Methane and nitrous oxide emissions from rice paddies in India

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Fair Climate Network

Environmental Defense Fund

- A non-profit founded in 1967
- Driven by science, economic & legal analysis
- 12 offices with >500 employees and >750,000 members
- Main areas of focus:
  - Climate and Energy
  - Ecosystems
  - Oceans
  - Health

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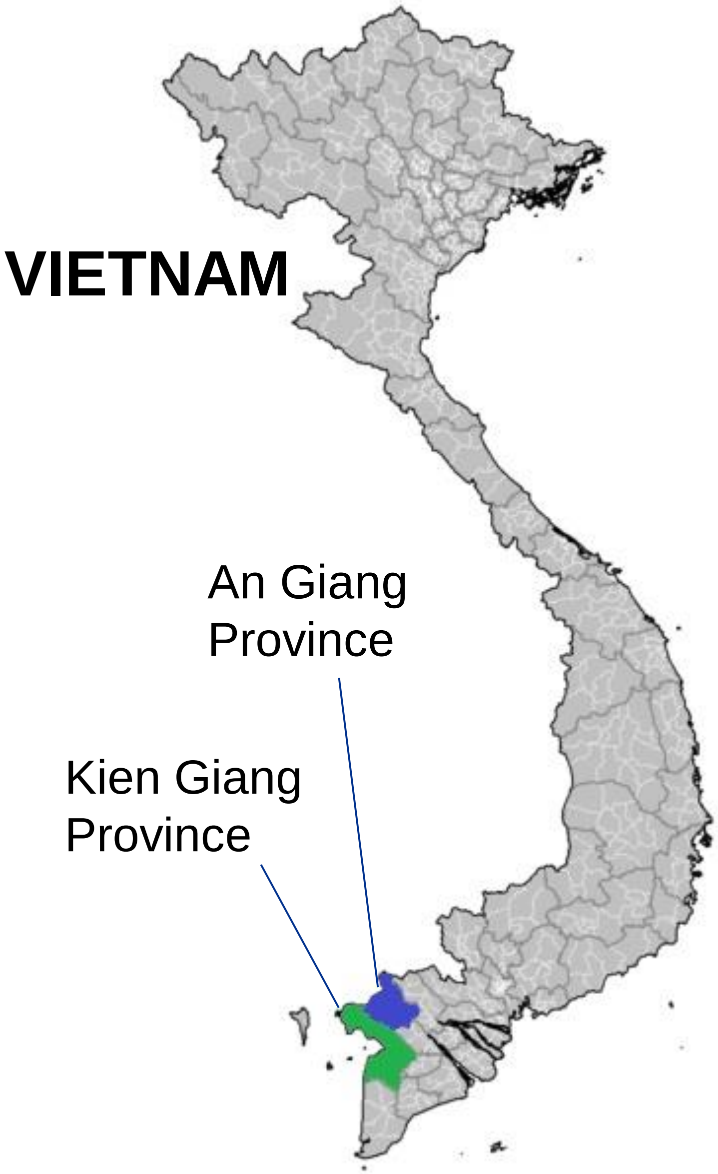
Where we work on agriculture



Indian Rice

- **Area: 144 million ha**
- **Production: 140-160 million tons/year**

- **GHG Emissions: India Govt (2007) *vs* EPA (2014)**

Methane:	**75 *vs* 90 MT CO_2e**
Nitrous oxide:	**0 *vs* 75 MT CO_2e**
Mitigation potential:	**?? *vs* 35 MT CO_2e**



Photos: Hong Tin, Can Tho University

Partners in India: EDF & Fair Climate Network

(Resources ←→ Clients ←→ Institutions)

the timbaktu collective
in celebration of life

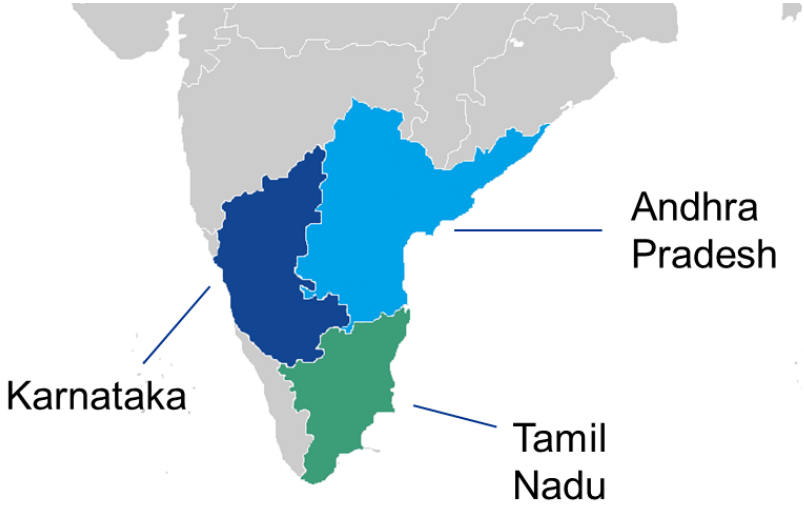
SEDS
towards a greener tomorrow

"SACRED" TRUST

ACCION FRATERNA ecology centre
sustainable . human . nature

PWDS
Palmyrah Workers Development Society

Goals



Baseline surveys

+

New practice package

↓

Plot GHG measurements

↓

Self-reporting Monitoring Verification

+

Large scale modeling

↓

Methodology for small-holder farmers

↓

Triple Win

+

C offsets

Scientific approach

- Farmer surveys for baseline conditions/practices
  - Major cropping systems
  - Fertilizer, manure, water management, pesticides
  - Soil qualities (T, pH), weather,

- New “sustainable” practices with NGO partners
  - Yield, low costs, soil and water quality, potential GHG mitigation

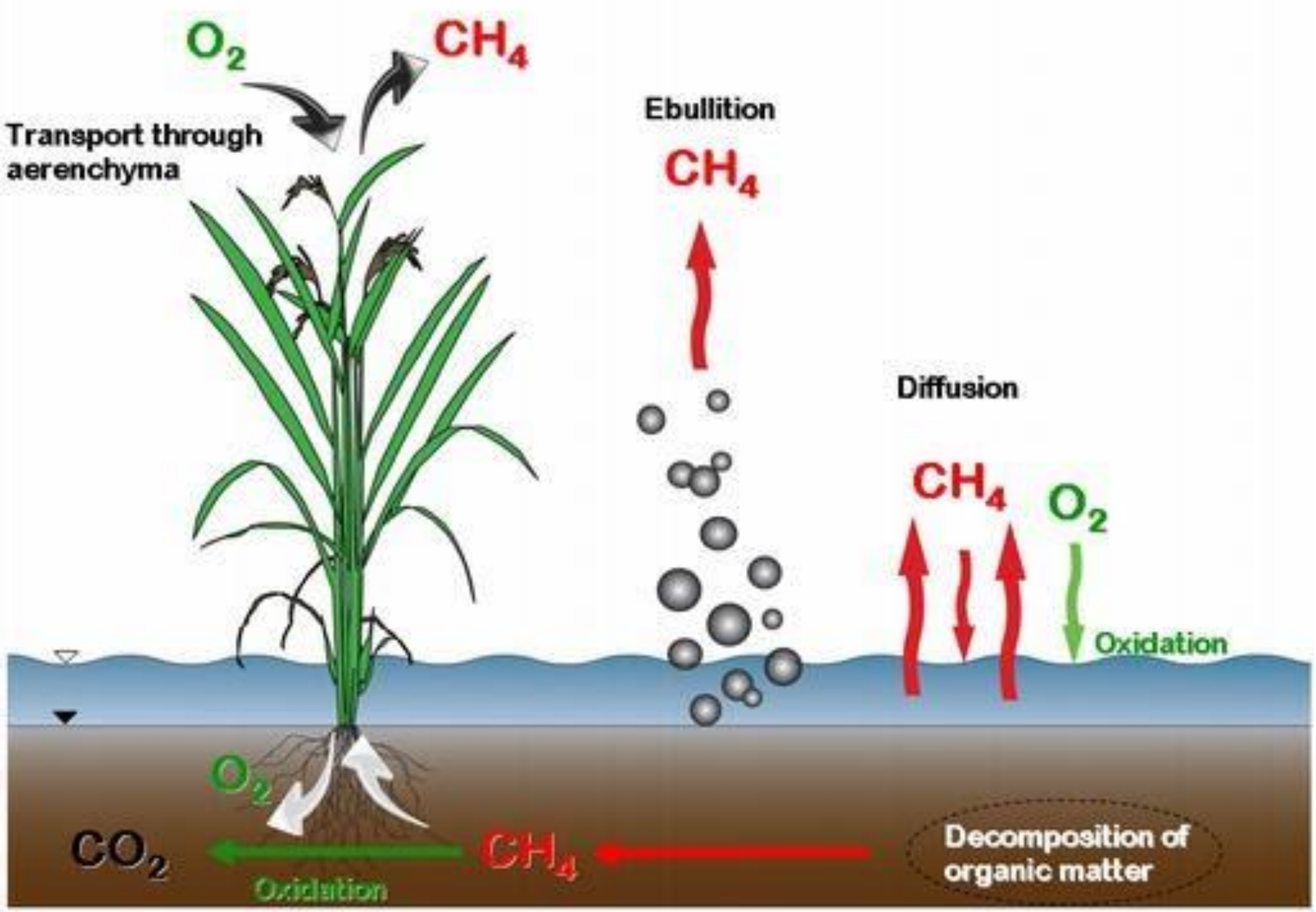
- Sample collection
  - Random replication
  - Design of chambers and sampling frequency
  - Temperature corrections

- Greenhouse gas emission measurements
  - Precision of GCs
  - Calibration and standards

- Data analysis and modeling

Training sessions

Rice CH_4 emissions: Why and how?



Methane oxidation:

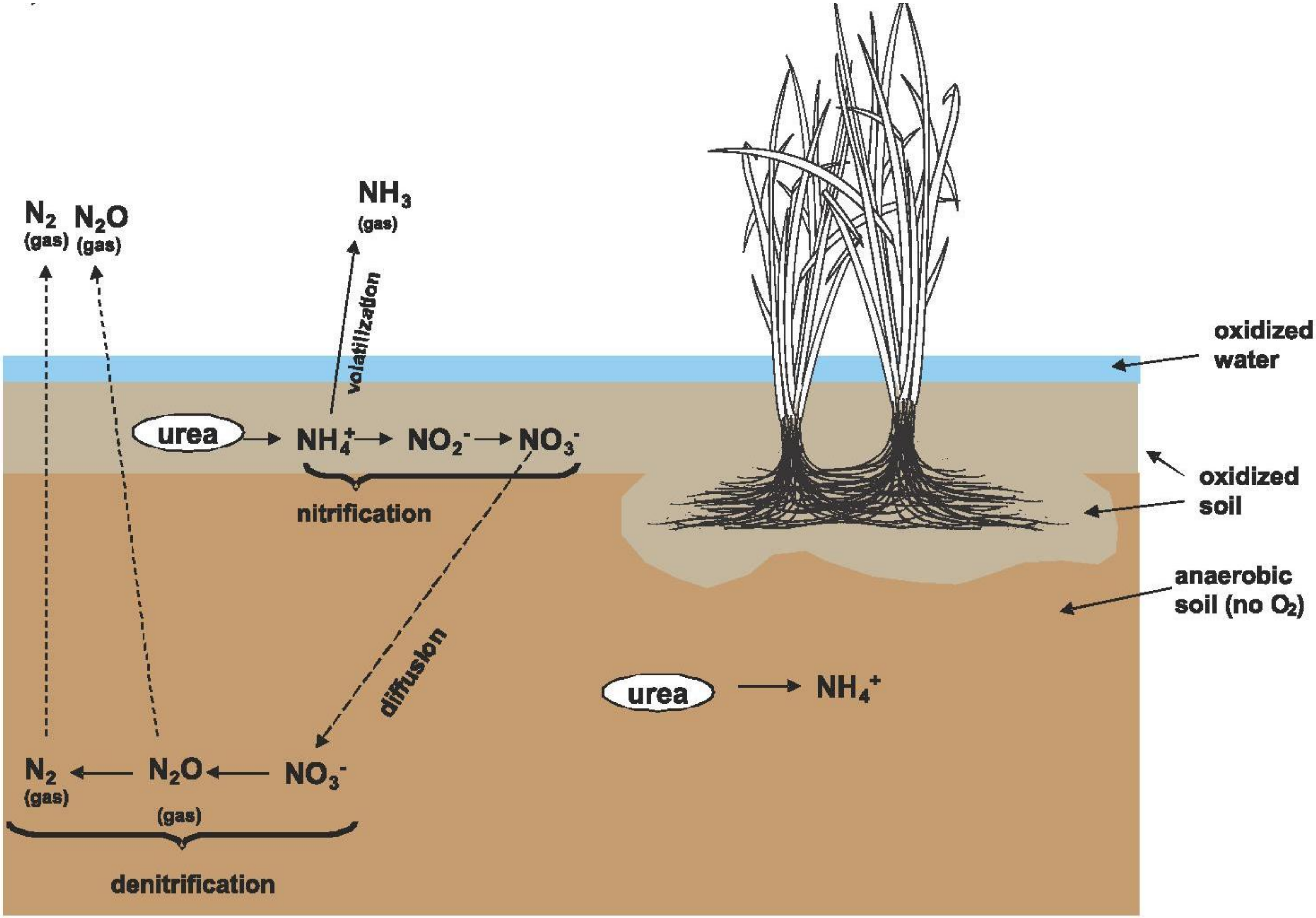
$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

Methanogenesis:

