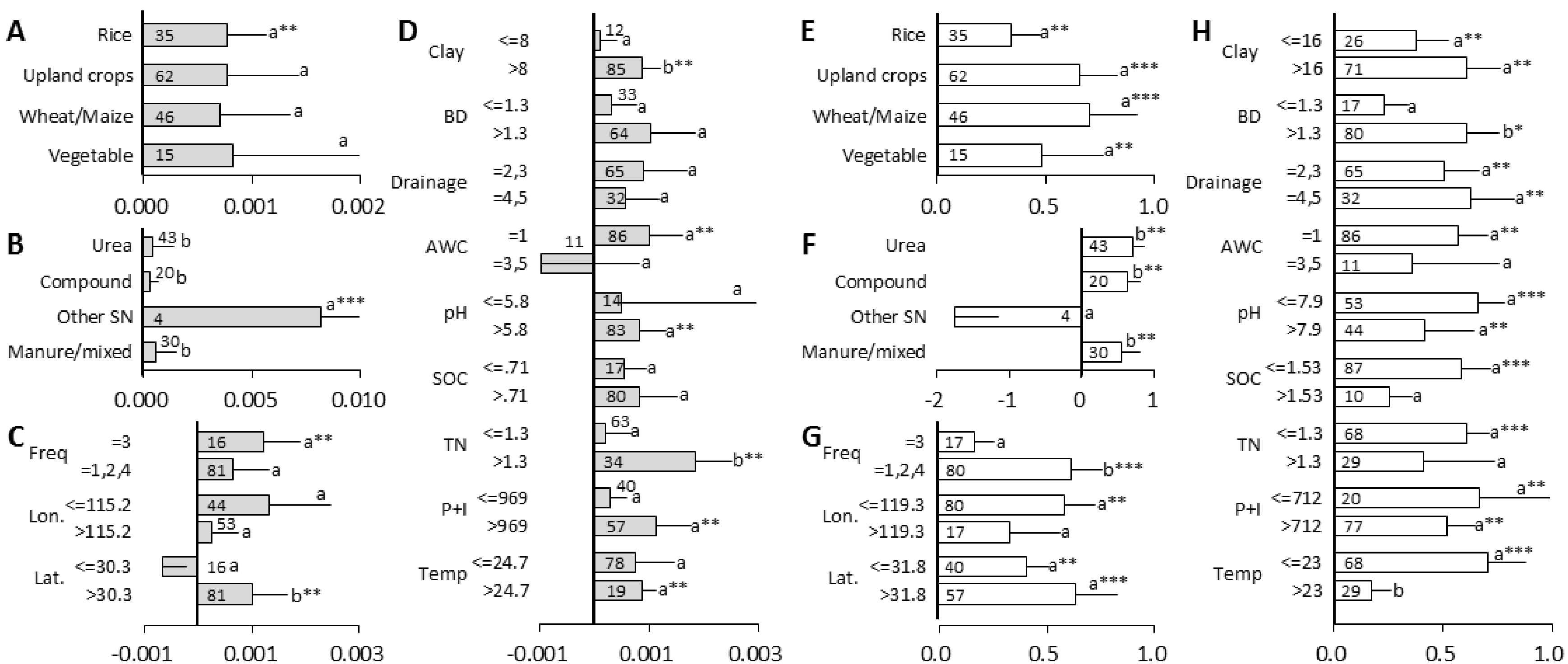
** significant differences from 0, P<0.01

*** significant differences from 0, P<0.001

a, b different letters indicate significant pairwise differences between attributes or factors

1. Motivation

N_2O $\Delta EF, EF^0 \propto X_k \rightarrow$ **Nonlinear response is differential when X_k changes**



ΔEF　　**EF^0**

1. Motivation

$$EF_l = \Delta EF_l(x_k) \cdot N + EF_l^0(x_k), \text{ where } x_k \in \Omega_l, \; k = 1,\ldots,K, \; l = 1,\ldots,L$$

Parameters ↗ *Split* ↗ *Factor* ↗ *Regionalization* ↗

SCIENTIFIC QUESTIONS:

1. How to determine "optimal" L, select x_k for splitting and regression?

2. Which and how factor x_k govern the differential ΔEF and EF^0 ?

AND

3. What are the implications on N_2O and NH_3 emission inventories and reductions when using explicitly-differential EF_l?

