Climate smart farming in Asia

Measurements, implementation strategy & challenges

Kritee

Senior Scientist, International Climate, Environmental Defense Fund

(With Fair Climate Network)

Email: kritee@edf.org, Twitter: @KriteeKanko

Environmental Defense Fund

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

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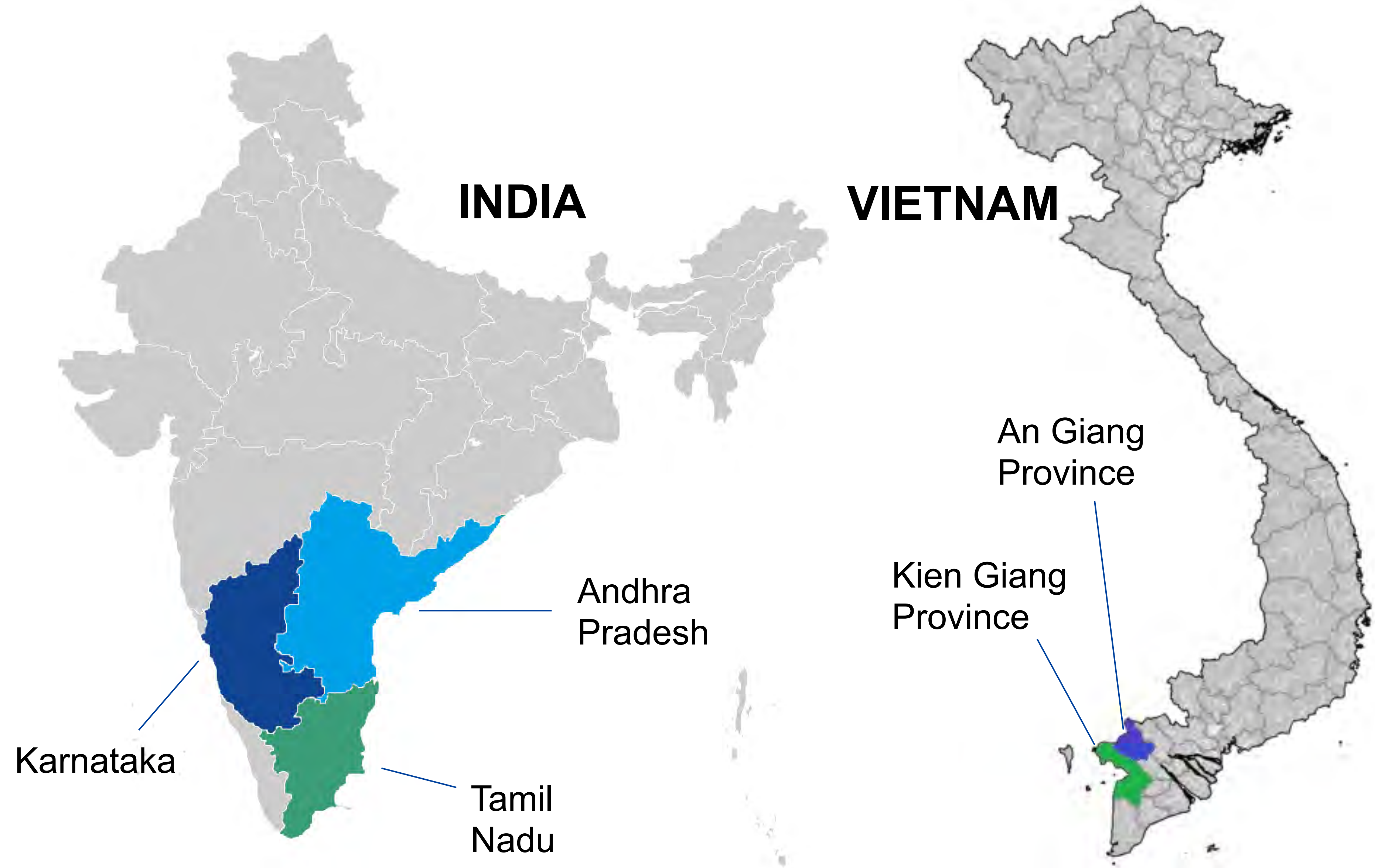
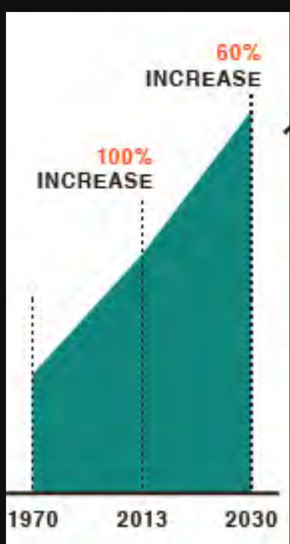
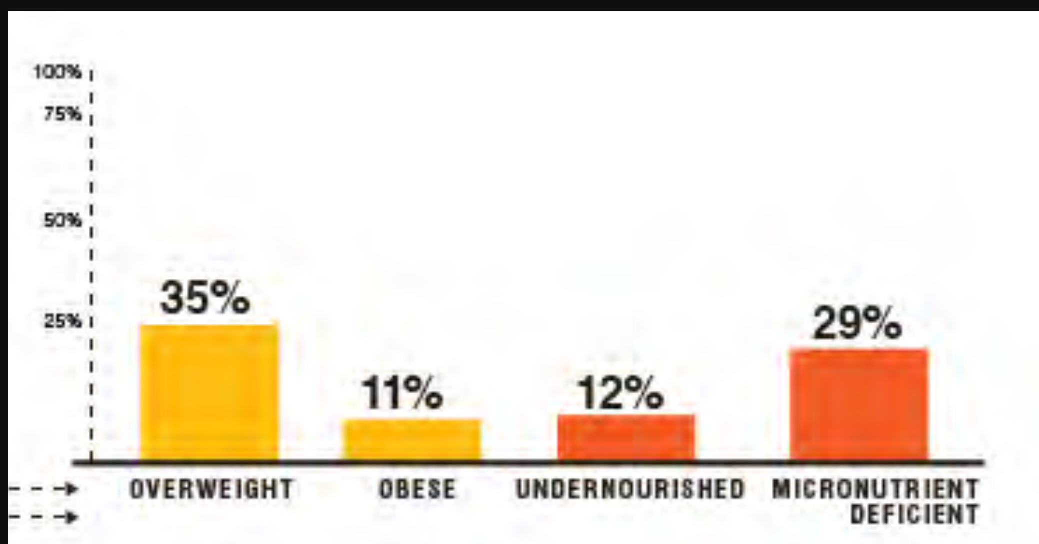
Where we work on agriculture