Hydrogenotrophic: $CO_2 + 4H_2 \rightarrow 2\,H_2O + CH_4$

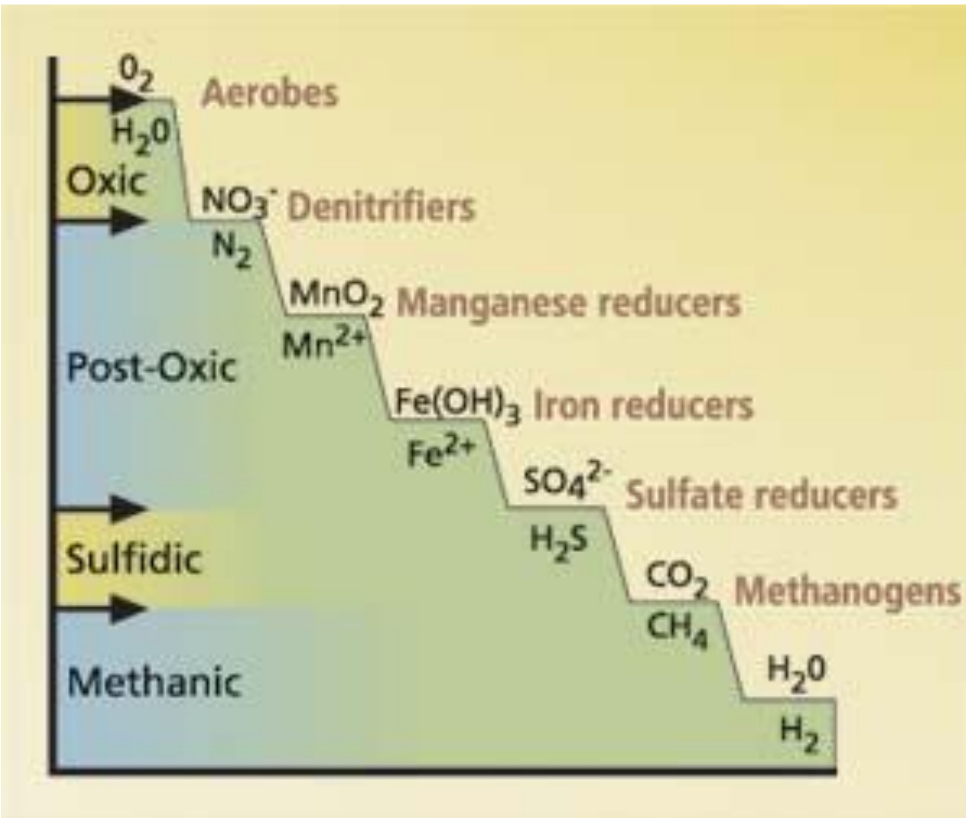
Acetotrophic: $CH_3COOH \rightarrow CO_2 + CH_4$

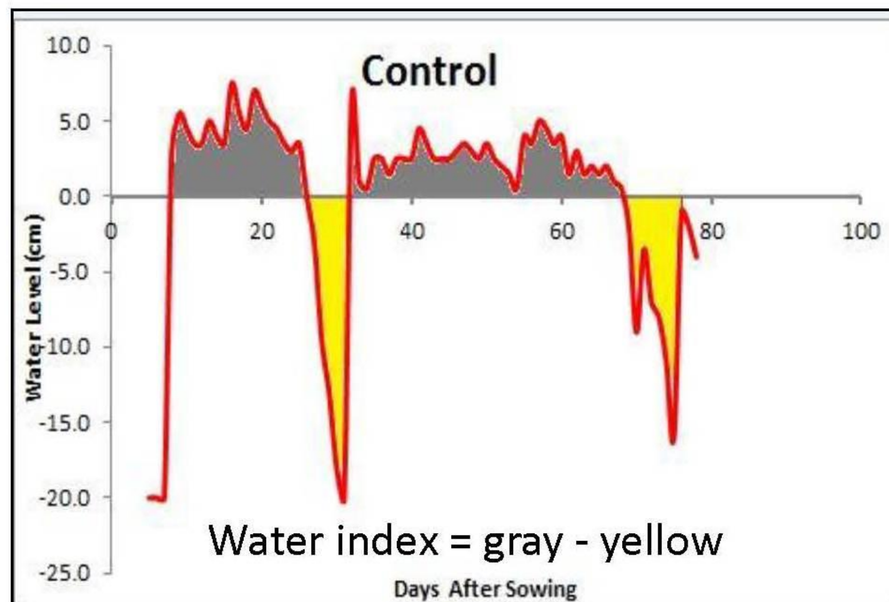
Rice N_2O emissions: Why and when?



Aerobic/irrigated paddy in sandy soils

Changing Water levels = Fluctuating redox = potential for high N_2O emissions



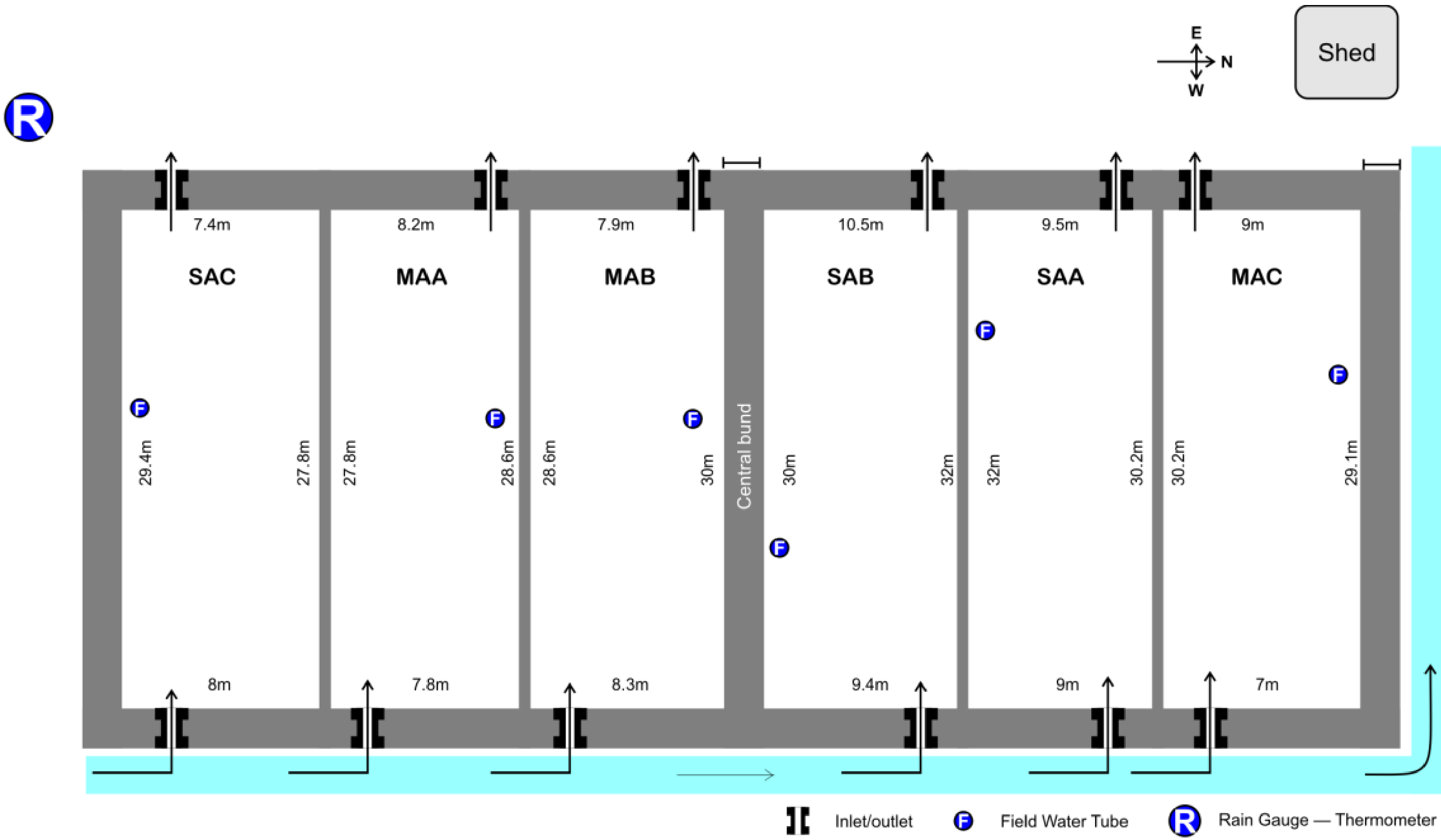


Methodology

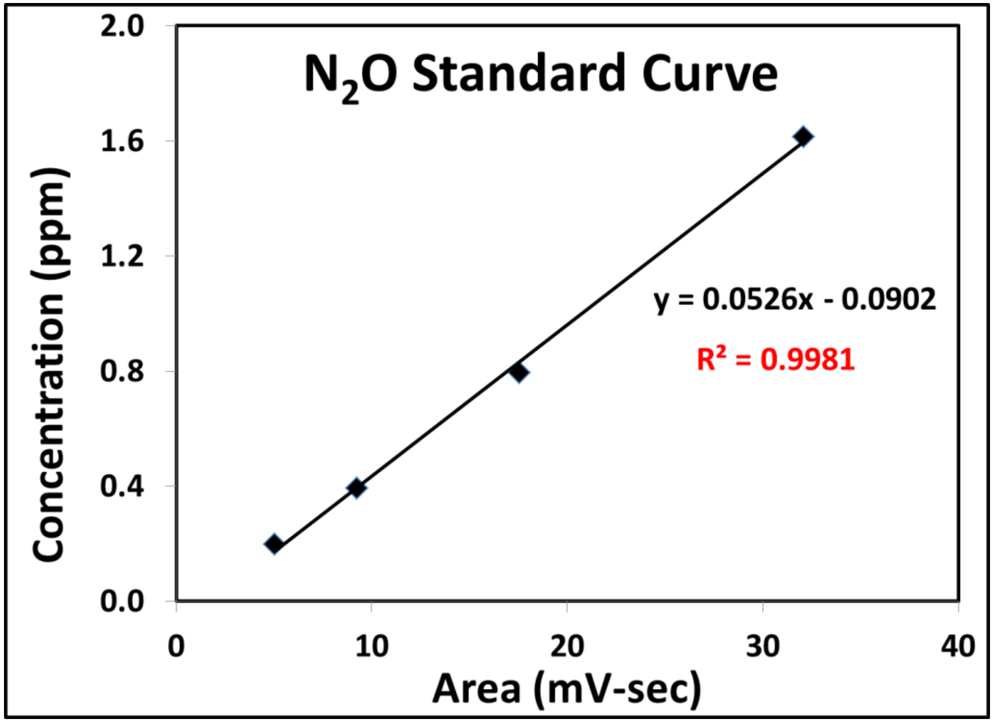
Rice GHG sampling

Photo: Dr. Tran Kim Tinh, Can Tho University

Replicates separated by levees



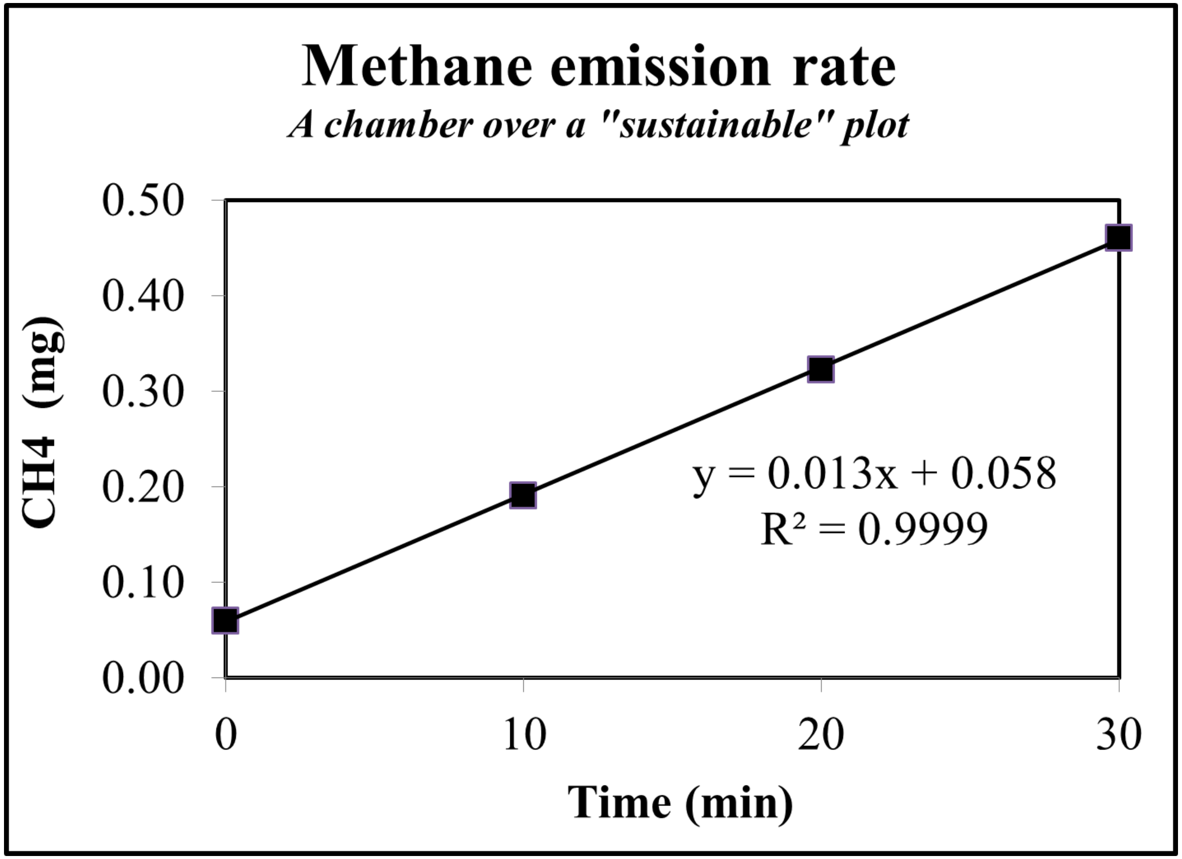
Multi-point calibration curves for GC



N_2O (ppmv)	CH_4 (ppmv)
0.197	1.535
0.393	3.352
0.795	7.152
1.615	15.682

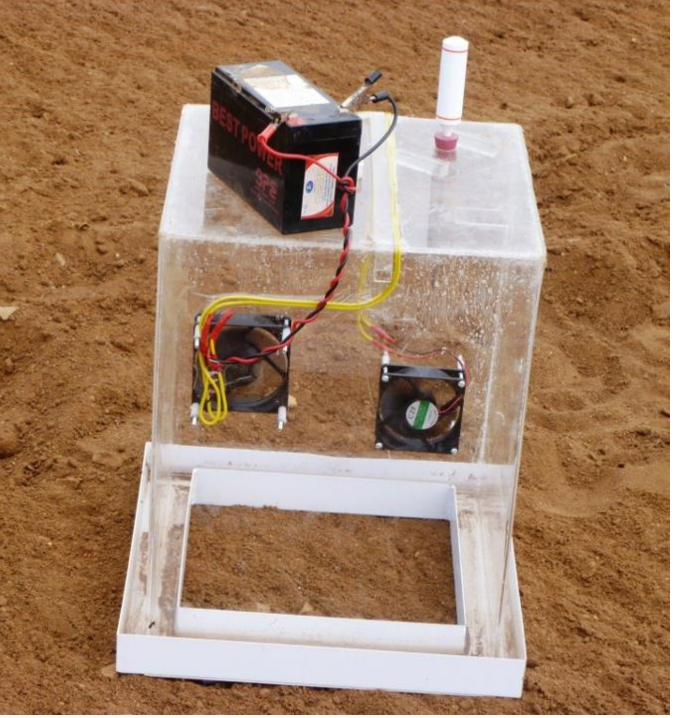
Methodology's minimum detection limit

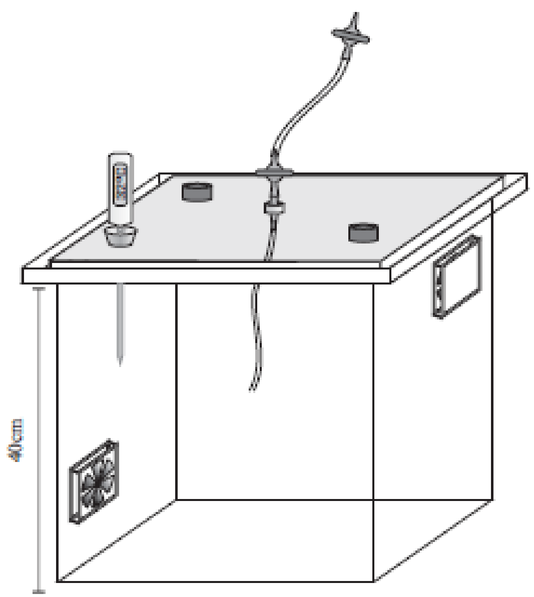
GC's Precision should be less than 2% RSD