Hoben et al., 2011; Butterbach-Bahl et al., 2013; Perlman et al., 2014; Shcherbak et al., 2014

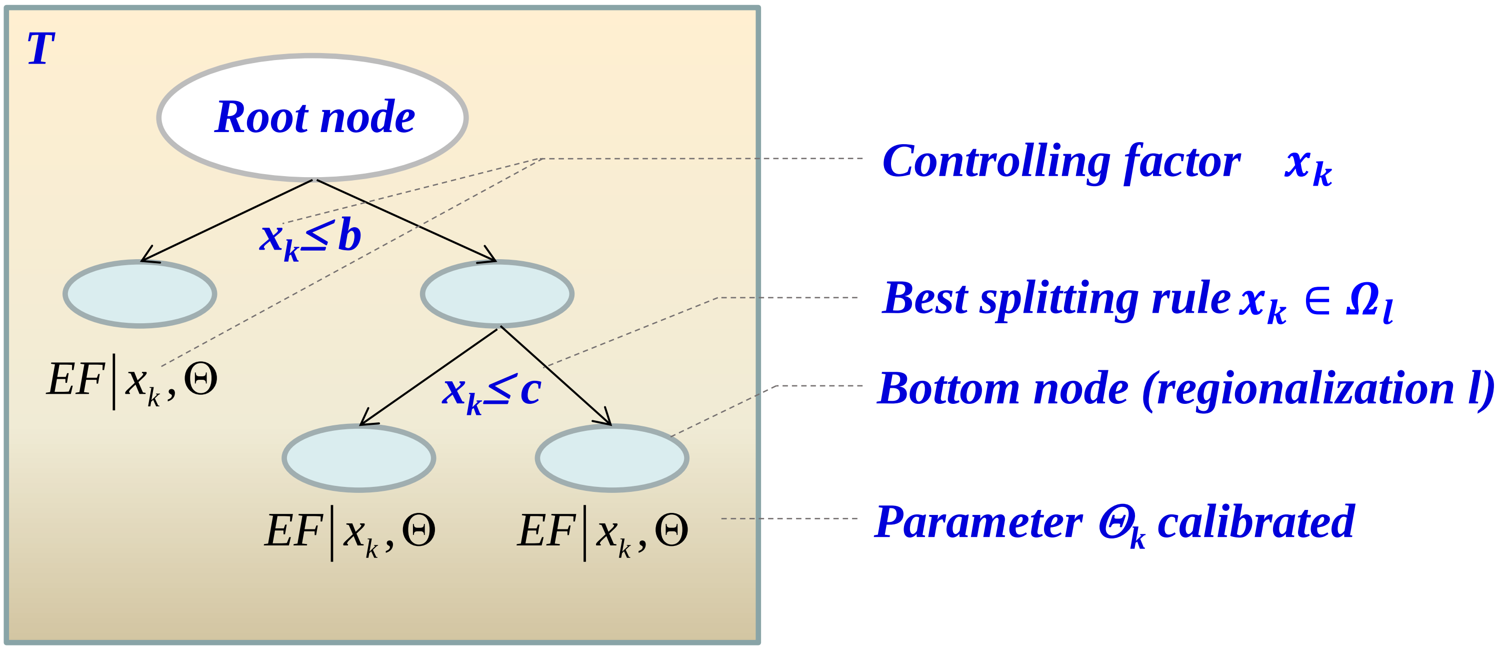
2. Model

Main difficulty in data mining: ***how many L? X_k selction? Efficency vs accuracy?***

$$EF_l = \Delta EF_l(x_k)\cdot N + EF_l^0(x_k),\ \text{where } x_k \in \Omega_l,\ k=1,\ldots,K,\ l=1,\ldots,L$$