Feeding 9 billion in 2050

Long term nutritional security

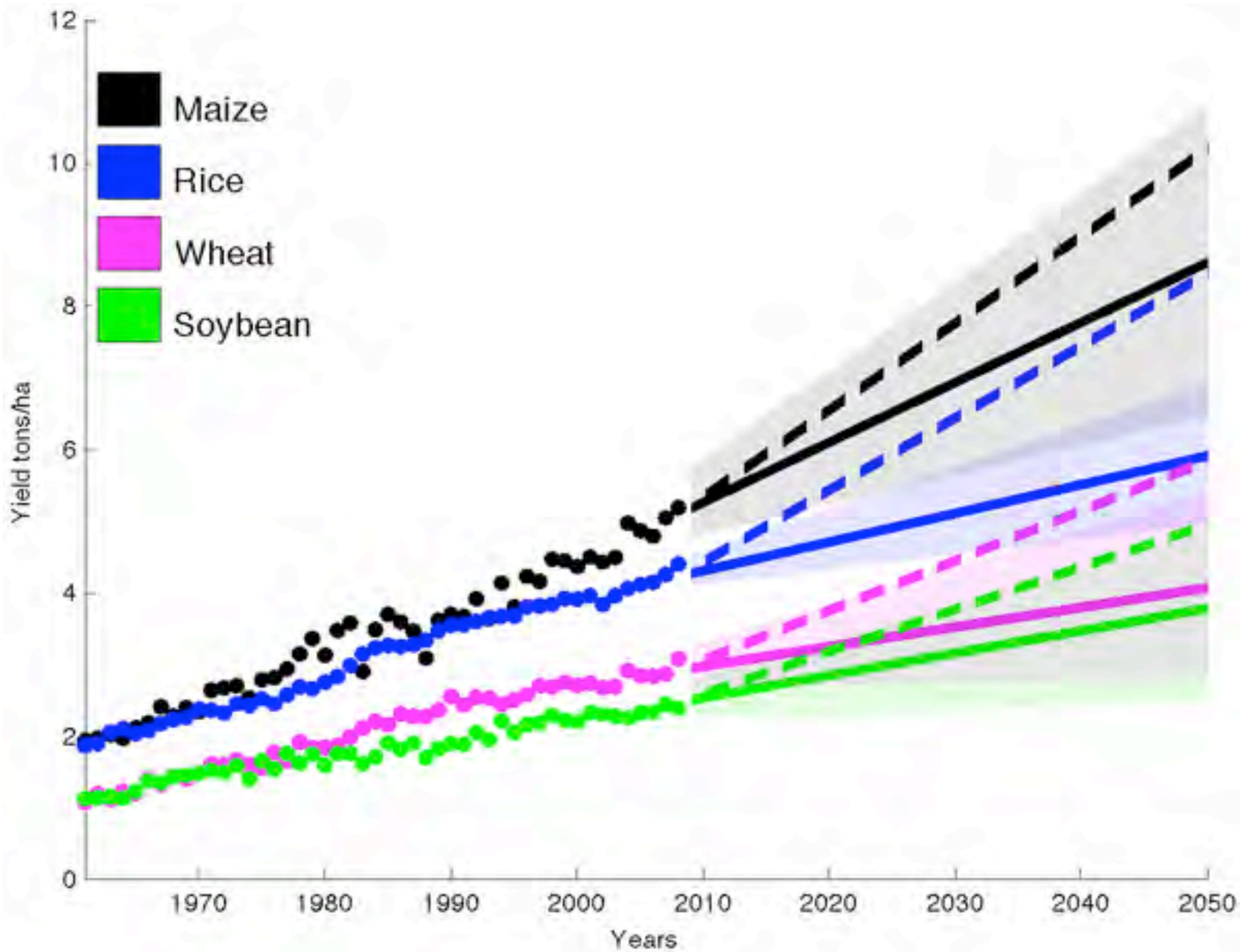




http://ccafs.cgiar.org/bigfacts2014/#

Feeding 9 billion : Yields

Projected necessary *vs* real trends (2.4% *vs* 0.2-0.7%)