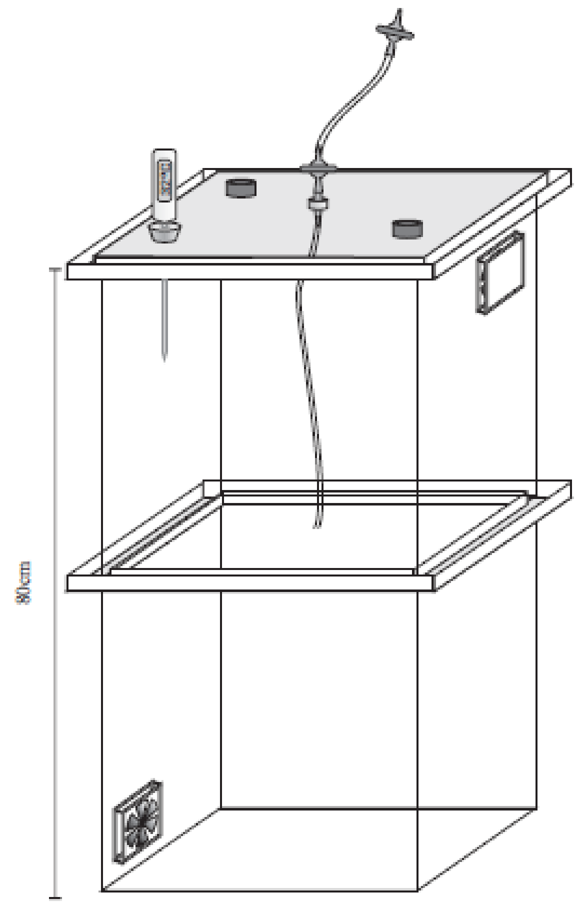
Linear increase in GHG concentration inside the chamber