Parameters ***Split*** ***Factor*** ***Regionalization***

New version of Bayesian Recursive Regression Tree model **(BRRT v2)**



Zhou, 2009; Zhou and Guo, 2010; Zhou et al., 2014b

2. Model

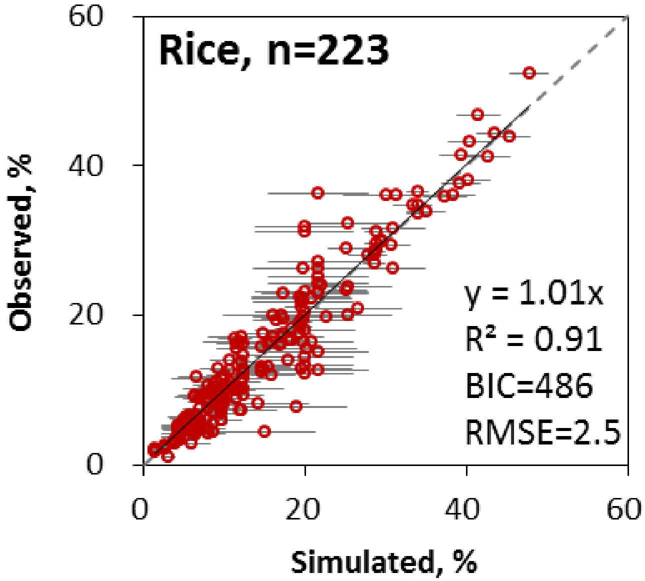
Factors used as forcings: **Fert type, crop type, lon, Lat, Nrate, Clay, BD, pH, CEC, SOC, TN, P+I, T**

Type	Resolution	Data source
Chemical fertilizers	County	PKU-N2O (Zhou et al., 2014)
Soil attributes (Clay content, Bulk density [BD], pH, CEC, SOC, TN)	1-km	HWSD v1.2
Precipitation [P], air temperature [T]	0.5-degree	CRU TS3.10
Irrigation volume [I]	City	Local statistical Yearbooks
Ratio of irrigation area	5-minute	MIRCA2000 (Portmann et al., 2010)
Landuse (Rice or upland)	1-km	CLUDs-CAS (Liu et al., 2014)