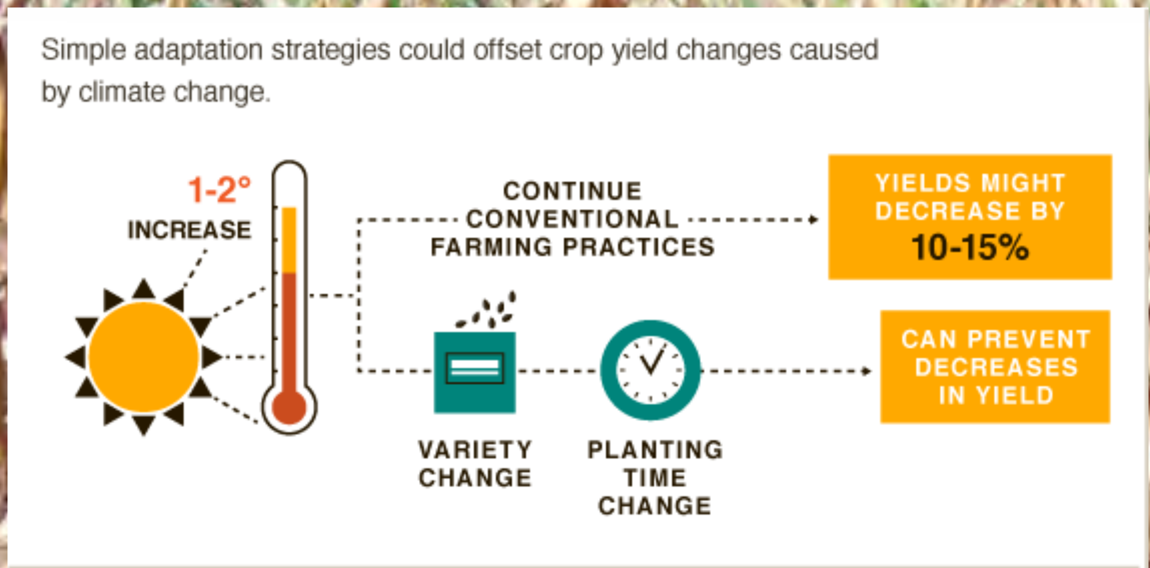


Yield Trends Are Insufficient to Double Global Crop Production by 2050

Ray DK, Mueller ND, West PC, Foley JA (2013). PLoS ONE

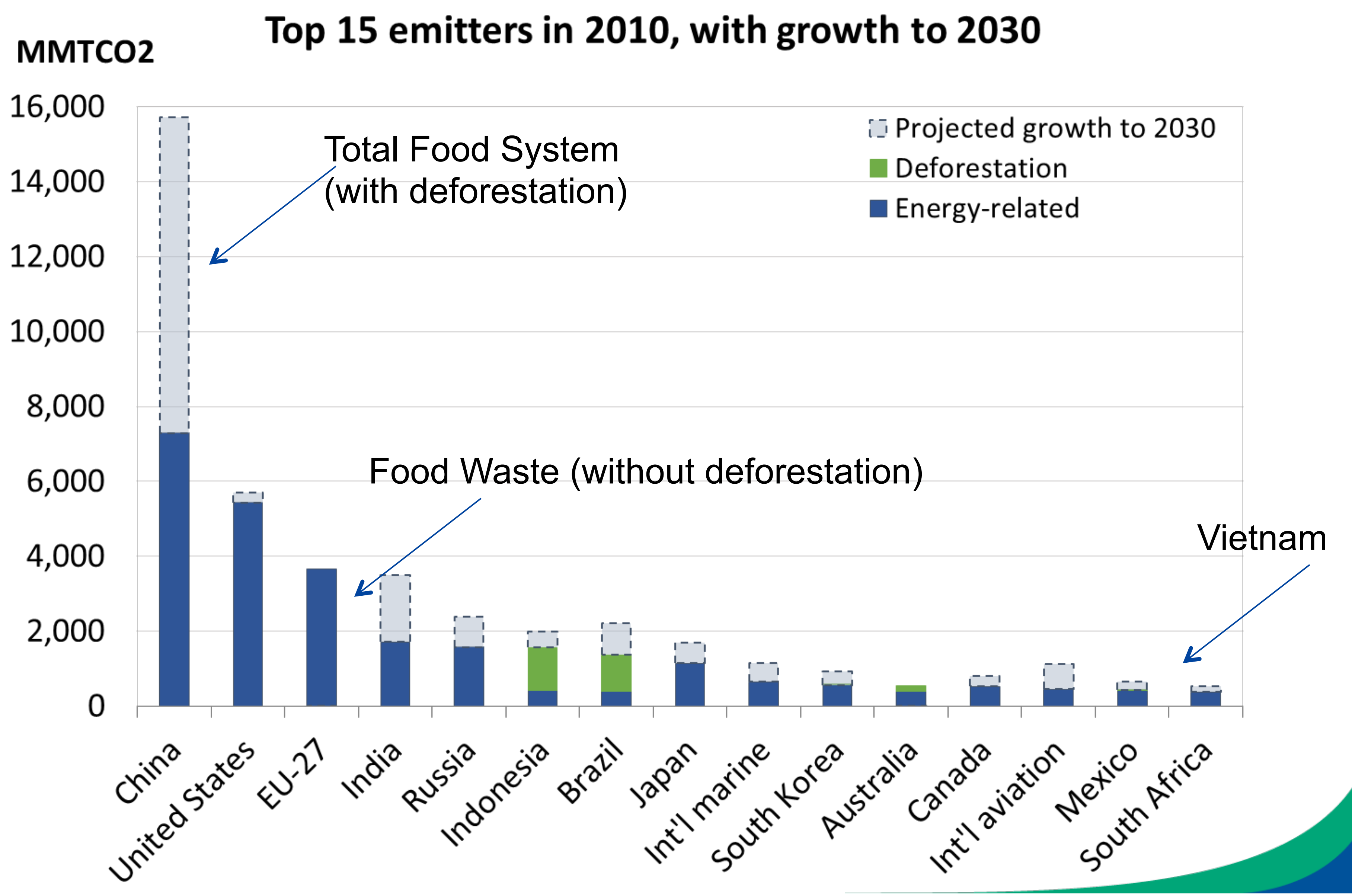
Effect of climate on agriculture

Limits of adaptation practices



- **40% yield decrease → changes associated with $2^{0}C$ local temp increase**
- **Droughts, floods, salt-water intrusion, weeds**
- **Short term forcers (ozone and black carbon)**
- **84% price increase because of Temp/rainfall alone**

Greenhouse gas emissions CO_2e (2010 & 2030)