Stackable chambers

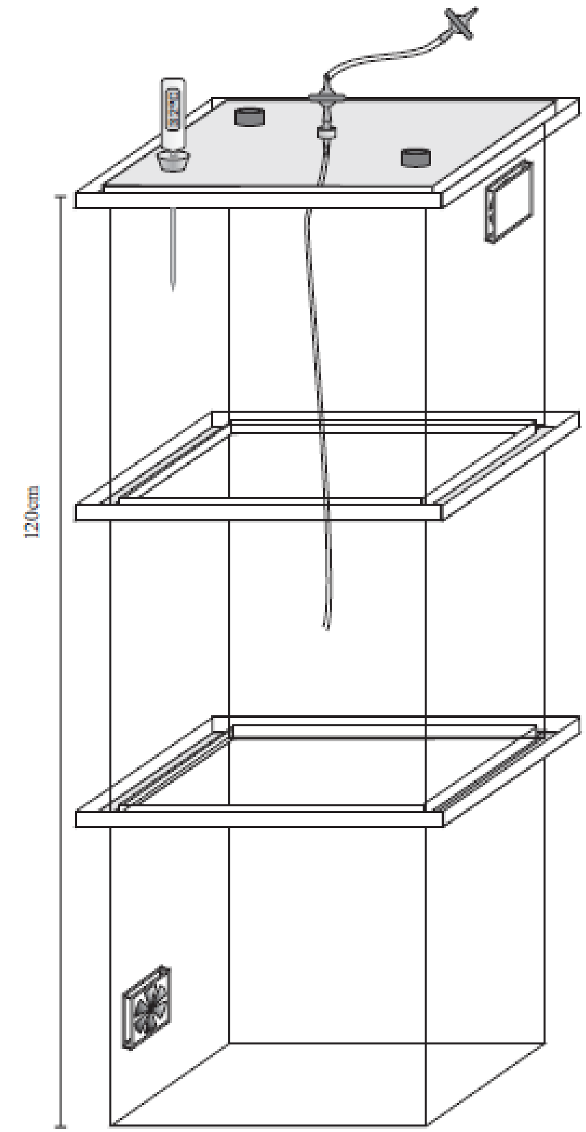




40cm
Sampling tube: 20cm



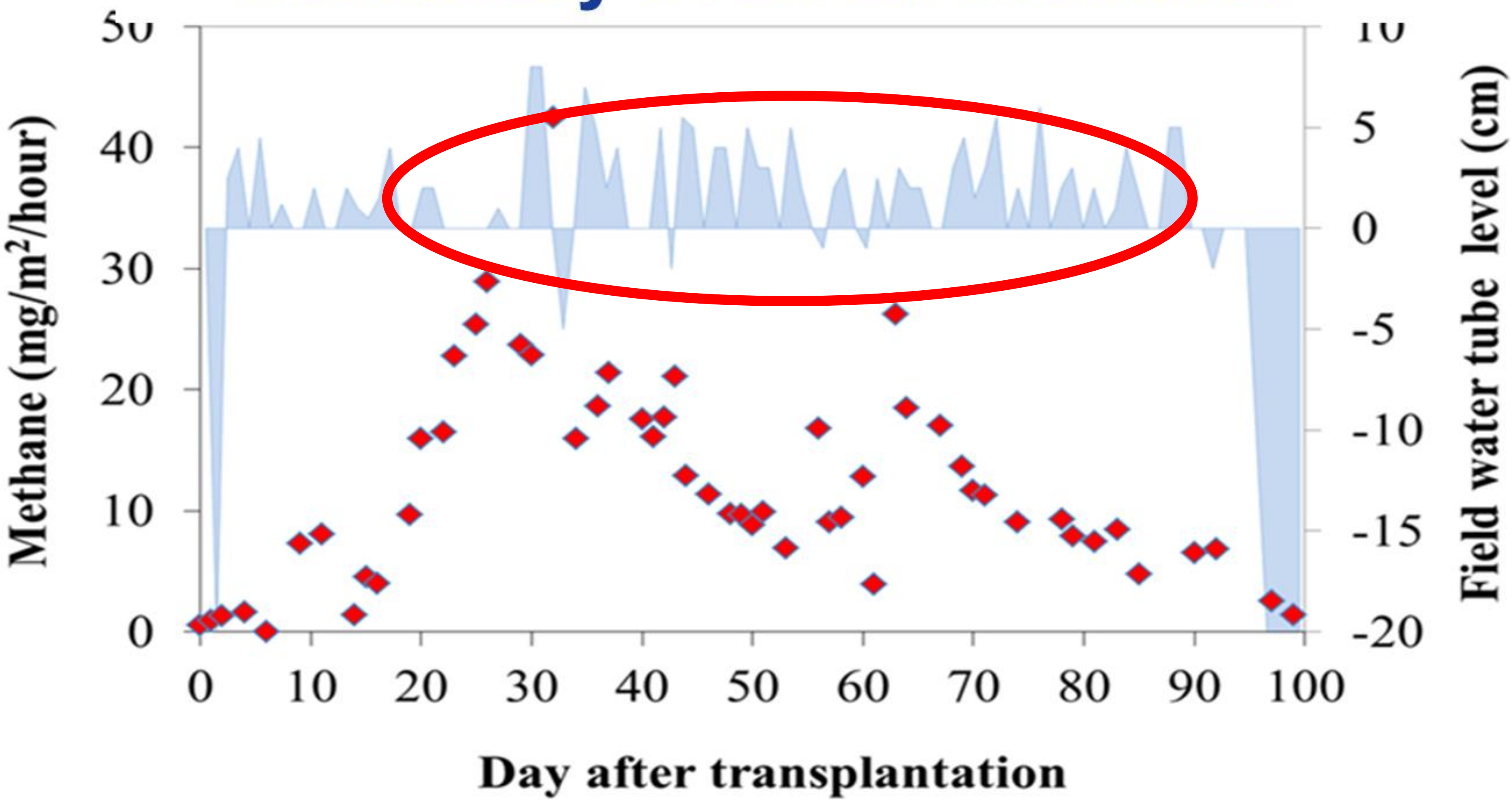
80cm
Sampling tube: 40cm

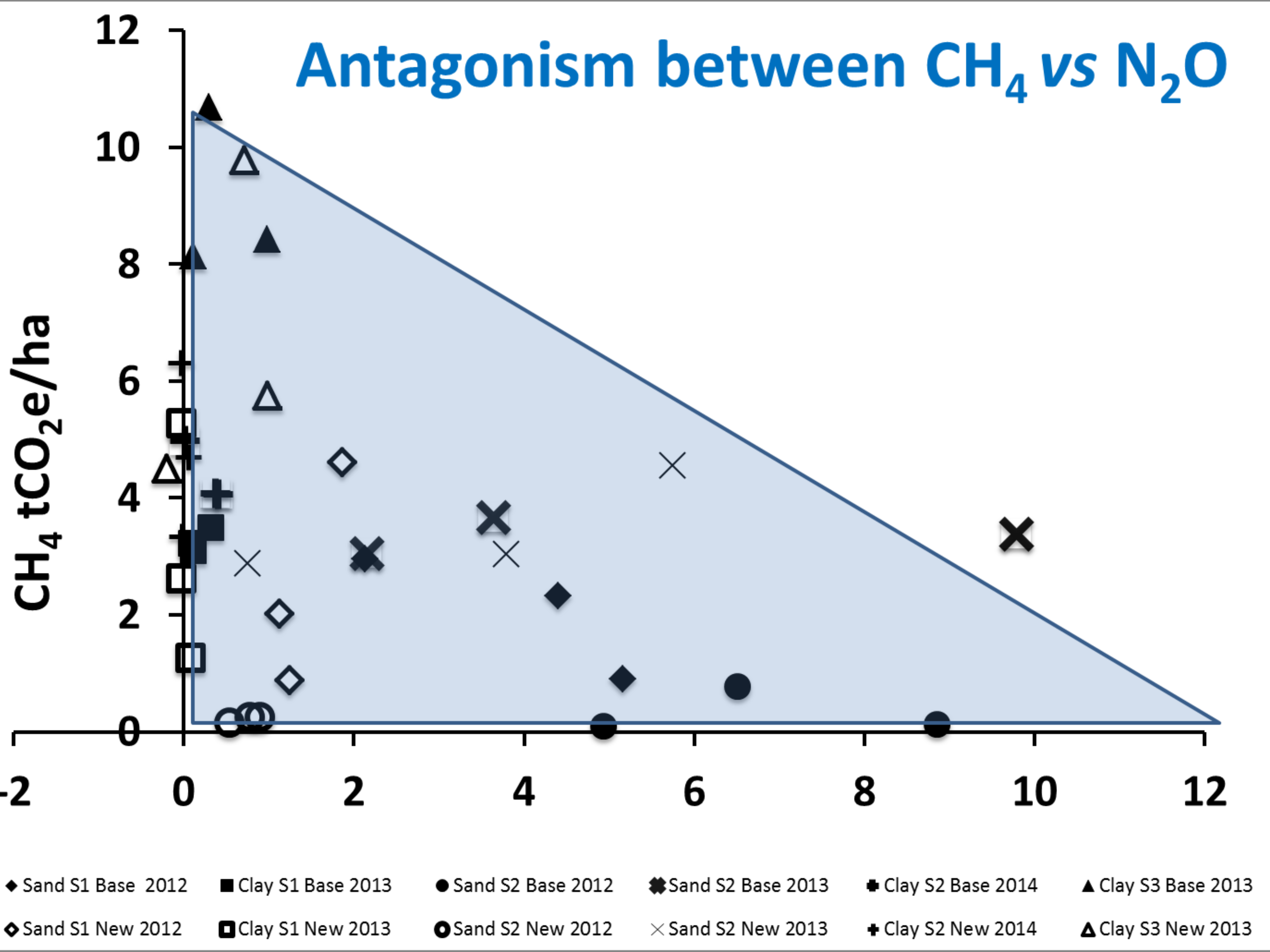


120cm
Sampling tube: 60cm

Results

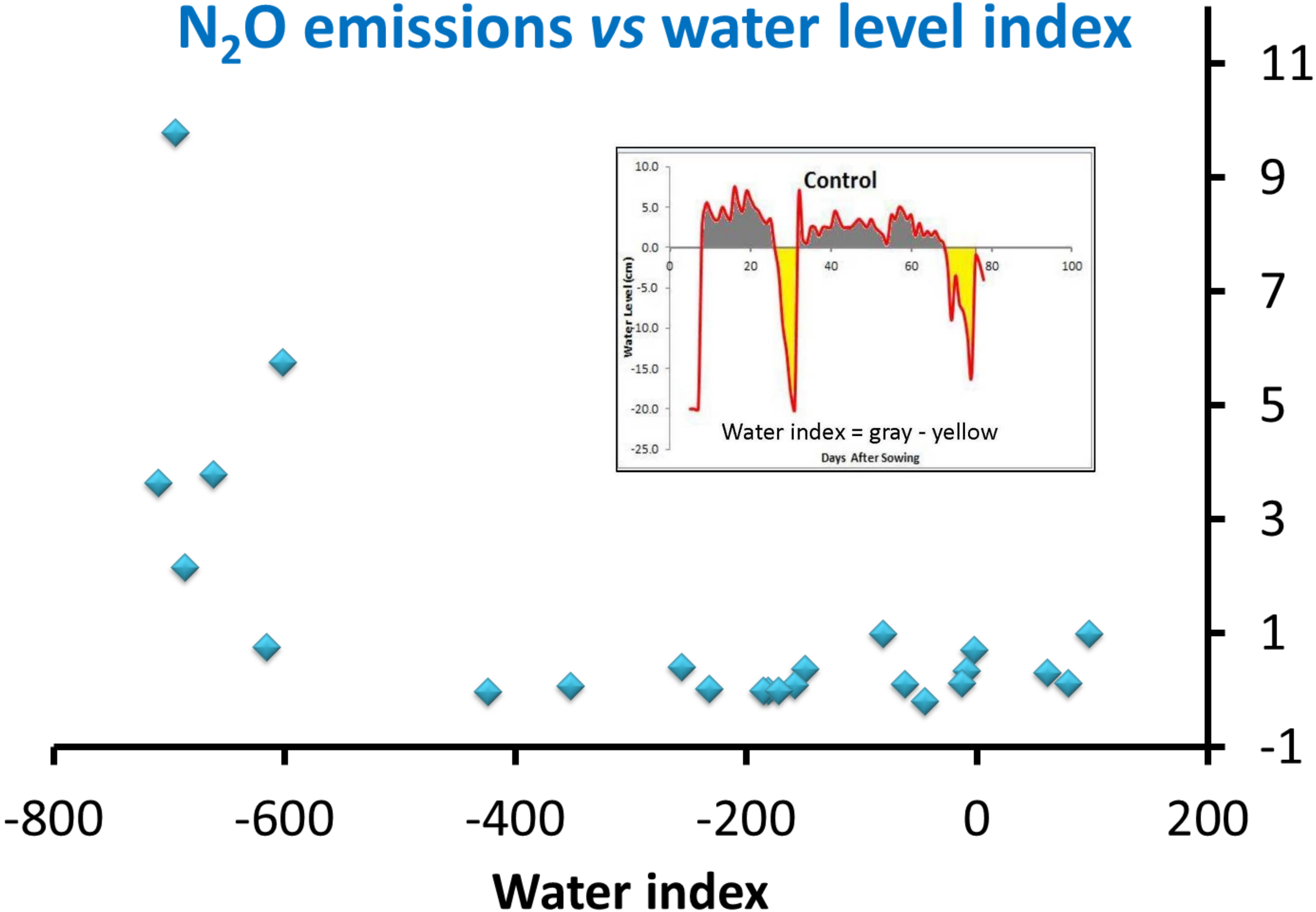
Frequent field sampling necessary even for methane





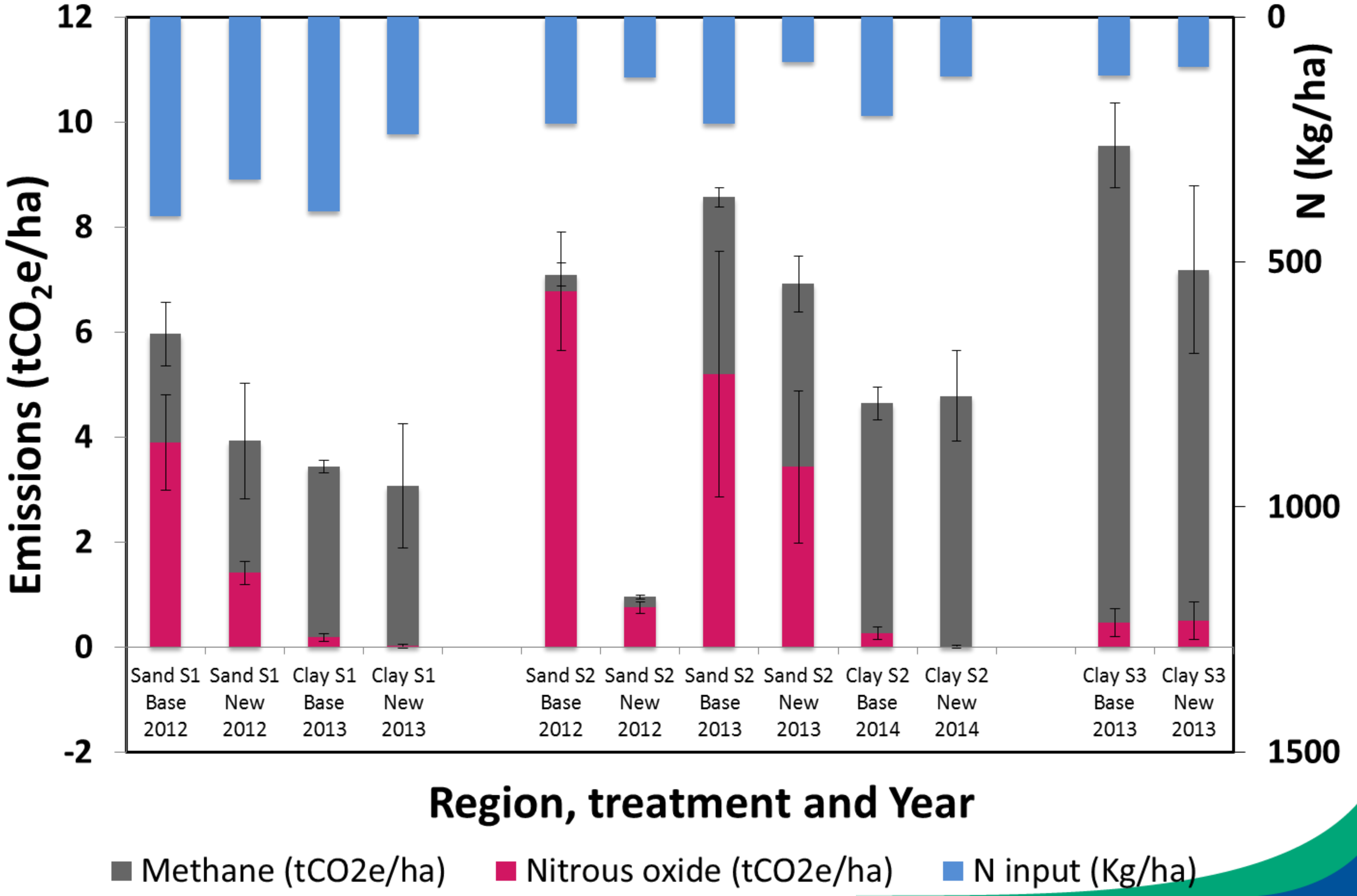
Antagonism between CH_4 *vs* N_2O
CH_4 tCO_2e/ha
12
10
8
6
4
2
0
-2
0
2
4
6
8
10
12
Sand S1 Base 2012
Clay S1 Base 2013
Sand S2 Base 2012
Sand S2 Base 2013
Clay S2 Base 2014
Clay S3 Base 2013
Sand S1 New 2012
Clay S1 New 2013
Sand S2 New 2012
Sand S2 New 2013
Clay S2 New 2014
Clay S3 New 2013

N_2O emissions *vs* water level index



Nitrous oxide *vs* Methane emissions

3 Agro-ecological zones over 3 years



Summary: Rice

In partnership with AF *(Accion Fraterna)*

Rice Fall 2012

N input (Kg N/ha): 406 → 331

N_2O (tCO2e/ha): 3.90 ± 1.0 → 1.40 ± 0.2

N_2O (N_2O-N Kg/ha): 8.32 ± 1.9 → 3.02 ± 0.49

CH_4 (tCO2e/ha): 2.06 ± 1.0 → 2.52 ± 1.0

Yield-scaled (tCO_2e/t yield) : 1.3 → 0.8

Emission factor (%) : 2.05 → 0.91

Rice Fall 2013

N input (Kg N/ha): 397 → 239

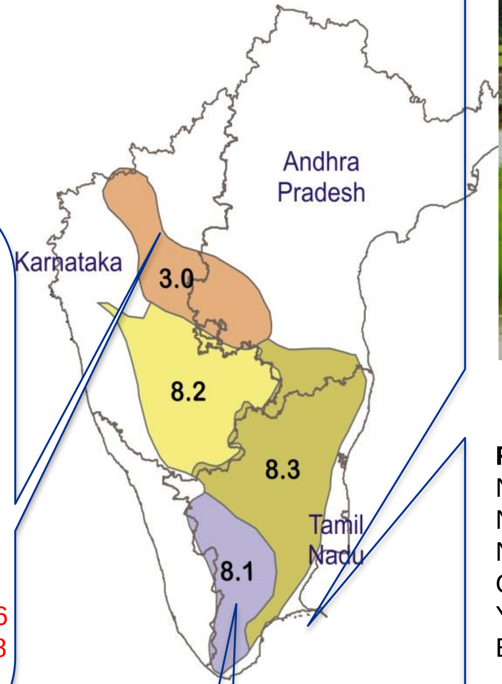
N_2O (tCO_2e/ha): 0.18 ± 0.07 → 0.02 ± 0.03

N_2O (N_2O-N Kg/ha): 0.39 ± 0.15 → 0.04 ± 0.06

CH_4 (tCO_2e/ha): 3.25 ± 0.11 → 3.05 ± 1.18

Yield-scaled (tCO_2e/t yield) : 0.73 → 1.14

Emission factor (%): 0.1 → 0.02



In partnership with BEST
(Bharat Environment Seva Team)

Rice Fall 2012

N input (Kg N/ha): 220 → 124

N_2O (tCO_2e/ha): 6.8 ± 1.1 → 0.7 ± 0.1

N_2O (N_2O-N Kg/ha): 14.0± 2.4 → 0.2 ± 0.2

CH_4 (tCO_2e/ha): 0.3 ± 0.2 → 0.2 ± 0.03

Yield-scaled (tCO_2e/t yield) : 1.7 → 0.4

Emission factor (%) : 6.6 → 1.2

Rice Fall 2013

N input (Kg N/ha): 220 → 93

N_2O (tCO_2e/ha): 5.2 ± 2.34 → 3.4 ± 1.4

N_2O (N_2O-N Kg/ha): 11.0 ± 4.9 →7.0 ± 3.1

CH_4 (tCO_2e/ha): 3.4 ± 0.2 → 3.5 ± 0.5

Yield-scaled (tCO_2e/t yield) : 1.5→ 1.7

Emission factor (%) : 5 → 8

Rice Fall 2014

N input (Kg N/ha): 202 → 121

N_2O (tCO_2e/ha): 0.26 ± 0.13 → 0.01 ± 0.03

N_2O (N_2O-N Kg/ha): 1.4 ± 0.6 → 0.03 ± .15

CH_4 (tCO_2e/ha): 4.37 ± 0.3 → 4.78 ± 0.8

Yield-scaled (tCO_2e/t yield) : 1.48→ 0.34

In partnership with PWDS
(Palmyrah Workers Development Society)

Rice Fall 2013

N input (Kg N/ha): 120 → 100

N_2O (tCO_2e/ha): 0.5 ± 0.26 → 0.49 ± 0.36

N_2O (N_2O-N Kg/ha): 0.99 ± 0.56 → 1.1 ± 0.76

CH_4 (tCO_2e/ha): 9.1 ± 0.8 → 1.5 ± 1.1

Yield-scaled (tCO_2e/t yield) : 0.54 → 0.41

Emission factor (%): 0.82 → 1.06

Conclusions

Technical conclusions

- Maximum observed N_2O 10 tCO_2e/ha/season (Max till date 2)
- Antagonism between N_2O and CH_4 emissions
- Emission factor: Maximum 8%

  Range 0.22% Linquist (2012), 0.31% Akiyama (2005), 04.-0.7% Sun (2012)
- High percolation rates & low water index can cause high N_2O
- Drainage can lead to both high N_2O and high CH_4
- AWD initiatives must evaluate potential N_2O increase
- Timing of synthetic fertilization (one time vs. multiple)
- Timing of organic matter addition (during dry season)
- Methane and soil C/long term soil quality and yields: future need of C/N additions?

Rice GHG emissions: Unresolved challenges

Net Global warming potential (100 year time scale) =

(**31*Methane**) + (**298*Nitrous Oxide**) **minus** (**3.66*Soil Carbon gain**)

- Antagonism between N_2O & CH_4 wrt water management is known; but
  - Once a week measurements can be very misleading.

- Antagonism between methane emissions and soil C gain is not yet appreciated
  - Water and C management for CH_4 reduction degrades stable soil C
  - Soil C loss (0.5-1 ton C/yr/ha) can undo effect of N_2O and CH_4 reductions

- Soil C loss → a negative impact on soil quality, climate resilience and crop yield
  - Will require more C and N input in future

- As a community, we should emphasize on
  - Water level monitoring near chambers
  - Soil analysis
  - Daily calibration
    - Use of only 1-2 points for calibration → faulty results
    - Use of 2-3 samples from a chamber → misleading emission rates

Questions?