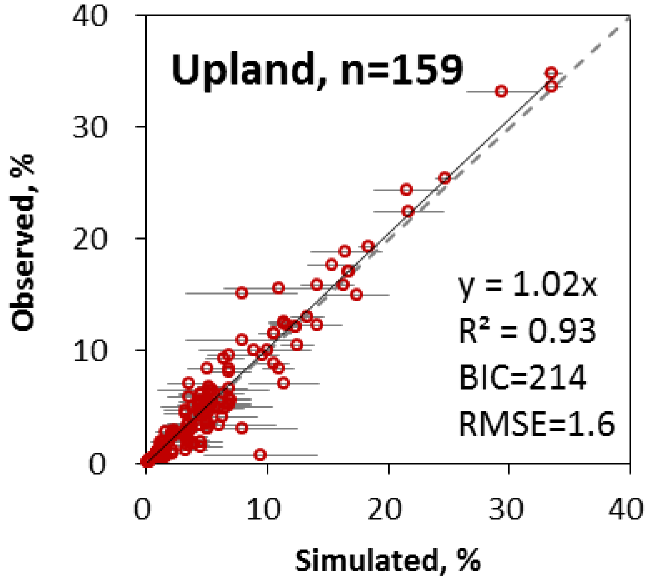
3. Model performance

NH_3

EFs for paddy rice



EFs for upland crops



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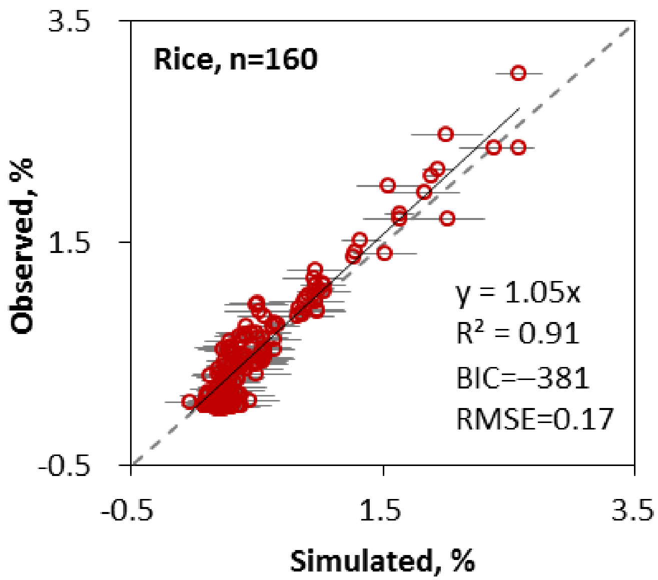
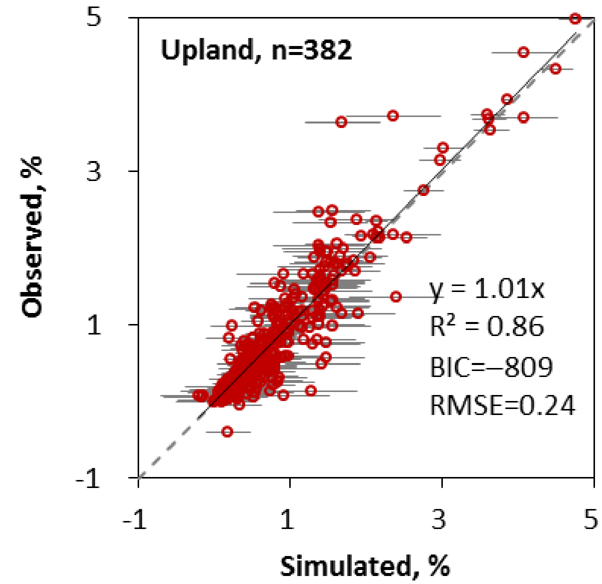
3. Model performance

N_2O

EFs for paddy rice

EFs for upland crops





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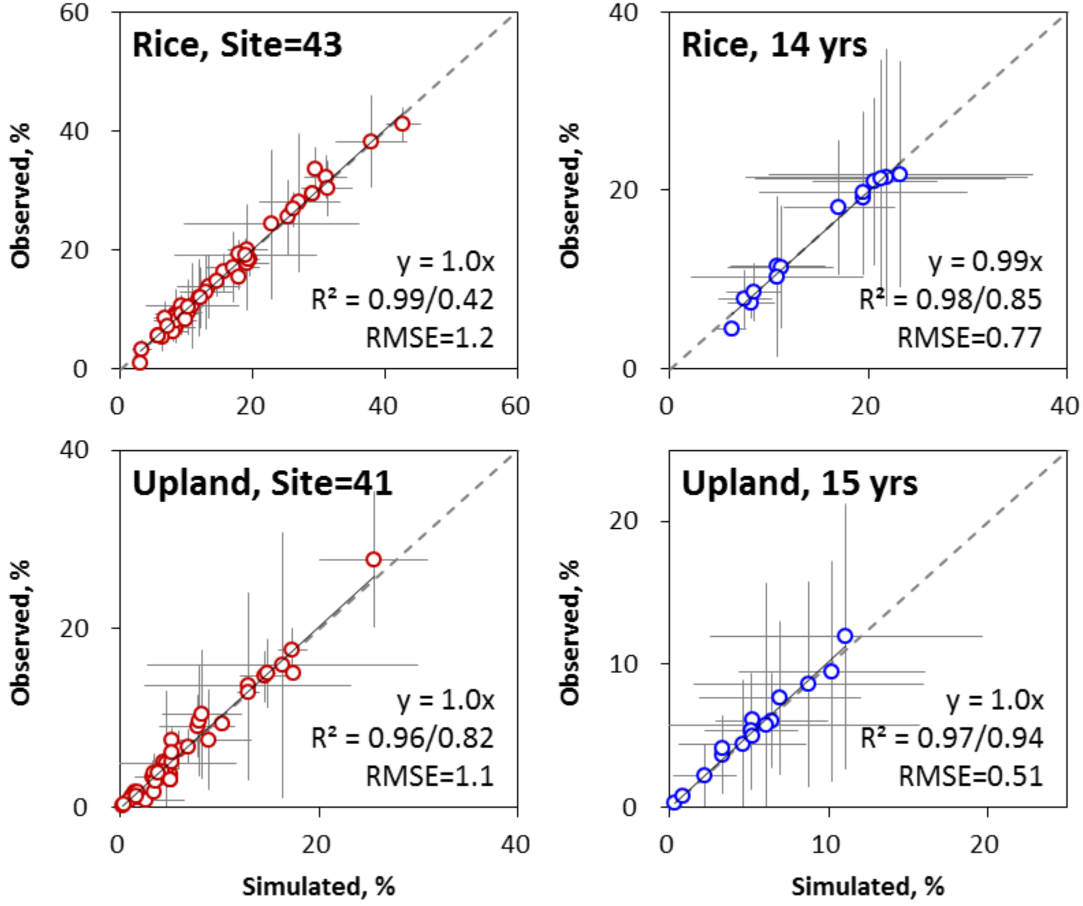
3. Model performance