Effect of agriculture on biosphere
Thin inter-connected layers

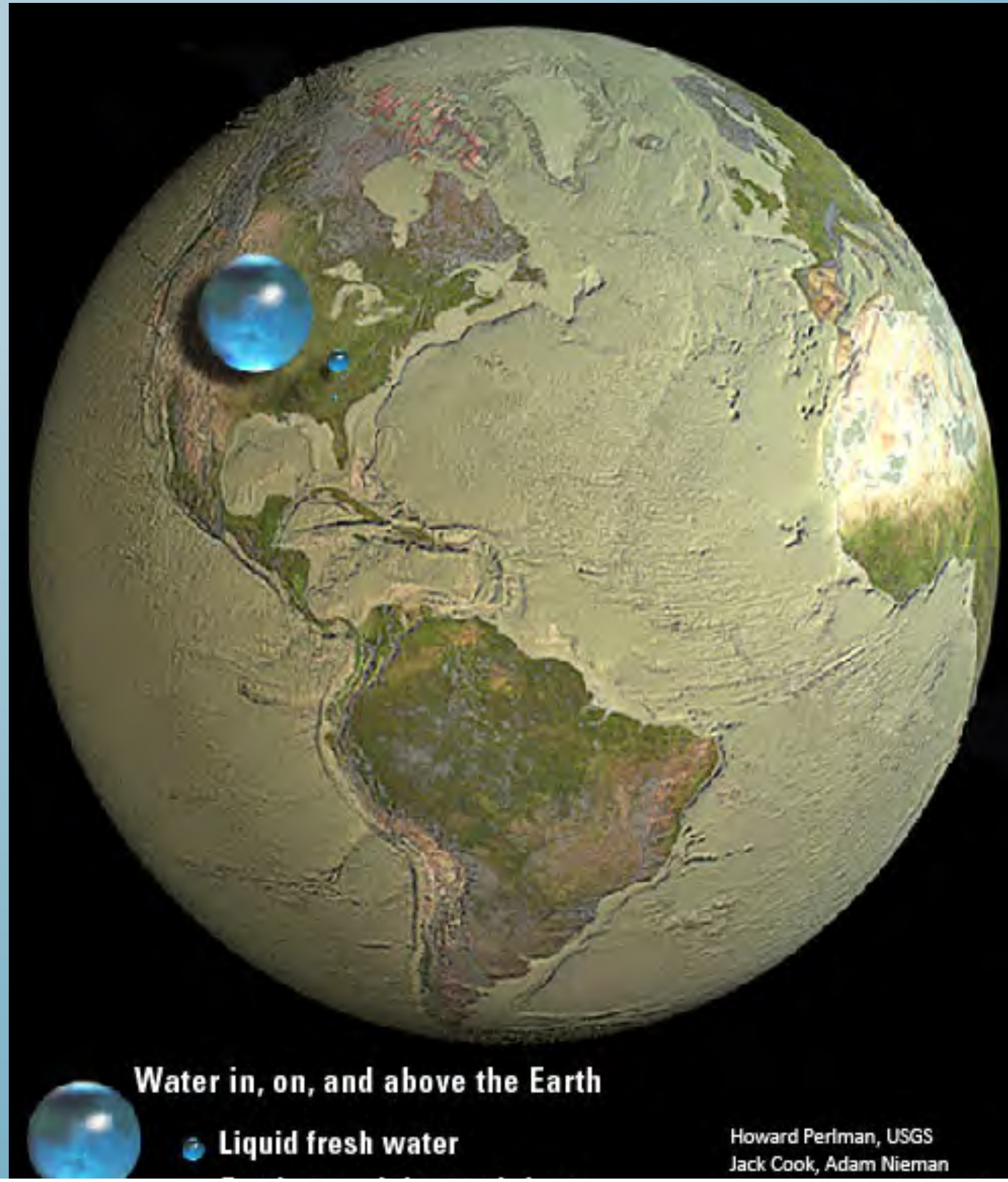
Freshwater
70% of 75 mile sphere

↕

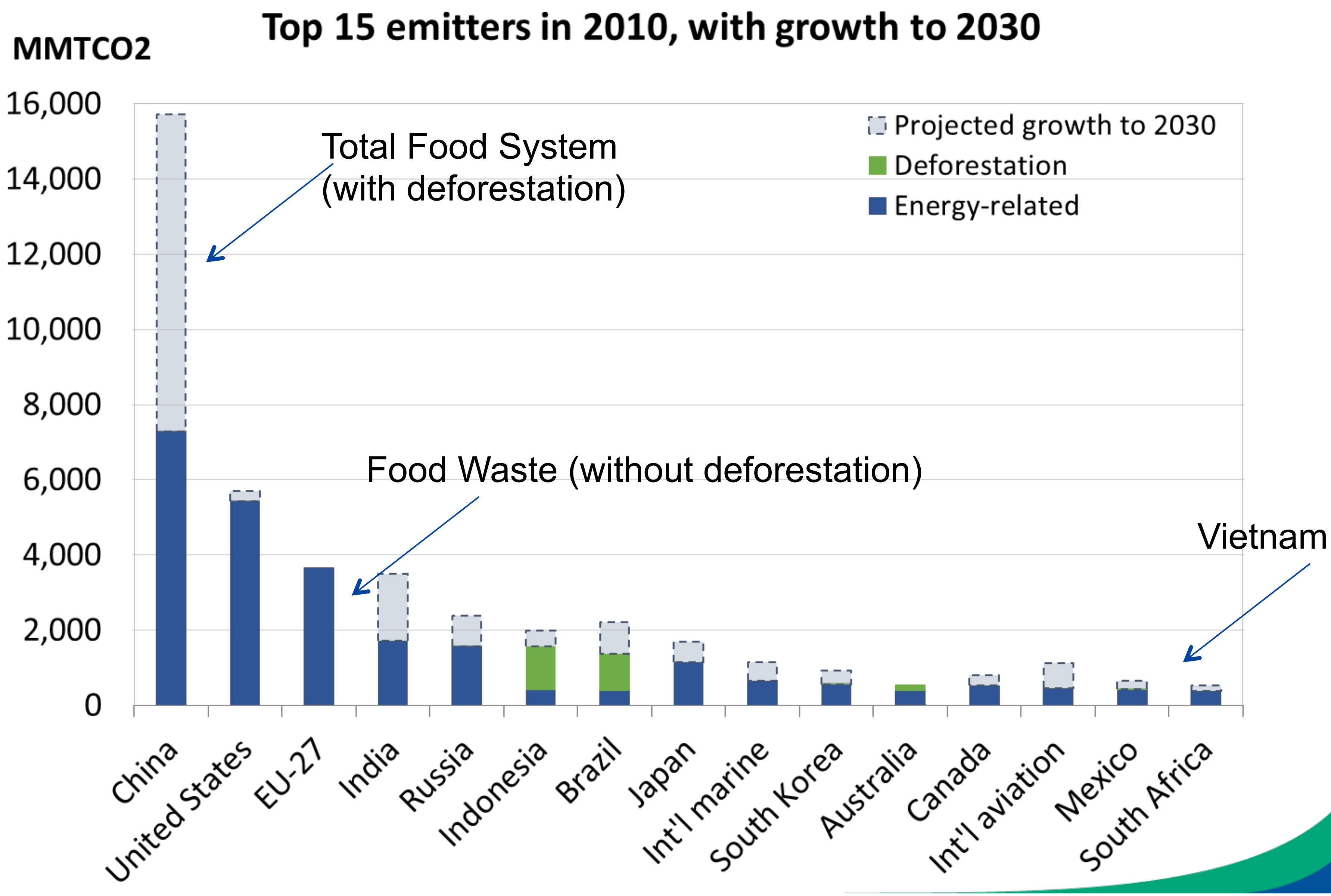
Topsoil
12-16 → → 2-8 inches

↕

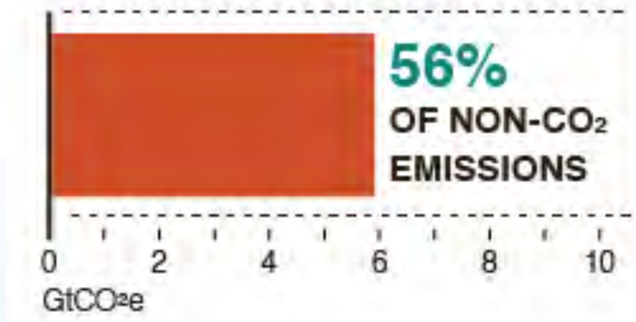
Atmosphere
20 miles

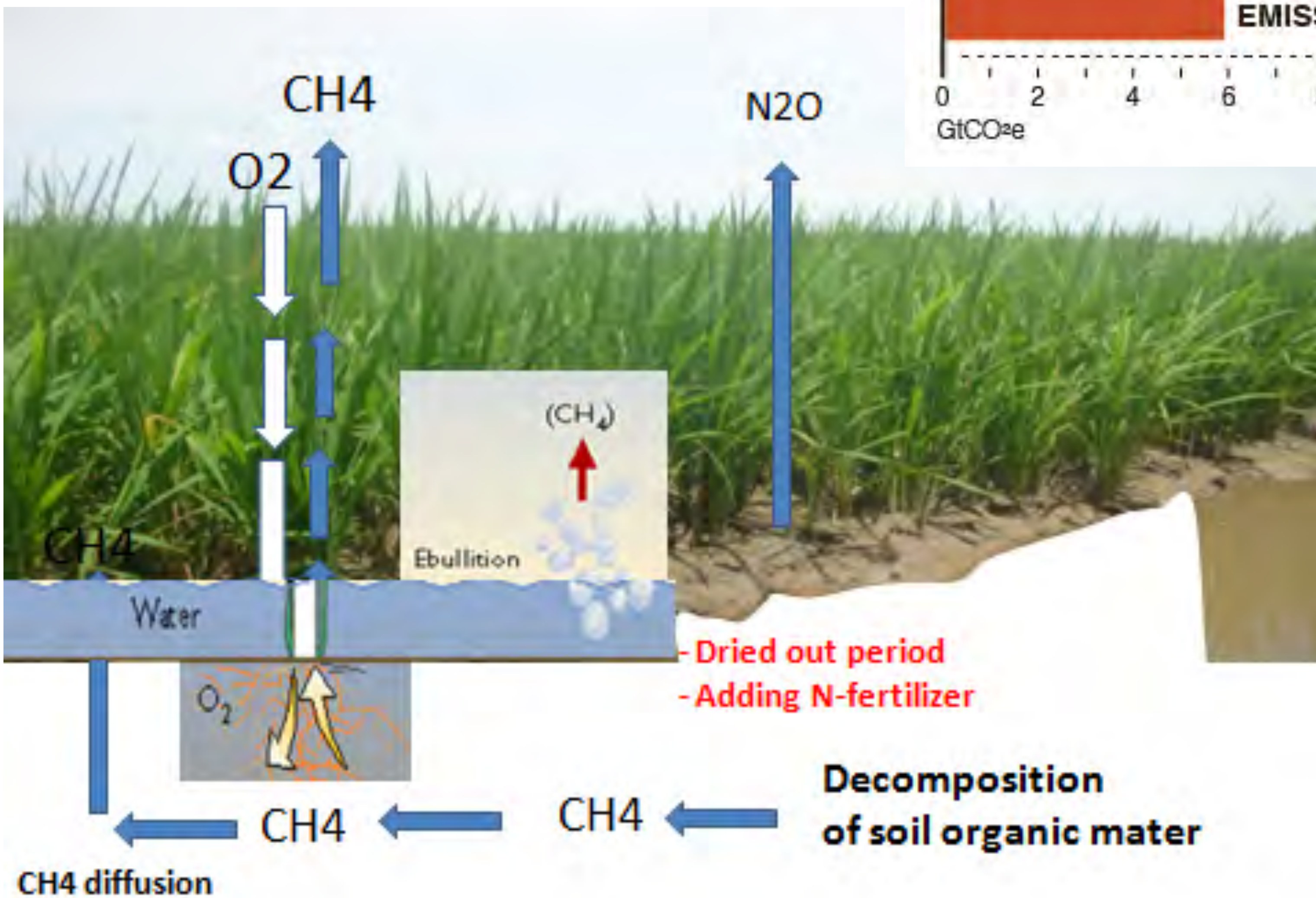


Greenhouse gas emissions CO_2e (2010 & 2030)



Agricultural CH_4 emissions: Why and how?





Dr. Tran Kim Tinh, Can Tho University

Agricultural N_2O emissions: Why and how?