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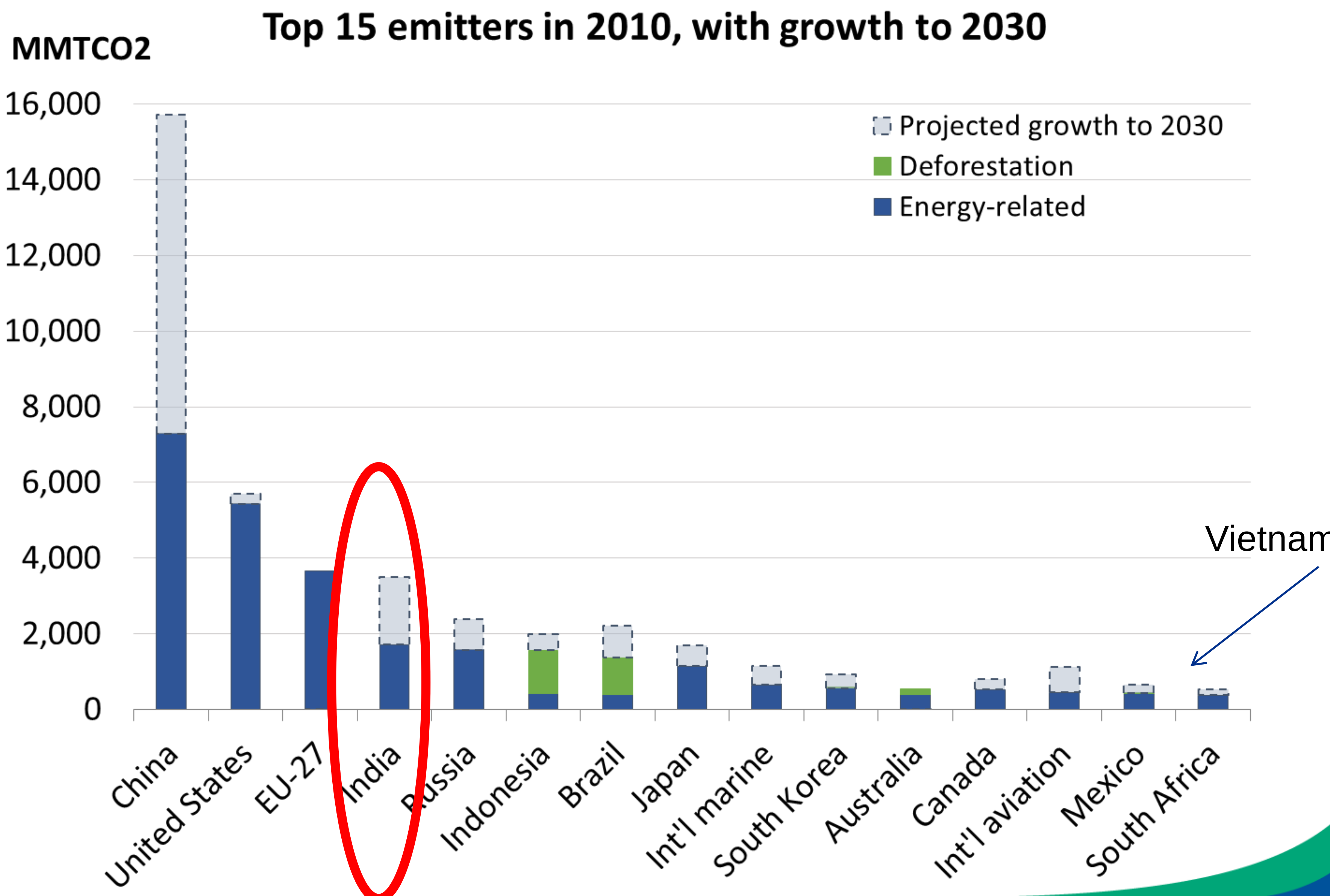
Greenhouse gas emissions CO_2e (2010 & 2030)



Policy & Management Implications

- AWD initiatives must evaluate potential N_2O increase
- High percolation rates & low water index can cause high N_2O
- Timing of organic matter addition (during dry season)
- Timing of synthetic fertilization (one time vs. multiple): Different for different regions

- Nitrous oxide emission on site vs. leaching off-site?
- Traditional seed variety vs. hybrids?
- Methane and soil C/long term soil quality and yields: future need of C/N additions?

Ensuring climate Integrity & meeting potential C market requirements

- Additionality
  - Surveys for baseline conditions/practices (2000 farmers)
  - New interventions “sustainable” practices

- Leakage and permanence
  - Sample collection & GHG emissions (30,000 samples)
  - Yields and economic data
  - Data analysis and modeling

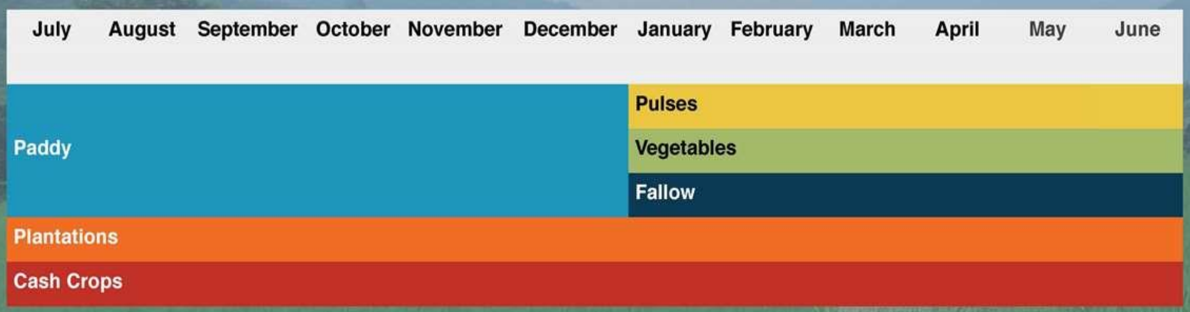
- Transparency and monitoring:
  - Farmer diaries (20,000)
  - Data storage and presentation

- Submission under an existing/new offset methodology
  - Peer reviewed publications (2 + 2)

Cropping Patterns and Land Use CeFHA 2012 - 2014

Crops Cultivated and Cropping Calendar

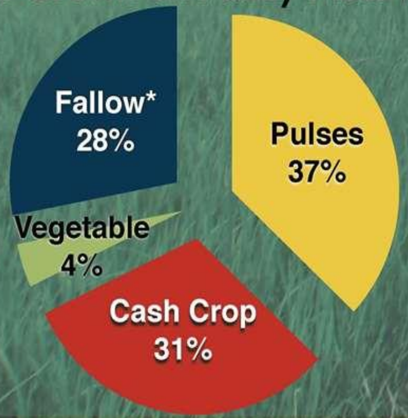
Cereals	Pulses	Cash Crops	Vegetables	Plantation
Paddy, Millets	Green Gram, Back Gram, Horse Gram, Yellow Gram	Cotton, Oilseed, Sugarcane, Tapioca	Gourds, Beans, Eggplant, Chilli, Ocra, Tomato	Casuarina, Banana, Coconut, Cashew, Mango



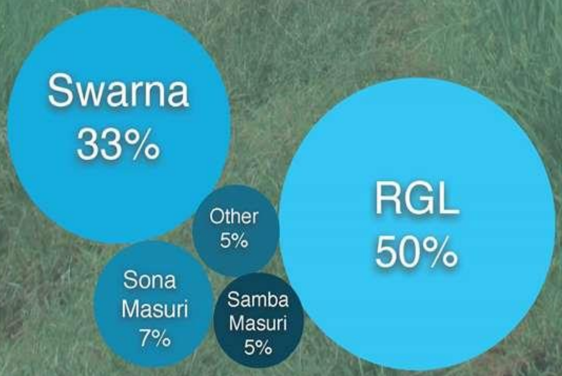
91% Farmers grow paddy in Kharif

% Area under Crop Type in Kharif

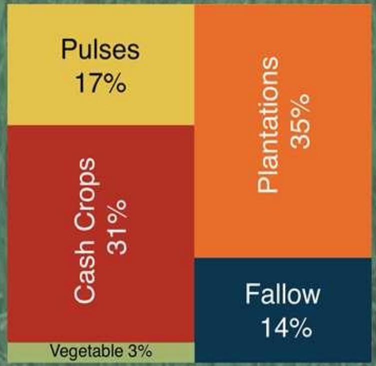
Crops Grown on Paddy Plots in Rabi



Rice Varieties Grown

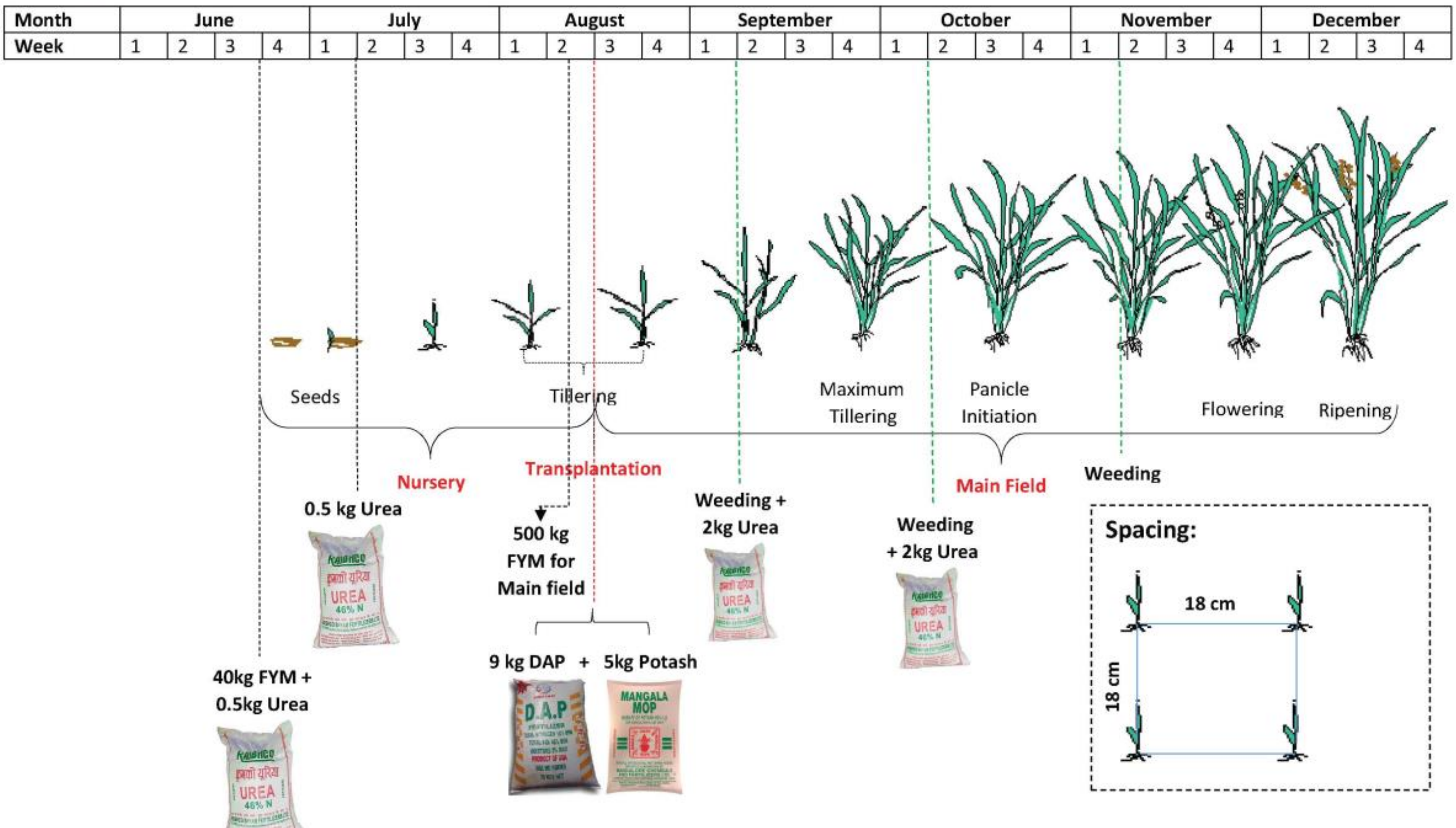


% Area under Crop Type in Rabi



*Fallow land includes 1% fodder crop
All data presented is taken from 3 year average

Designing new (LCF) practices



Extra Slides for soil conference: include upland crop data and other details

Agricultural N_2O emissions: Wh

non-CO_2 GHGs.

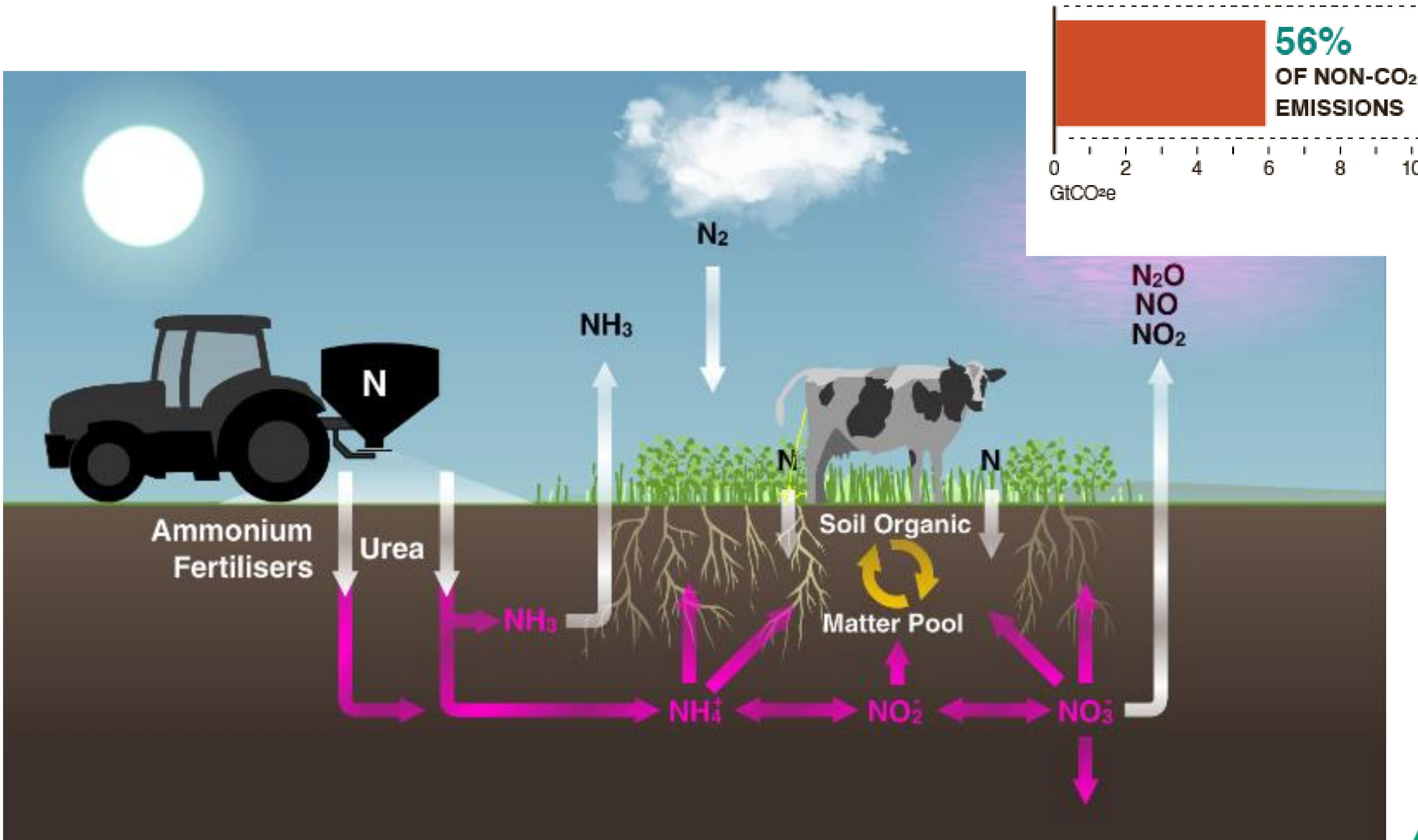
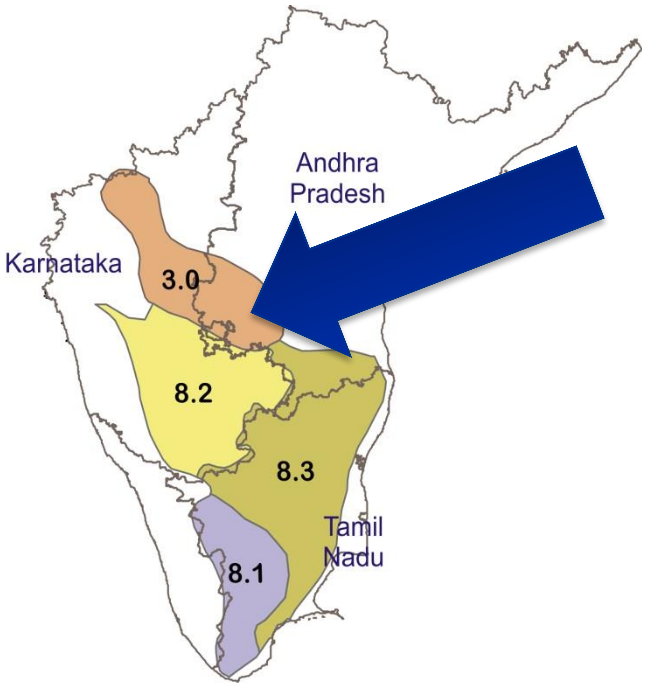