***Spatial pattern* and *annual anomalies* of mean and SE**

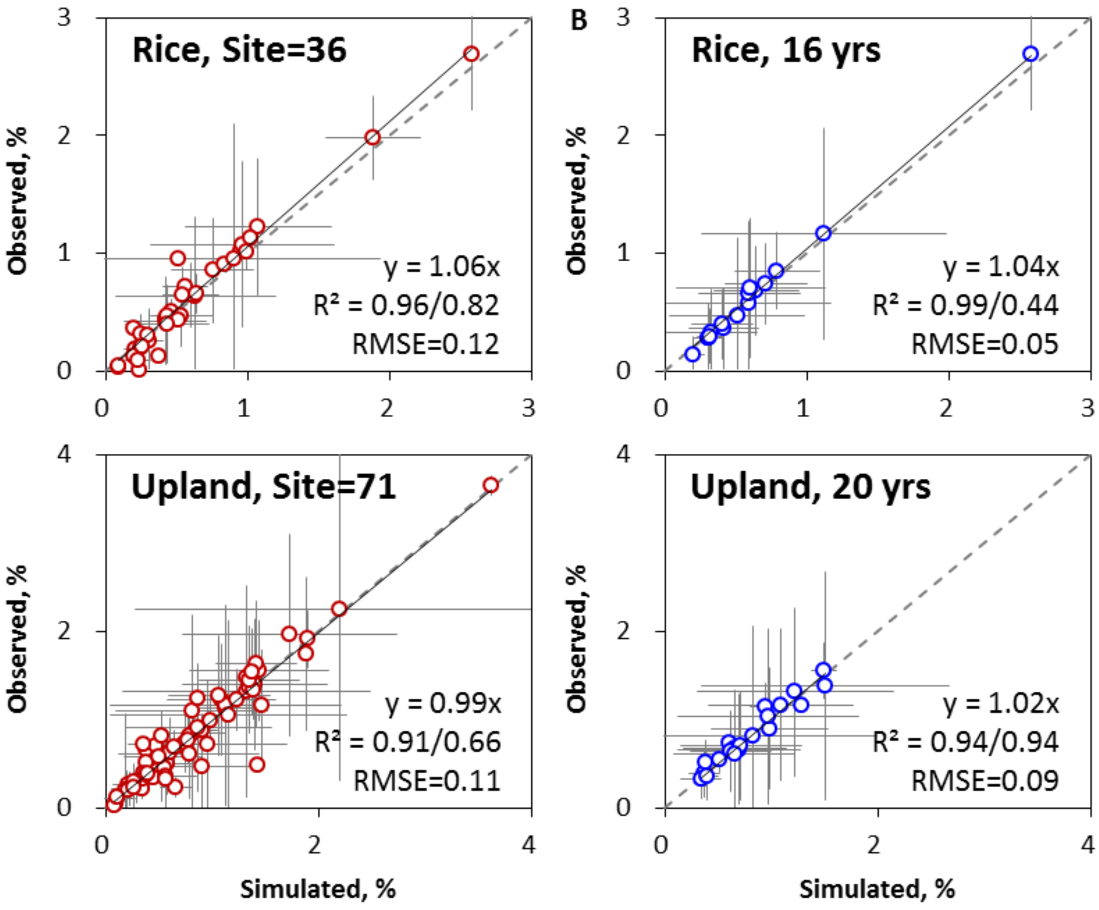
NH_3



3. Model performance

***Spatial pattern* and *annual anomalies* of mean and SE**

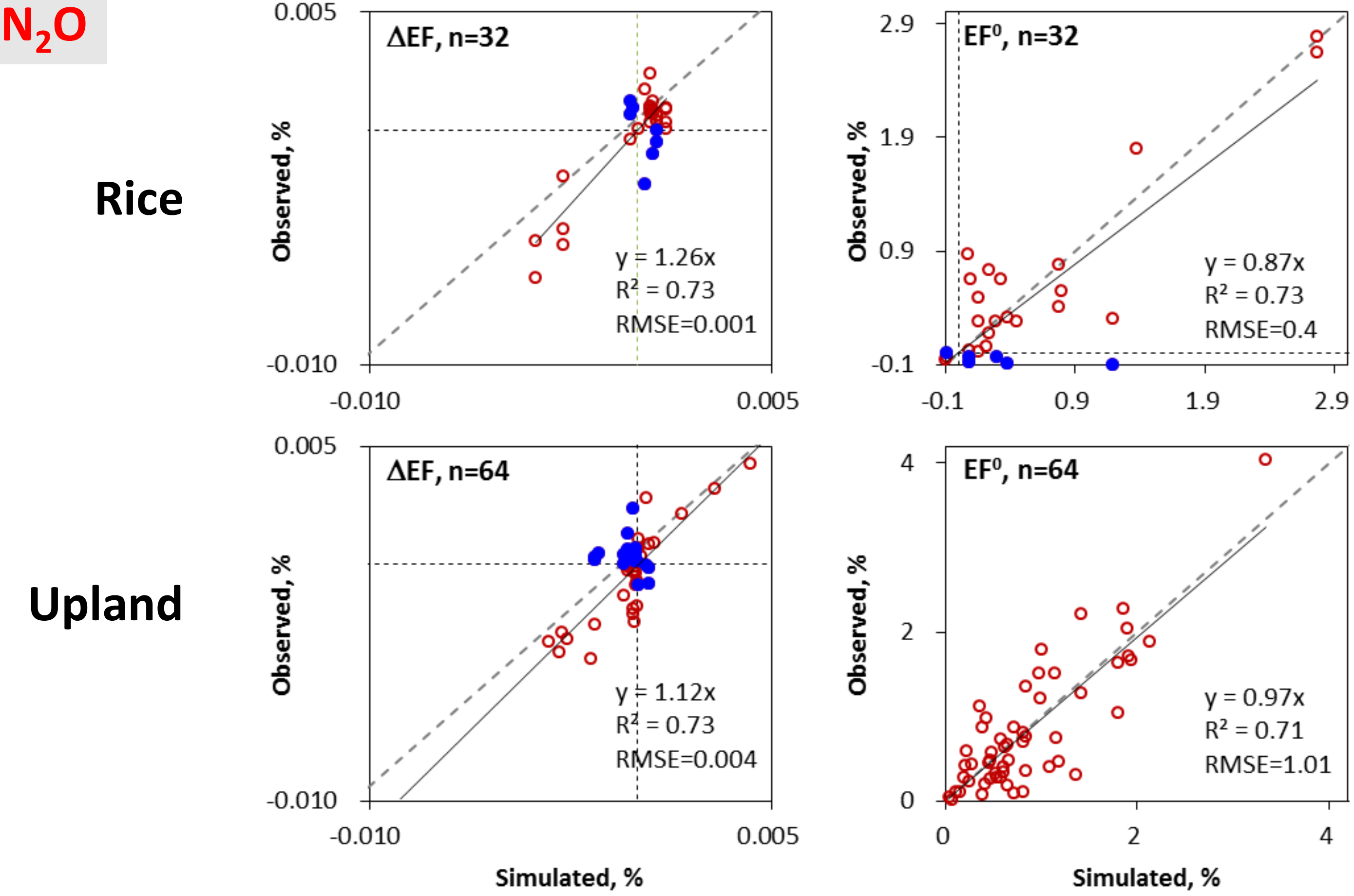
N_2O



3. Model performance

ΔEF *and* EF^0

N_2O



4. Discussion

a. Explicitly-differential EFs

Comparison*: our model, IPCC default, quadratic regression model based on all samples, and BCART (Chipman et al., 1998, 2002, 2006)*

	Paddy rice				Upland crops			
	IPCC	Quadratic model	BCART	Our model	IPCC	Quadratic model	BCART	Our model
R^2	--	0.32	0.92	**0.91**	--	0.25	0.94	**0.93**
RMSE	15	11.1	2.4	**2.5**	18.7	6.4	1.4	**1.6**
BIC	1220	1083	1622	**486**	936	594	1435	**214**
95% CI	[3, 30]	[6, 27]	PLR25*	**PLR9***	[3, 30]	[1.4, 12]	PLR32*	**PLR10***
Parameters	--	1	225	**9**	--	1	252	**10**