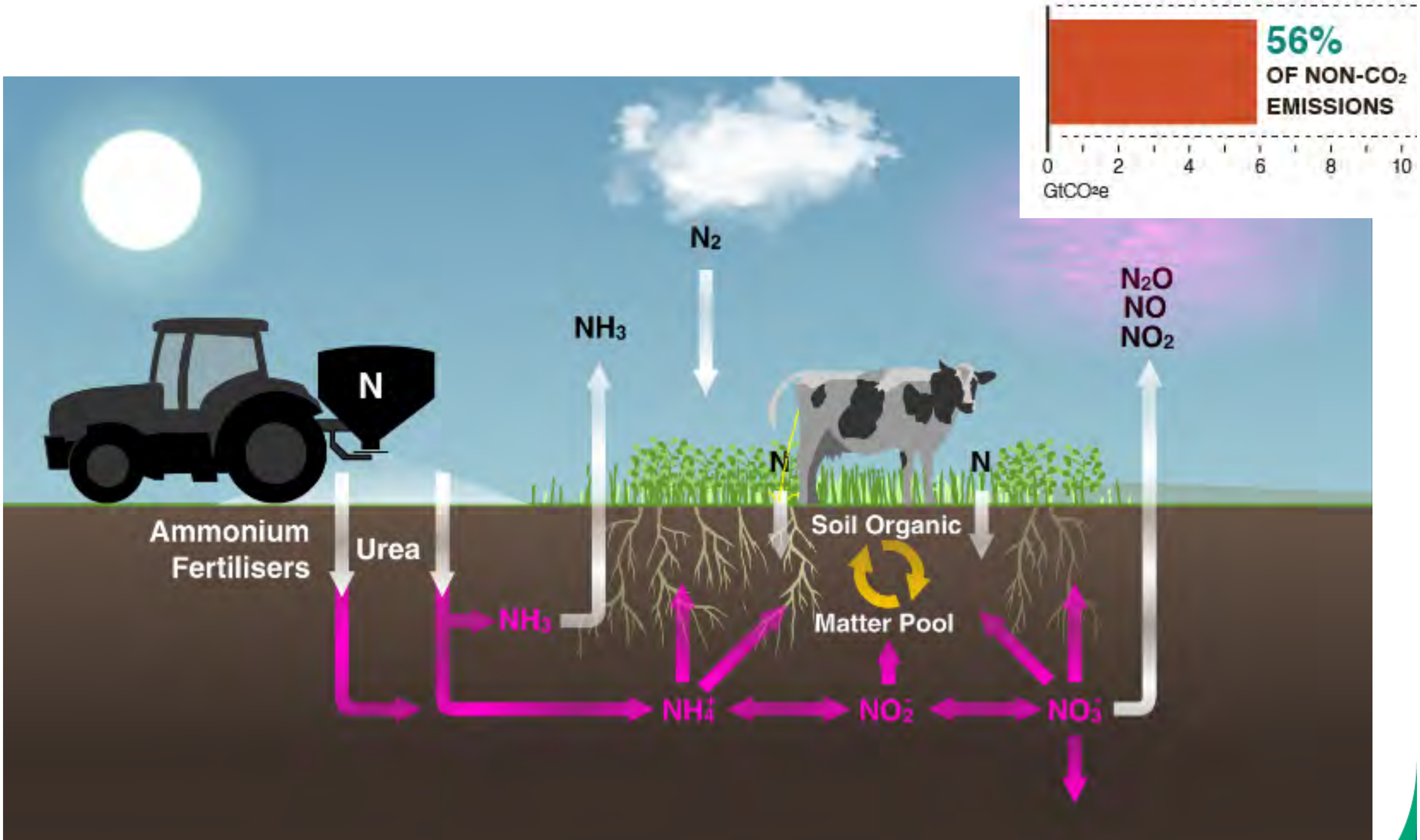
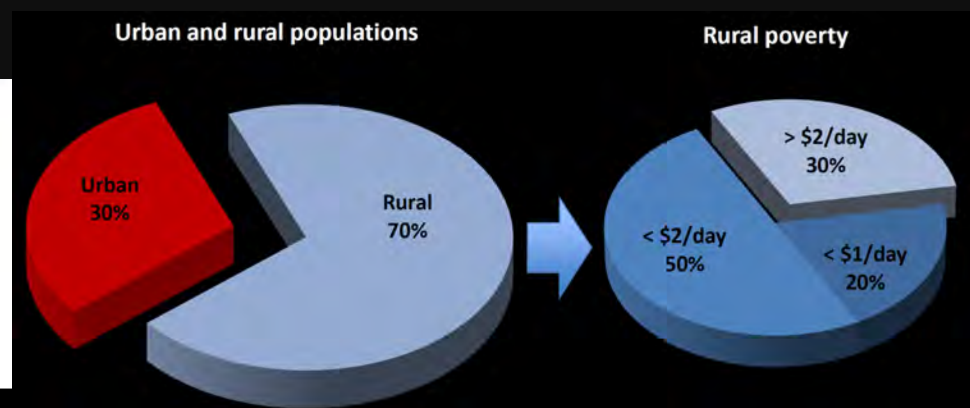


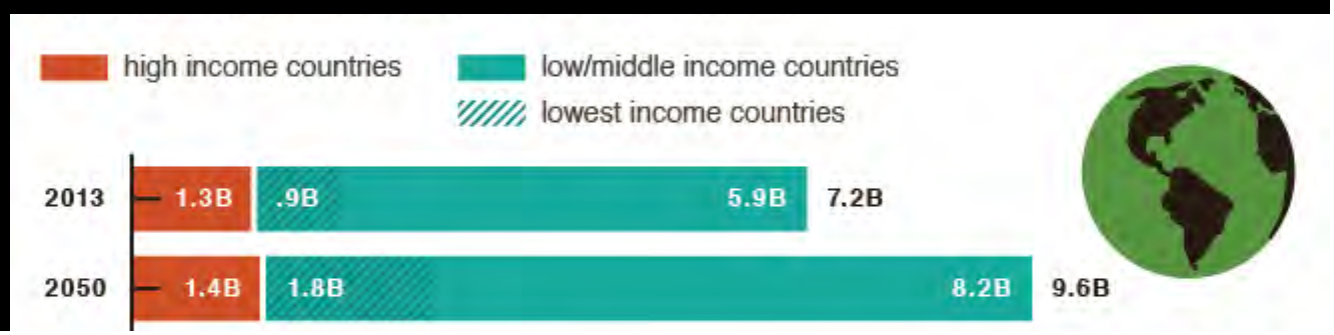
Figure from http://cwfs.org.au/nitrous_oxide__n2o__losses_from_cropping_in_low_rainfall_environments

Feeding 9 billion & facing climate change

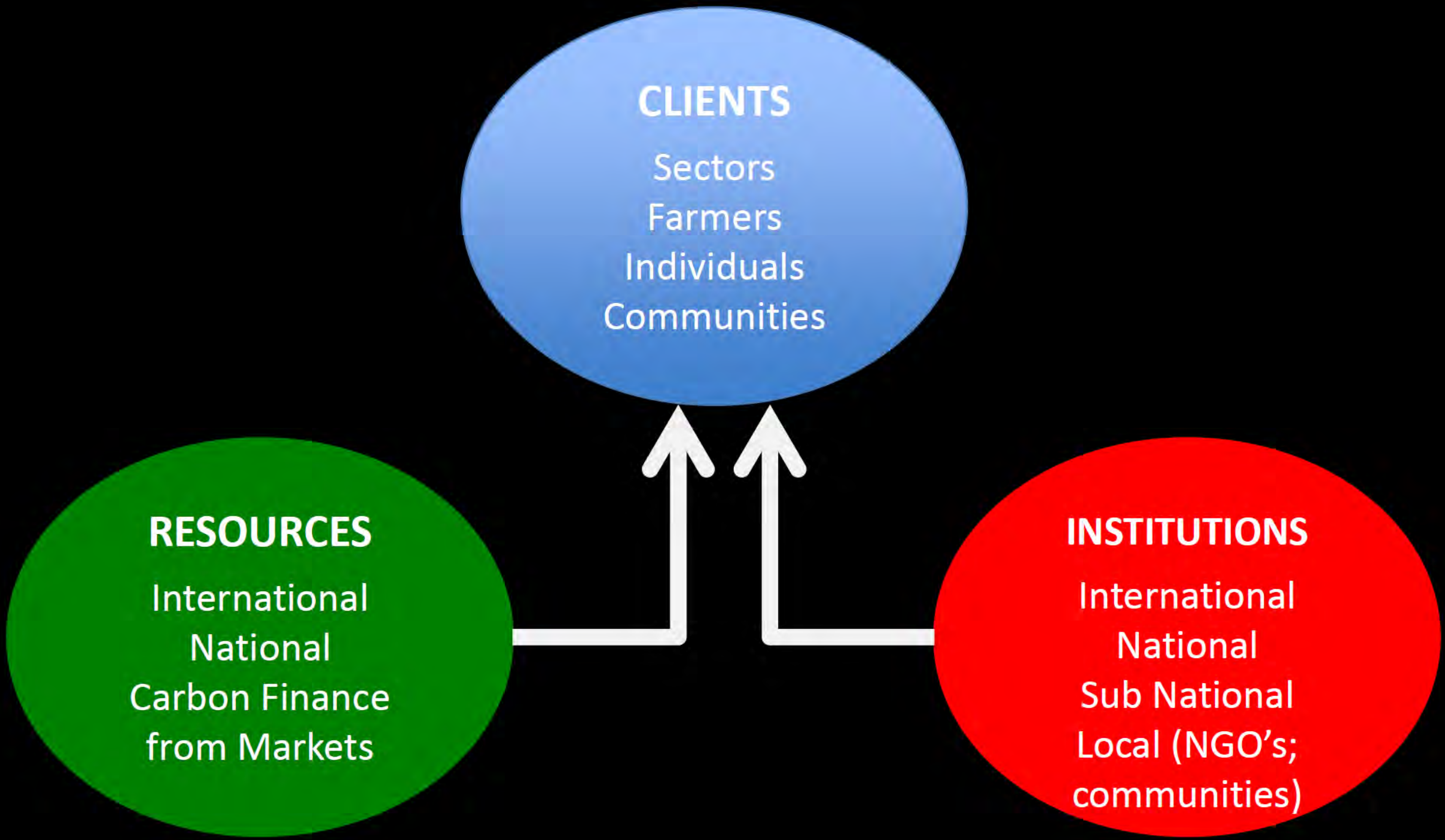
= Working with >2 billion on <$2/day and <2 ha