Figure from http://cwfs.org.au/nitrous_oxide__n2o__losses_from_cropping_in_low_rainfall_environments

Peanut (AEZ 3.0)

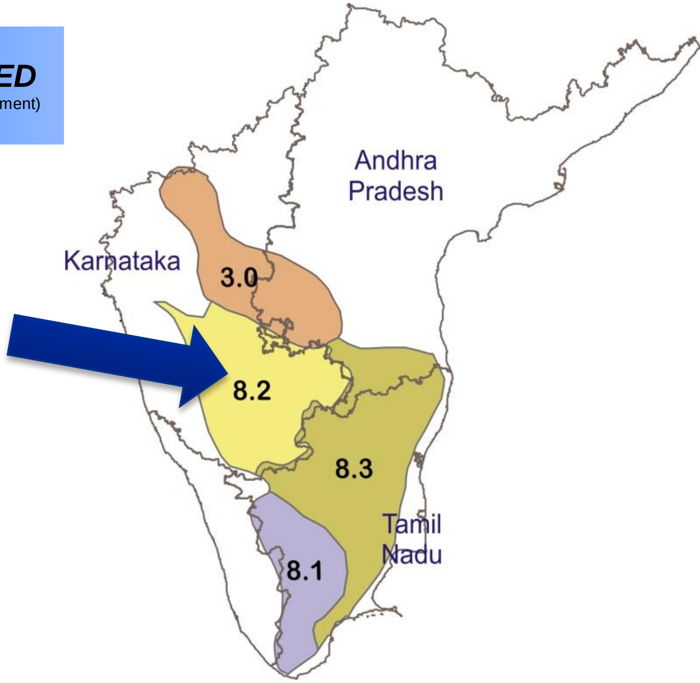
In partnership with AF
(Accion Fraterna)



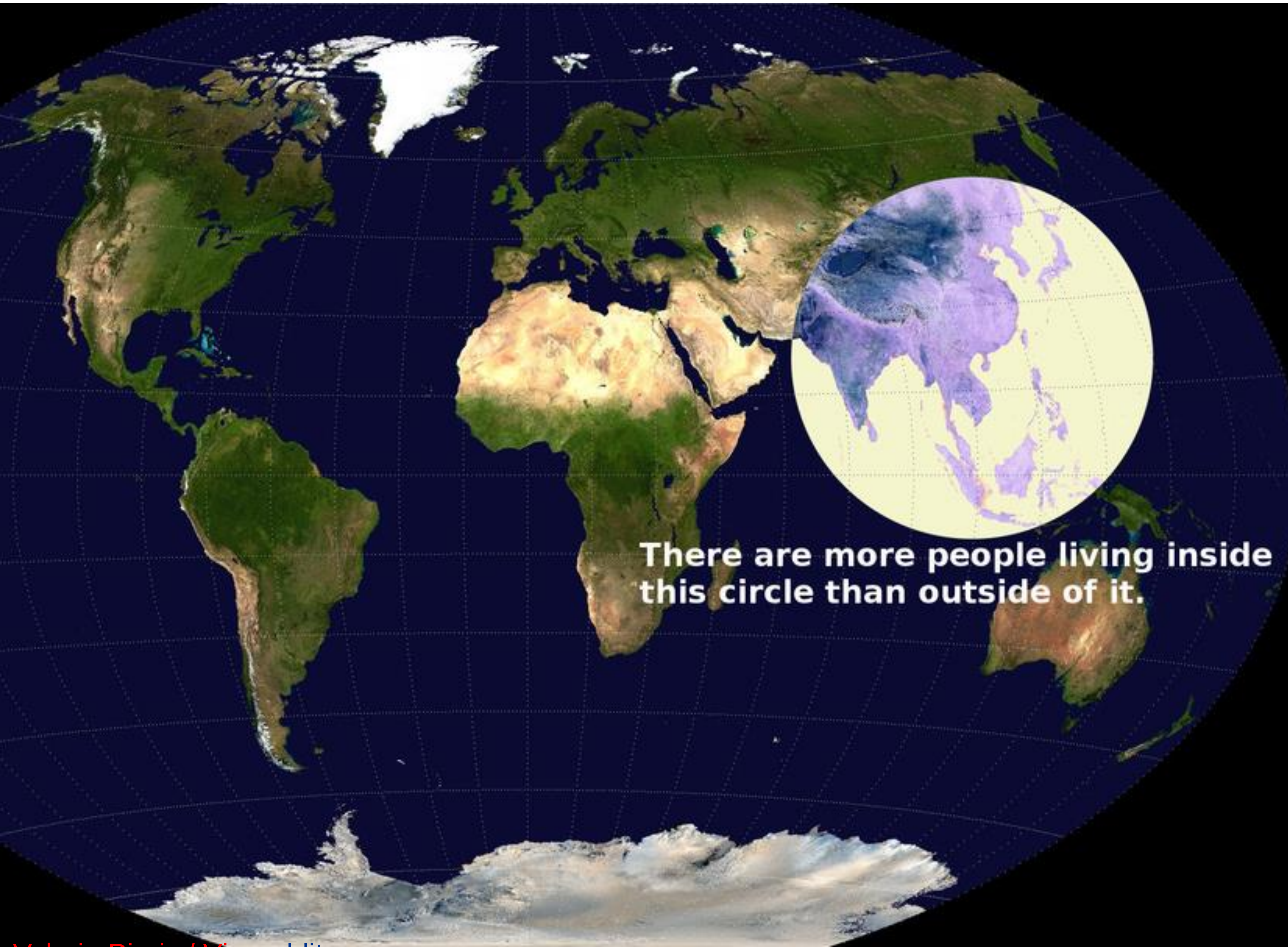
	2012 *Kharif*	2012 *Rabi*	2013 *Kharif*	2014 *Kharif*
N input (kg N/ha)	66 → 41	104 → 42	97 → 78	101 → 57
N_2O (tCO_2e/ha)	0.61 → 0.47	0.88 → 0.64	0.5 ± 0.1 → 0.3 ± 0.04	1.3 ± 0.3 → 0.5 ± 0.1
N_2O (N_2O-N kg/ha)	1.3 ± 0.3 → 1.0 ± 0.03	1.9 ± 0.3 → 1.4 ± 0.4	1.1 ± 0.1 → 0.64 ± 0.1	2.9 ± 0.5 → 1.1 ± 0.3
Yield-scaled (tCO_2e/t yield)	1.6 ± 0.4 → 0.8 ± 0.02	0.9 ± 0.1 → 0.5 ± 0.1	0.8 ± 0.05 → 0. 6 ± 0.04	5.6 ± 0.3 → 1.9 ± 0.1
Emission factor (%)	1.7% → 2.1%	1.6% → 2.9%	0.9% → 0.6%	2.4% → 1.1%

Finger millet *Kharif* (AEZ 8.2)

In partnership with SACRED
(Social Animation Center for Rural Education & Development)



	2012	2013	2014
N input (kg N/ha)	211 → 72	470 → 72	475 → 72
N_2O (tCO_2e/ha)	1.55 ± 0.69 → 0.34 ± 0.14	8.41 ± 1.05 → 0.11 ± 0.08	6.07 ± 2.40 → 0.16 ± 0.05
N_2O (N_2O-N kg/ha)	3.30 ± 1.46 → 0.73 ± 0.29	17.96 ± 2.25 → 0.23 ± 0.17	12.97 ± 5.13 → 0.34 ± 0.12
Yield-scaled (tCO_2e/t yield)	3.66 ± 0.87 → 0.64 ± 0.17	15.05 ± 1.89 → 0.16 ± 0.12	12.07 ± 4.28 → 0.26 ± 0.08
Emission factor (%)	1.5% → 0.9%	3.8% → 0.19%	2.66% → 0.002%
	96mm CPR	149mm CPR	337 mm CPR



Valerie Pieris / Via reddit.com

Effect of agriculture on biosphere

Thin inter-connected layers

Freshwater

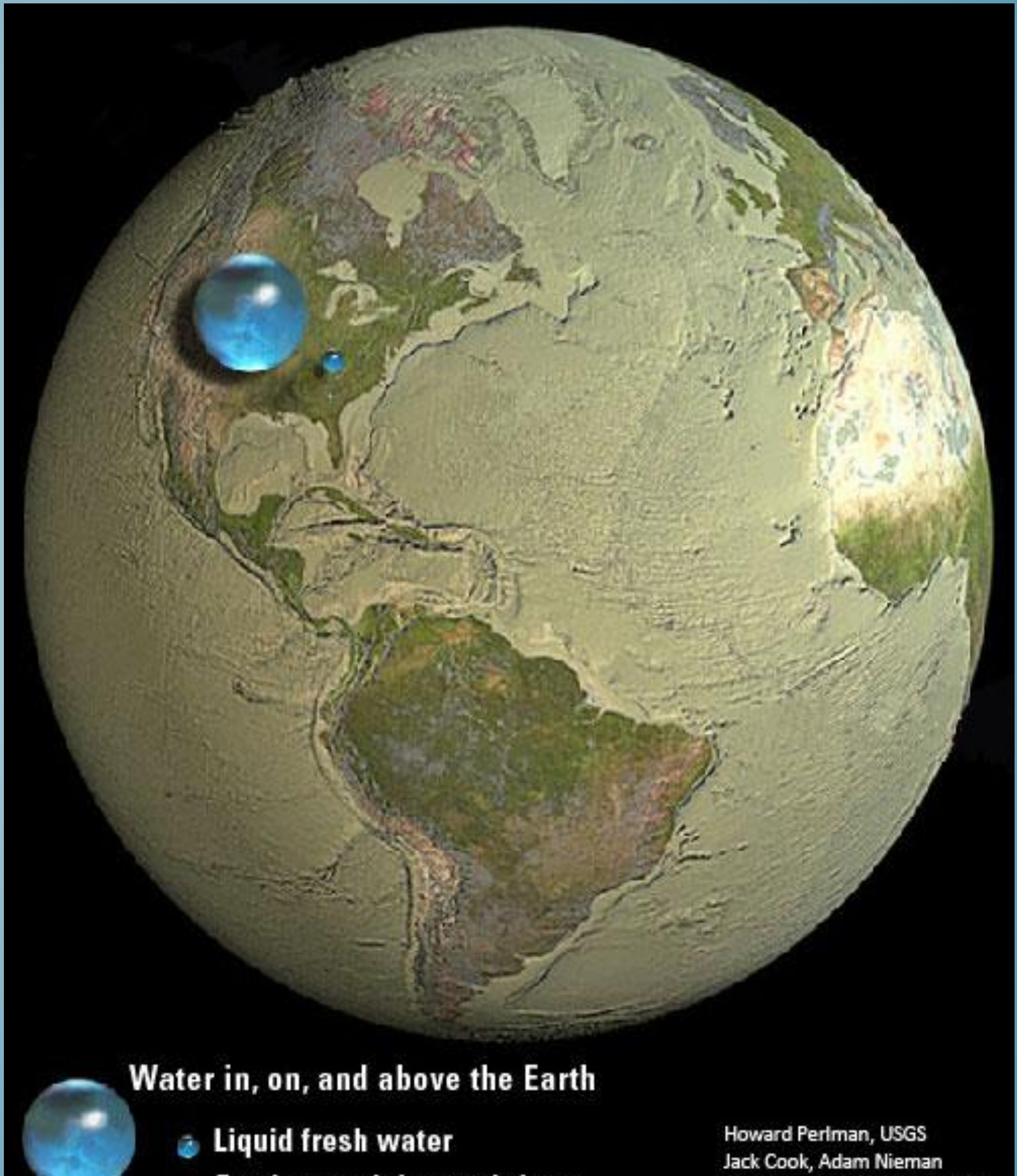
70% of 75 mile sphere

Topsoil

12-16 → → 2-8 inches

Atmosphere

20 miles



An IndiGo Airlines Airbus A320 aircraft is pictured parked at a gate at Mumbai's Chhatrapathi Shivaji International Airport on February 3, 2013. REUTERS/Vivek Prakash

Airline travelers in India who fly the country's largest airline now have an opportunity to support low-carbon rural development programs across the country.