***** PLR: Piecewise linear regression equations, the following letter is the number of equations

4. Discussion

c. Implications in inventory

China's NH_3 emissions in 2008 and comparison in EF and V with results based on IPCC, mean-EF, Quadratic regression and BCART models

	EF, %		V, Gg/yr		
	Rice	Upland	Rice	Upland	**Total**
IPCC	10	10	510	2341	**2851**
Mean	15	5.9	765	1381	**2146**
Quadratic	13.5	10.2	688	2392	**3080**
BCART	12	14.4	612	3371	**3983**
Huang et al.	14.3		--	--	**3214***
Our model	11.8	14.3	600	3358	**3957**

* Data in 2006, Huang et al. (2012)

4. Discussion

c. Implications in inventory

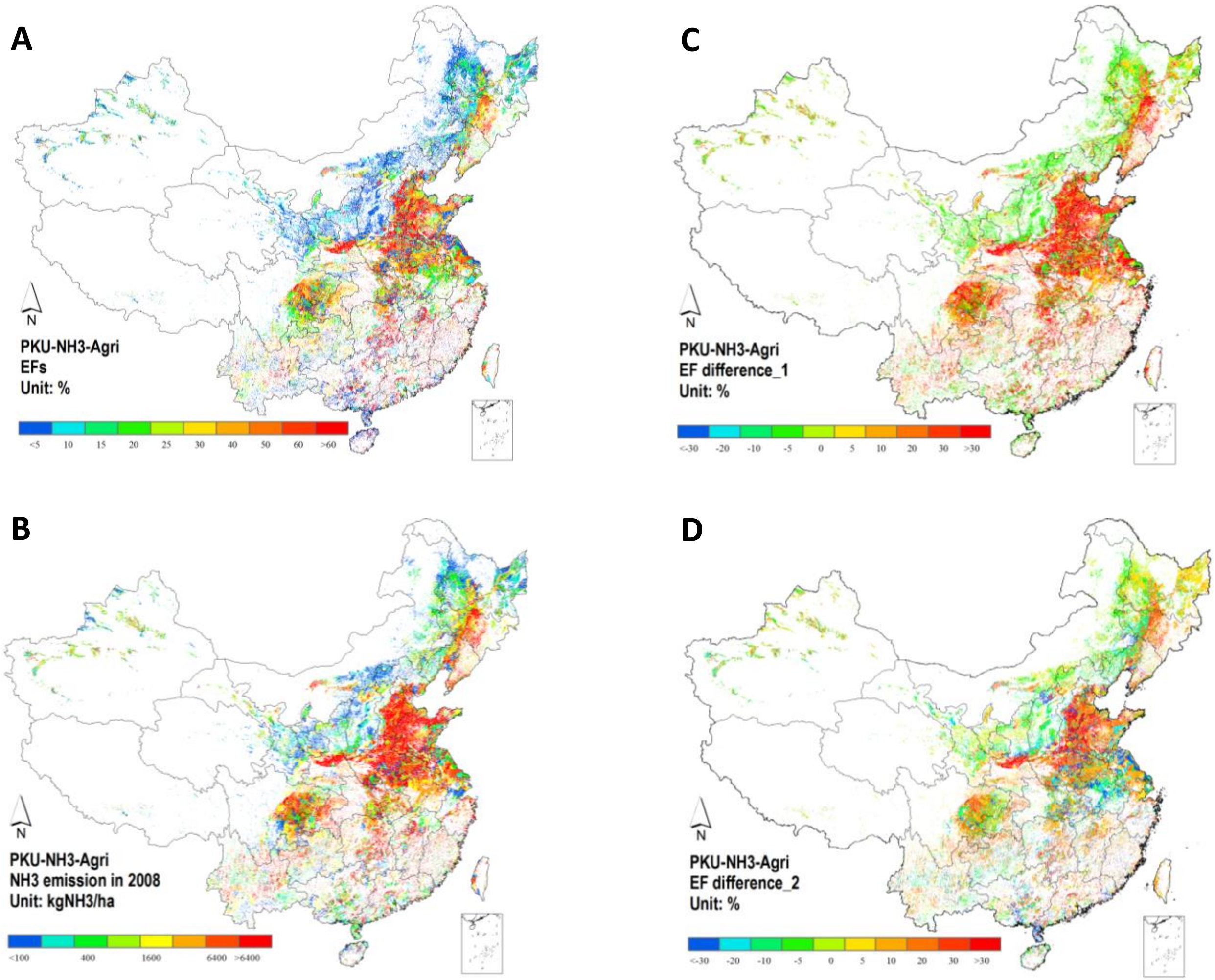
China's N_2O emissions in 2008 and comparison in EF and V with results based on IPCC, mean-EF, Quadratic regression and BCART models