- These family farms grow ~90% rice, ~65% wheat and ~55% corn.
- With about 43% (60%) of the world's population employed in agriculture
- Many barriers to implementation including accessibility to … financing, … institutional, ecological, technological development, diffusion and transfer barriers.

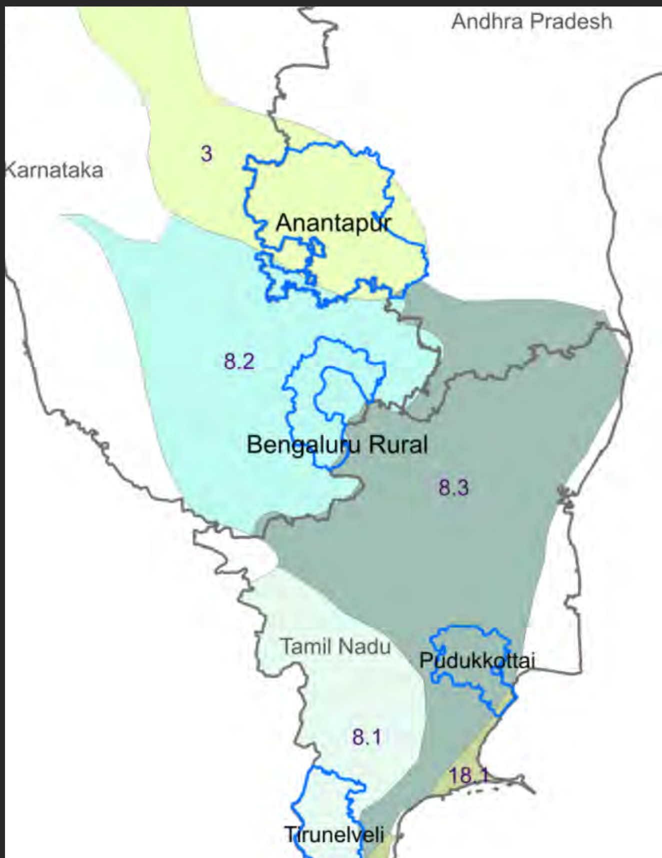




Model for Climate smart farming



Climate smart farming in India



the timbaktu collective
in celebration of life

SEDS
towards a greener tomorrow

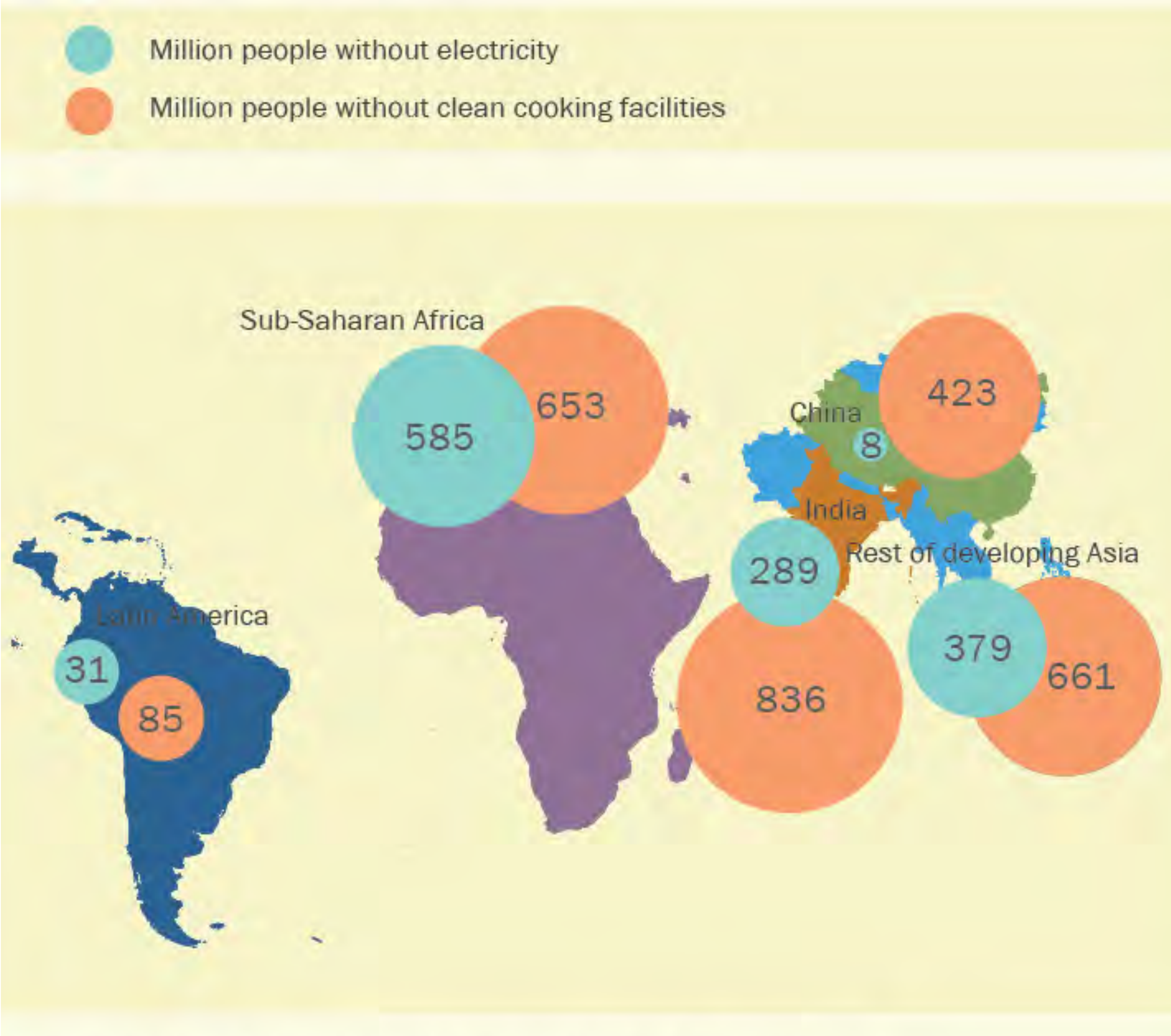
"SACRED" TRUST

ACCION FRATERNA