The landmark partnership was **unveiled this weekend** between the Fair Climate Network (FCN), a consortium of Indian groups that is committed to improving health and livelihoods in rural communities, promoting climate resilience and reducing climate pollution, and IndiGo, the country's largest and fastest growing airline.

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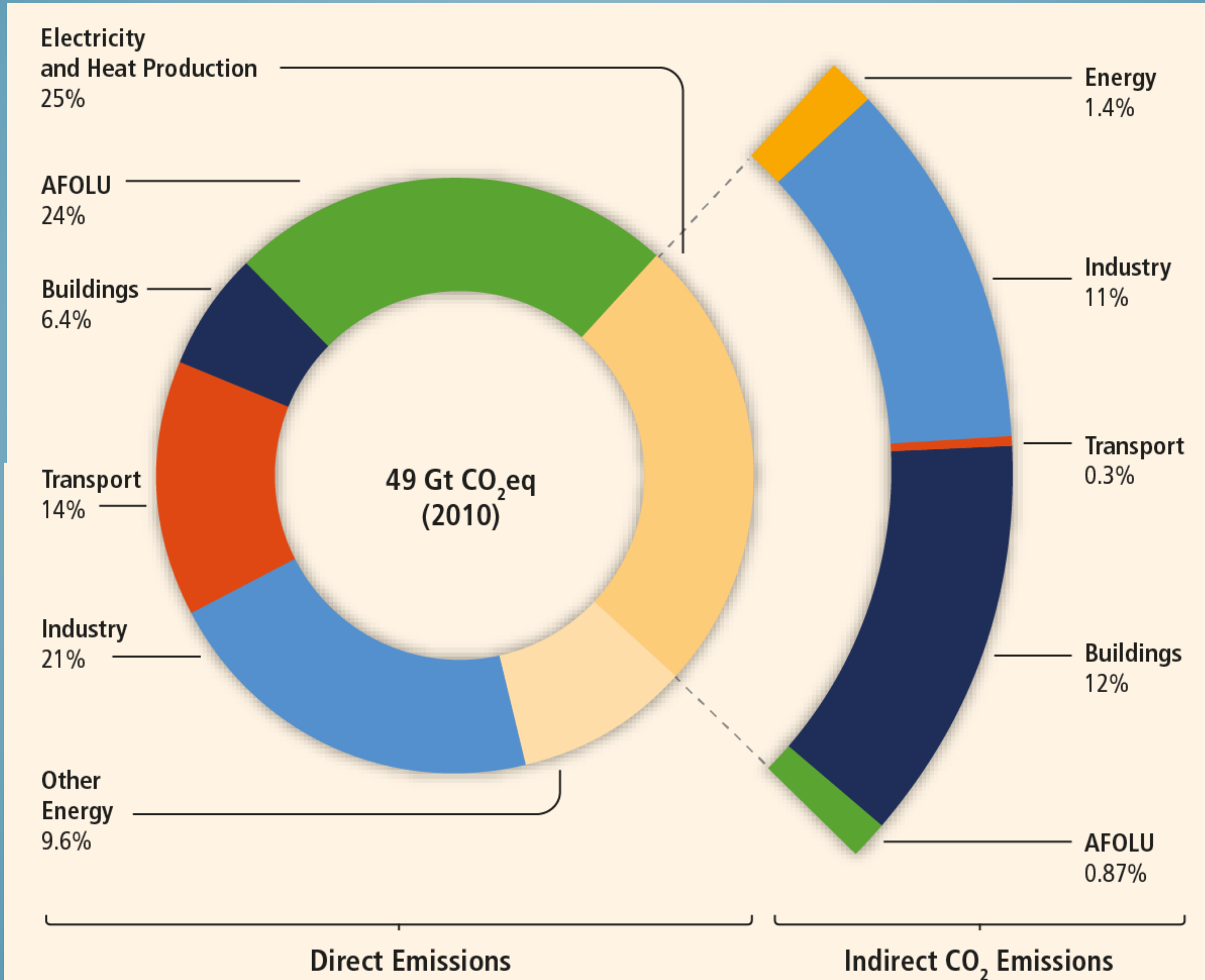
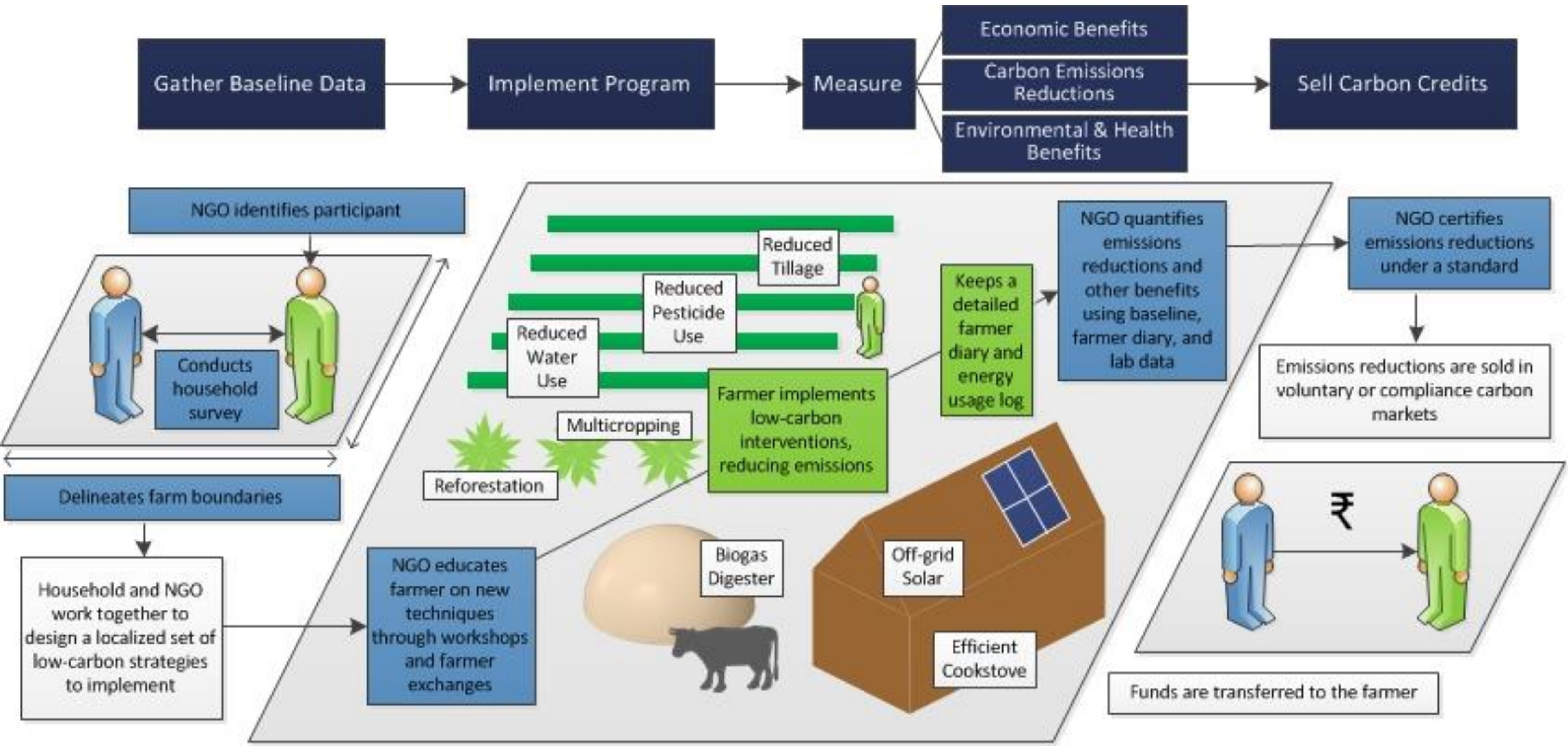


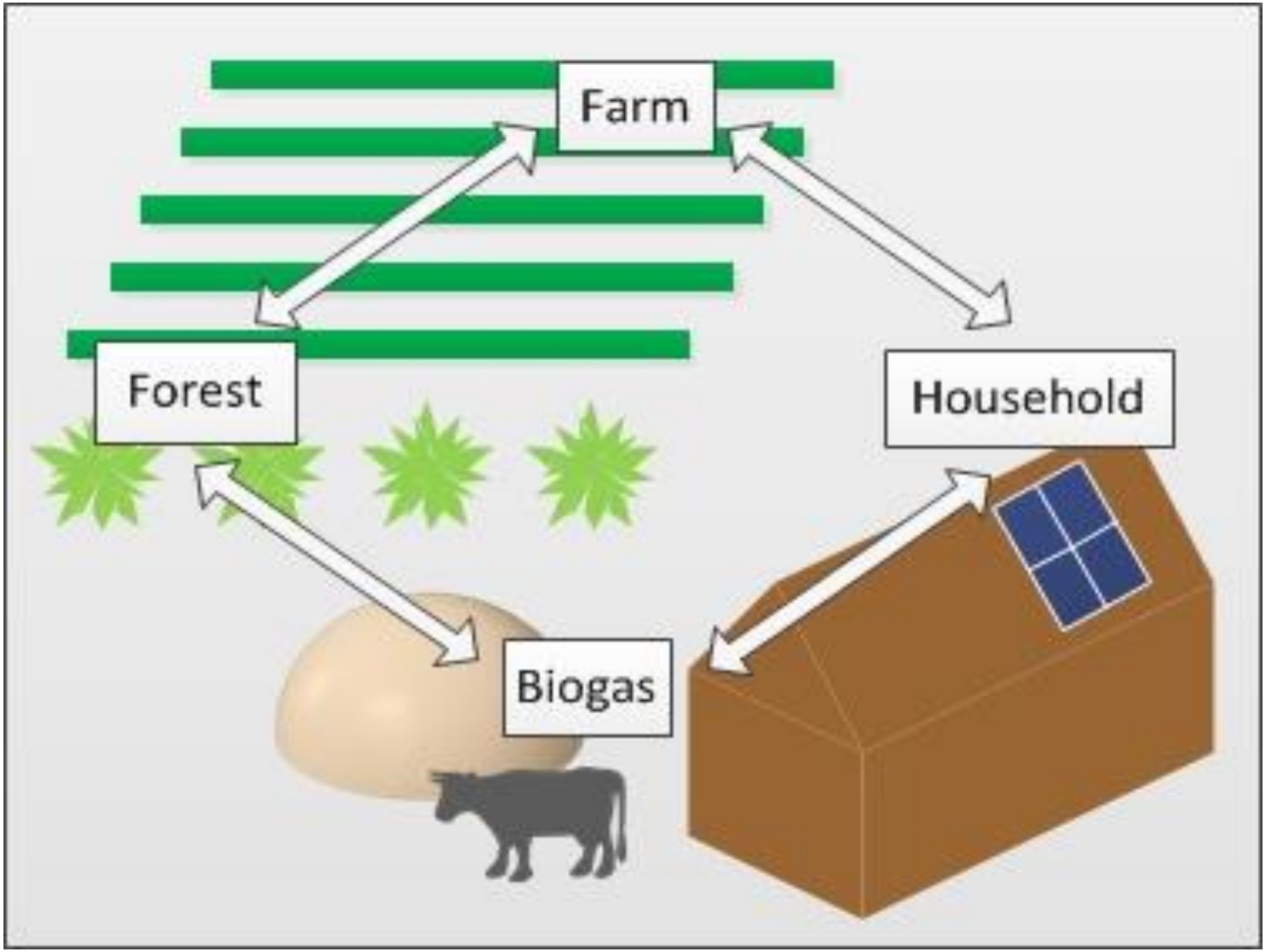
Electricity
and Heat Production
25%
AFOLU
24%
Buildings
6.4%
Transport
14%
Industry
21%
Other
Energy
9.6%
49 Gt CO_2eq
(2010)
Energy
1.4%
Industry
11%
Transport
0.3%
Buildings
12%
AFOLU
0.87%
Direct Emissions
Indirect CO_2 Emissions