	EF, %		V, Gg/yr		
	Rice	Upland	Rice	Upland	**Total**
IPCC	0.3	1	49	600	**649**
Zhou et al.	0.8	1.6	130	961	**1091**
Quadratic	0.2	0.8	39.2	492	**531**
BCART	0.5	0.8	134	495	**629**
EDGAR	0.3	1	--	--	**892**
Our model	0.6	0.8	140	477	**617**

* Data in 2006, Huang et al. (2012)

4. Discussion

c. Implications in inventory (2008 results)



A: EF

B: V

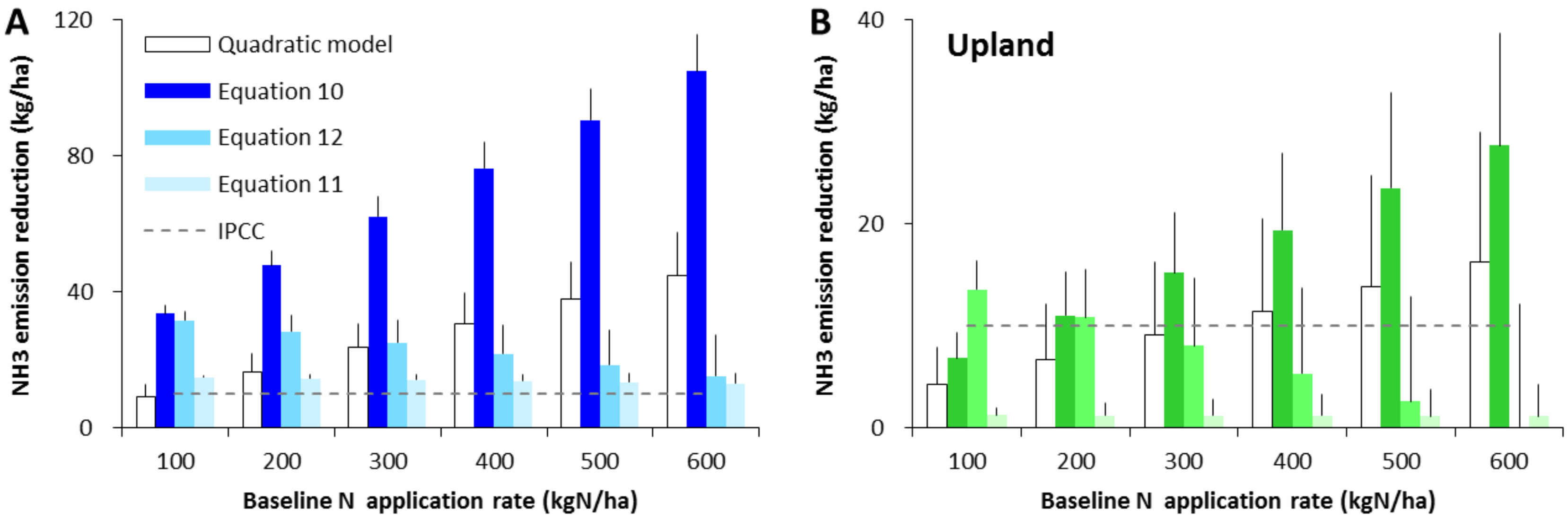
C: EF difference with IPCC

D: EF difference with QR

4. Discussion

d. Implications in Nr reductions

Comparison of NH3 emission models for N fertilizer reduction scenarios (100 reduction from baseline of 100, 200, …, 600 kgN/ha)



5. Next step

confidential

Thanks for your attention :)