ecology centre
sustainable . human . nature

PWDS
Palmyrah Workers Development Society

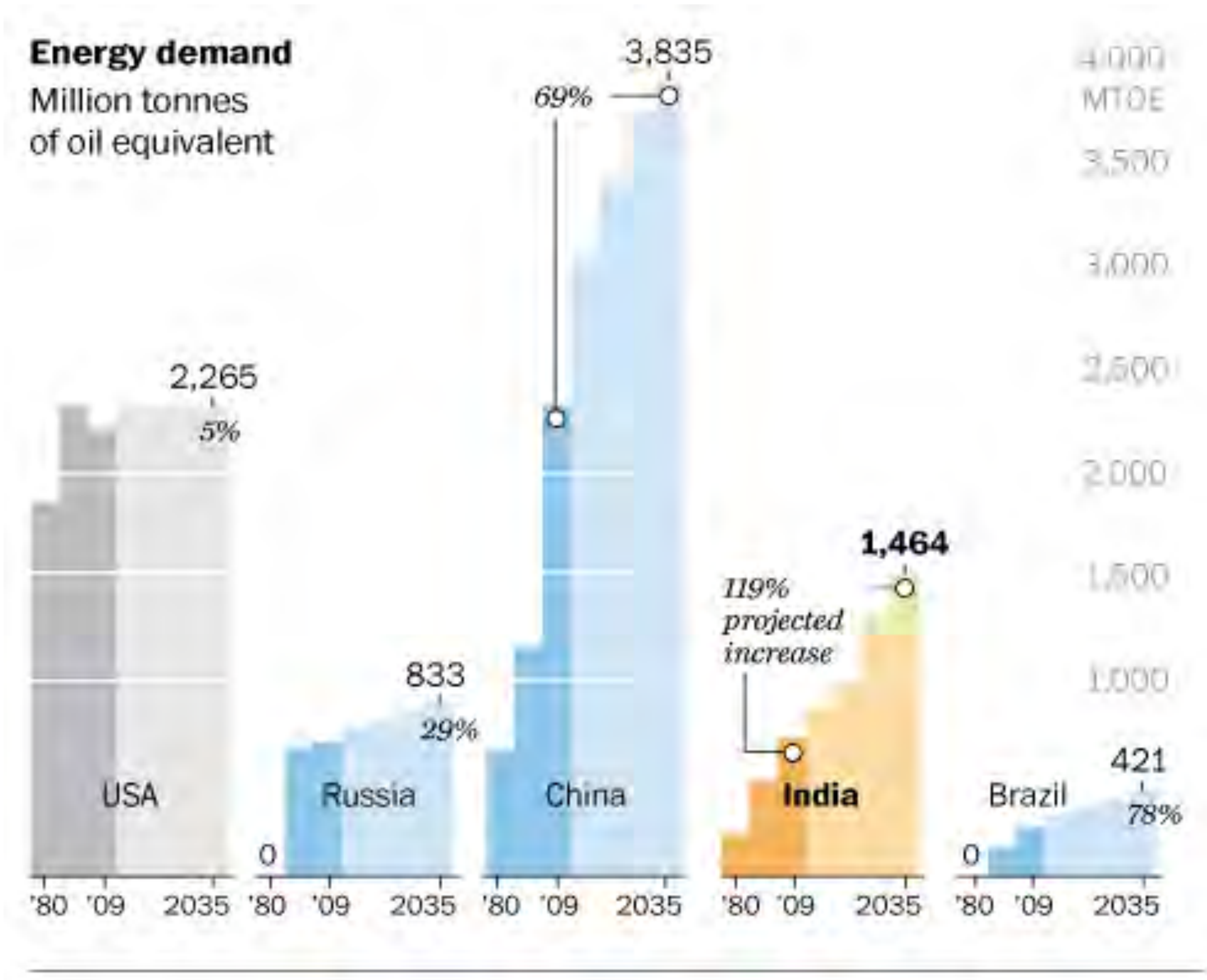
Mitigating climate change and Poverty
= *Low carbon rural development*

ELECTRICITY & CLEAN COOK-STOVE GAP



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

Energy demand trajectories



Source: IEA

An avoided ton of carbon is as important as a reduced ton of carbon

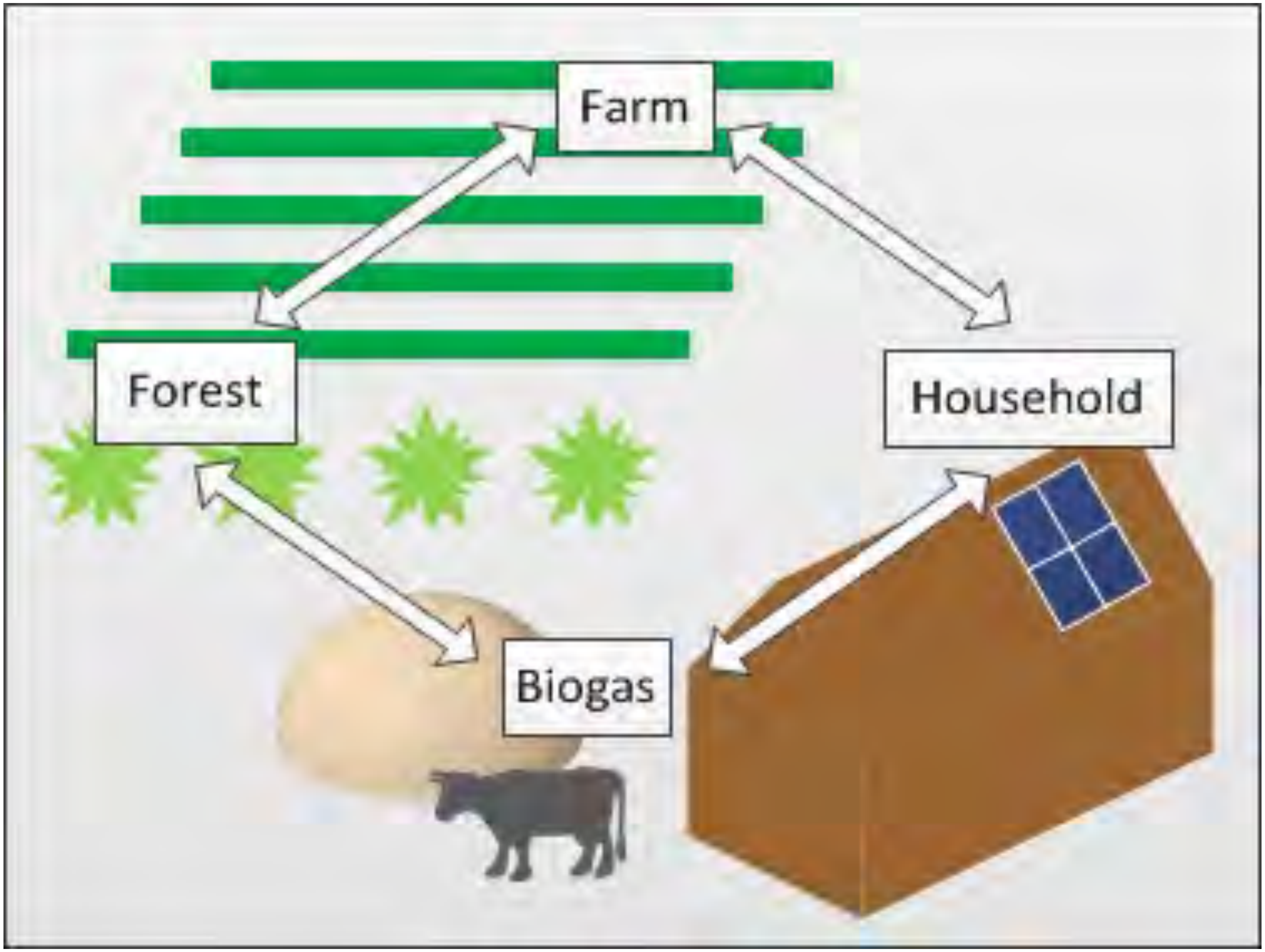
Carbon market needs

Additionality
Permanence
Accounting for leakage
Monitoring
Measurement
Transparency