Strategy

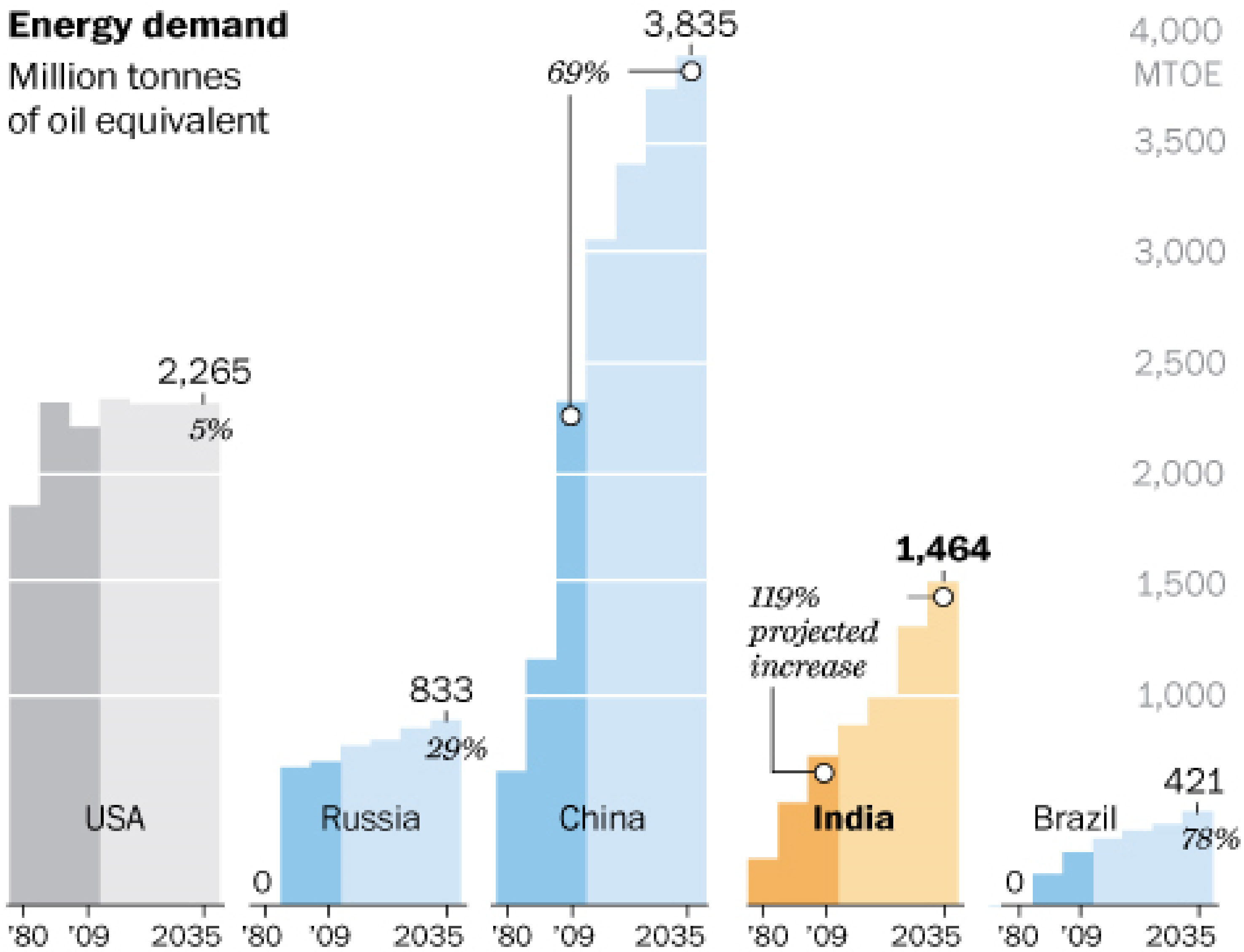


Gather Baseline Data
Implement Program
Measure
Economic Benefits
Carbon Emissions Reductions
Environmental & Health Benefits
Sell Carbon Credits
NGO identifies participant
Conducts household survey
Delineates farm boundaries
Household and NGO work together to design a localized set of low-carbon strategies to implement
NGO educates farmer on new techniques through workshops and farmer exchanges
Reduced Tillage
Reduced Pesticide Use
Reduced Water Use
Multicropping
Reforestation
Farmer implements low-carbon interventions, reducing emissions
Biogas Digester
Off-grid Solar
Efficient Cookstove
Keeps a detailed farmer diary and energy usage log
NGO quantifies emissions reductions and other benefits using baseline, farmer diary, and lab data
NGO certifies emissions reductions under a standard
Emissions reductions are sold in voluntary or compliance carbon markets
₹
Funds are transferred to the farmer

Interconnections & Energy Flows

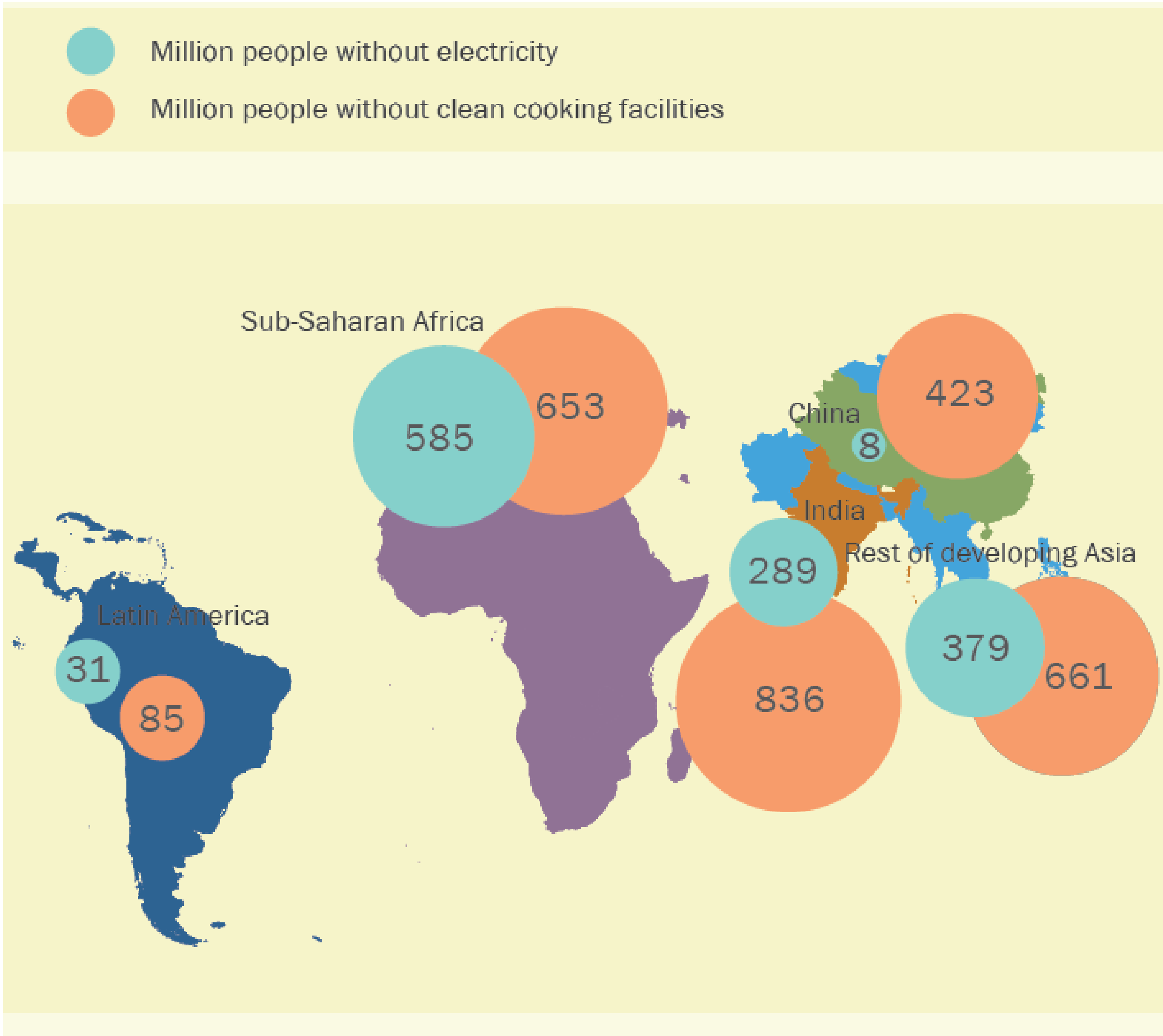


Energy demand trajectories



Source: IEA

ELECTRICITY & CLEAN COOK-STOVE GAP



Source: International Energy Agency, "Energy for All: Financing for the Poor," October 2011.

GHG emission reduction measurements

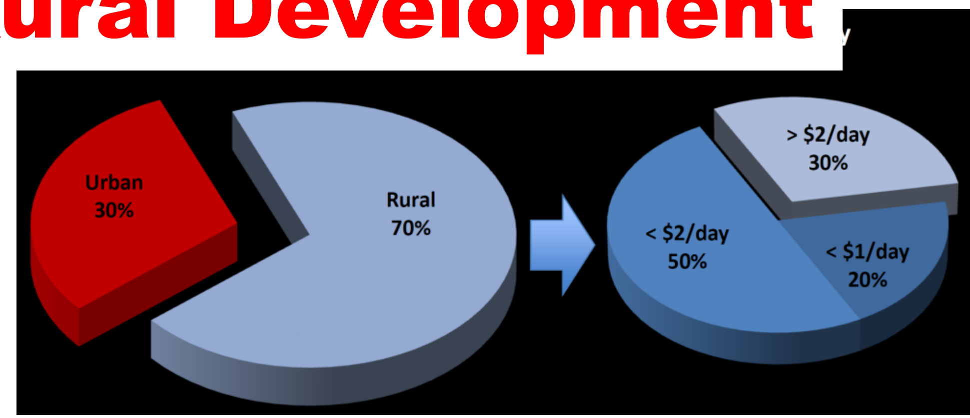
Feeding 9 billion & facing climate change

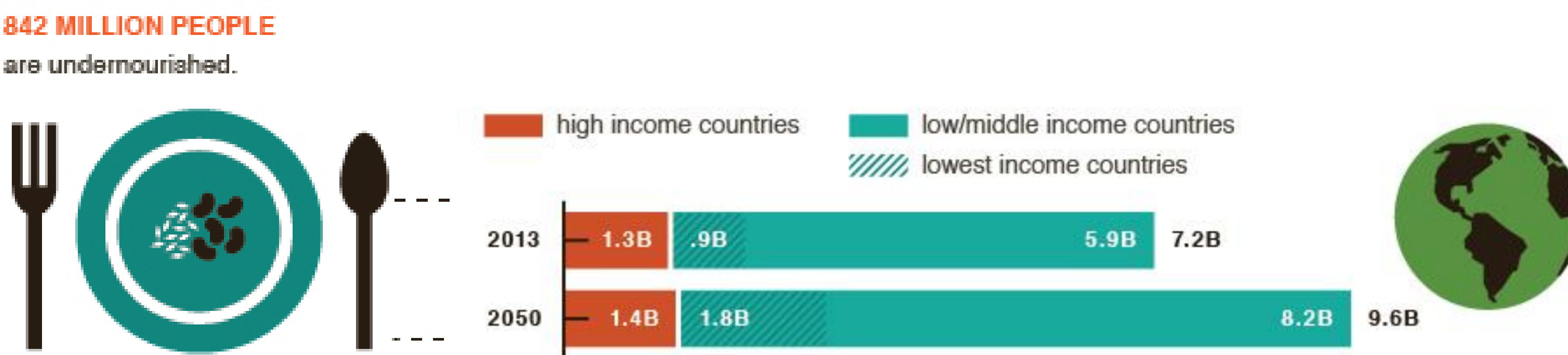
= Working with >2 billion who live on <$2/day and <2 ha

- 40-60% of a nation’s population is employed in agriculture
- These family farms grow ~90% rice, ~65% wheat and ~55% corn.
- Financial, institutional, ecological, diffusion & transfer barriers to implementations

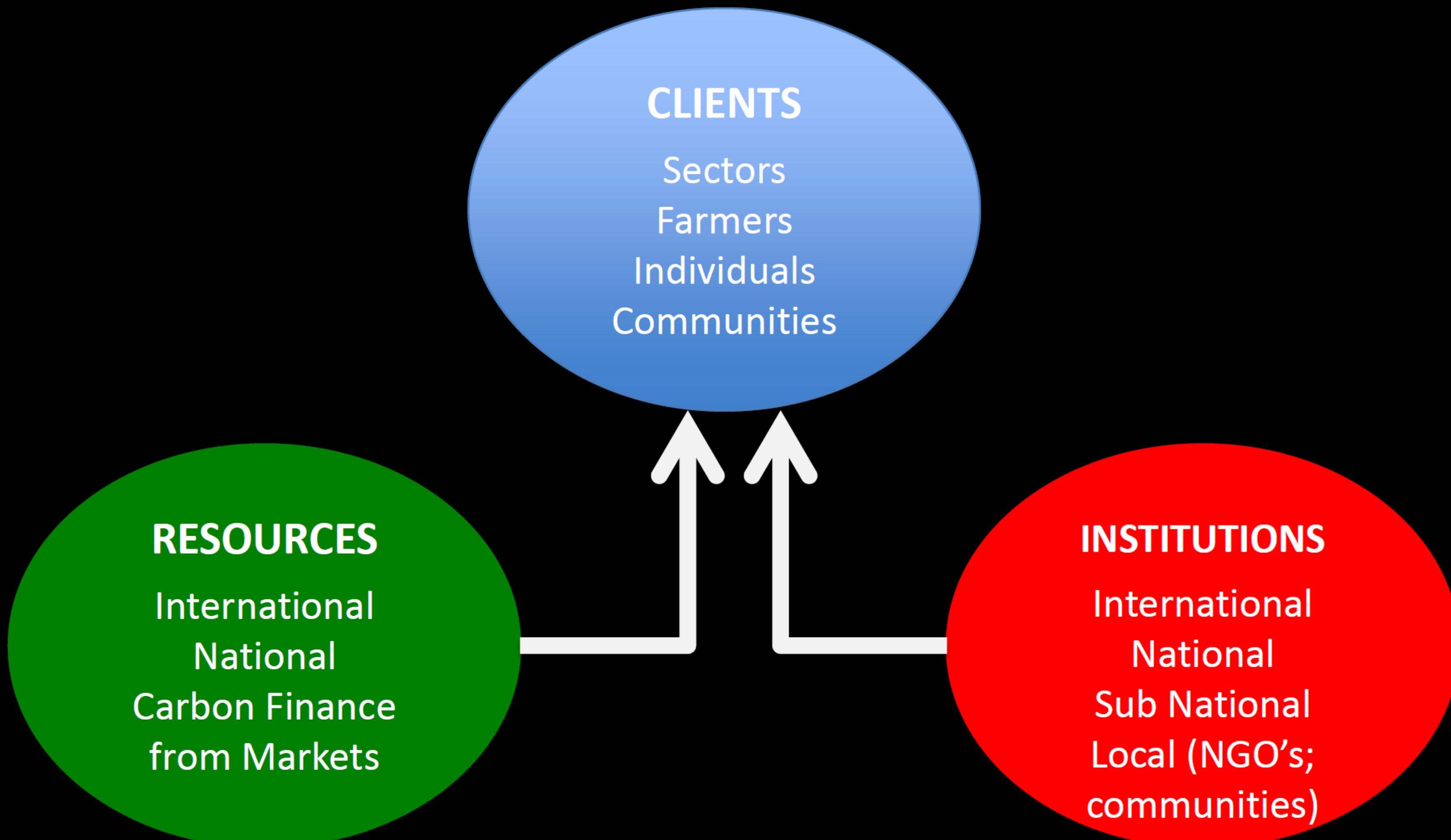
Low Carbon Rural Development

98% of undernourished are not in low/medium income countries which are also projected to have most increase in their population by 2050





Model for Low carbon farming



Challenges at rural smallholder farms

- Scientific
  - Diversity of crops/seasons
  - Size of plots and land type
  - Diversity of sustainable practices
  - Absence of level fields
  - Dryland soils → Low water retention
  - Sampling and measurements in tropical conditions

- Infrastructure
- Limited understanding among lab/field workers of
  - Climate change: “Its about ozone destruction”
  - Carbon markets: “You can sell air?”

- Educational/cultural background
  - Staff retention
  - Gender gap & language barriers