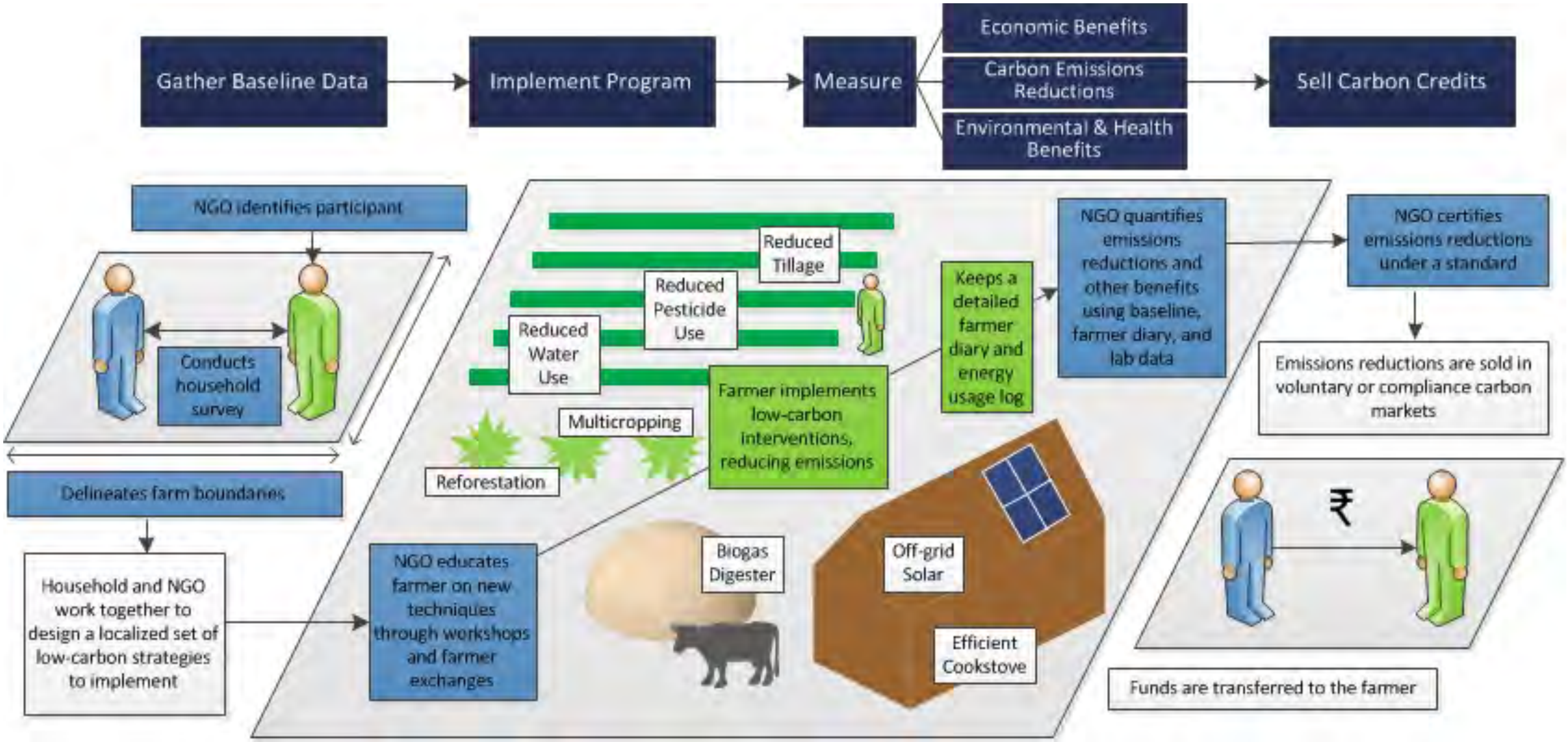
Our goals for India

consulting local peoples
supporting institutional capacity
establishing replicable practices
meeting the needs of markets
Certification

Interconnections & Energy Flows



Strategy



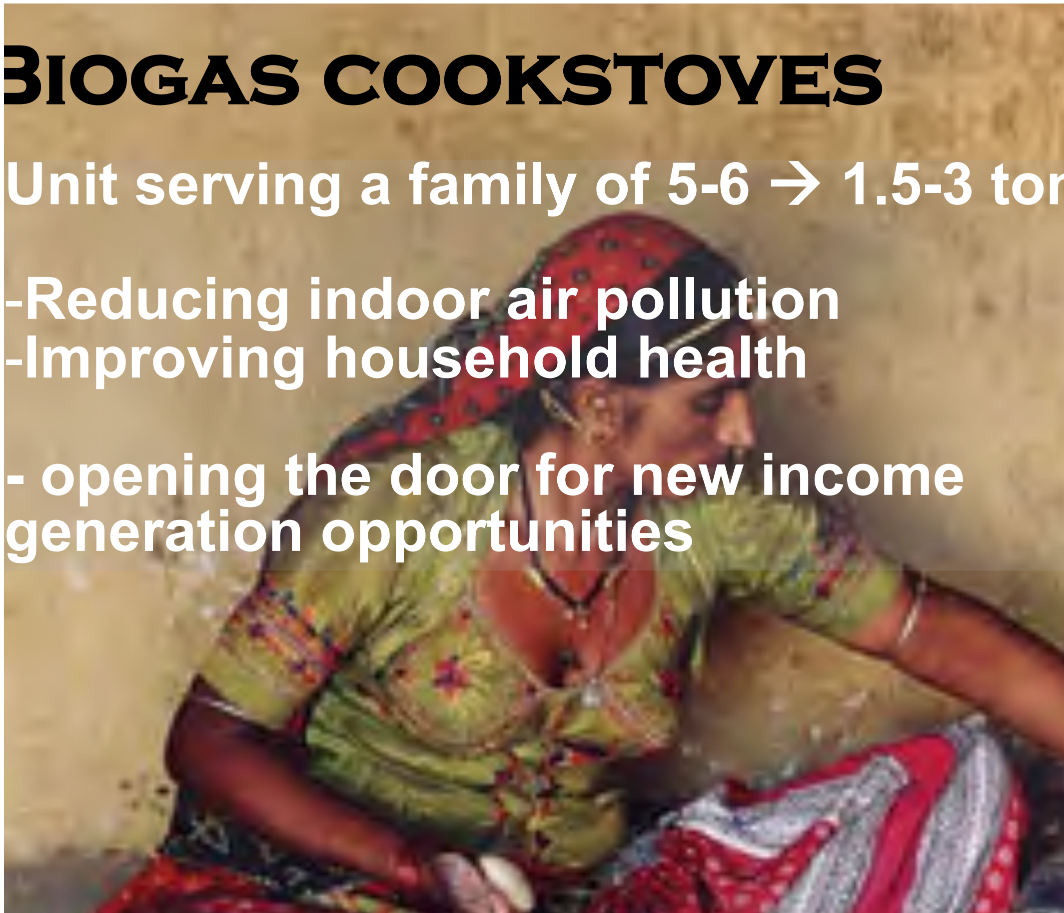
Gather Baseline Data
Implement Program
Measure
Economic Benefits
Carbon Emissions Reductions
Environmental & Health Benefits
Sell Carbon Credits
NGO identifies participant
Conducts household survey
Delineates farm boundaries
Household and NGO work together to design a localized set of low-carbon strategies 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
Keeps a detailed farmer diary and energy usage log
Biogas Digester
Off-grid Solar
Efficient Cookstove
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

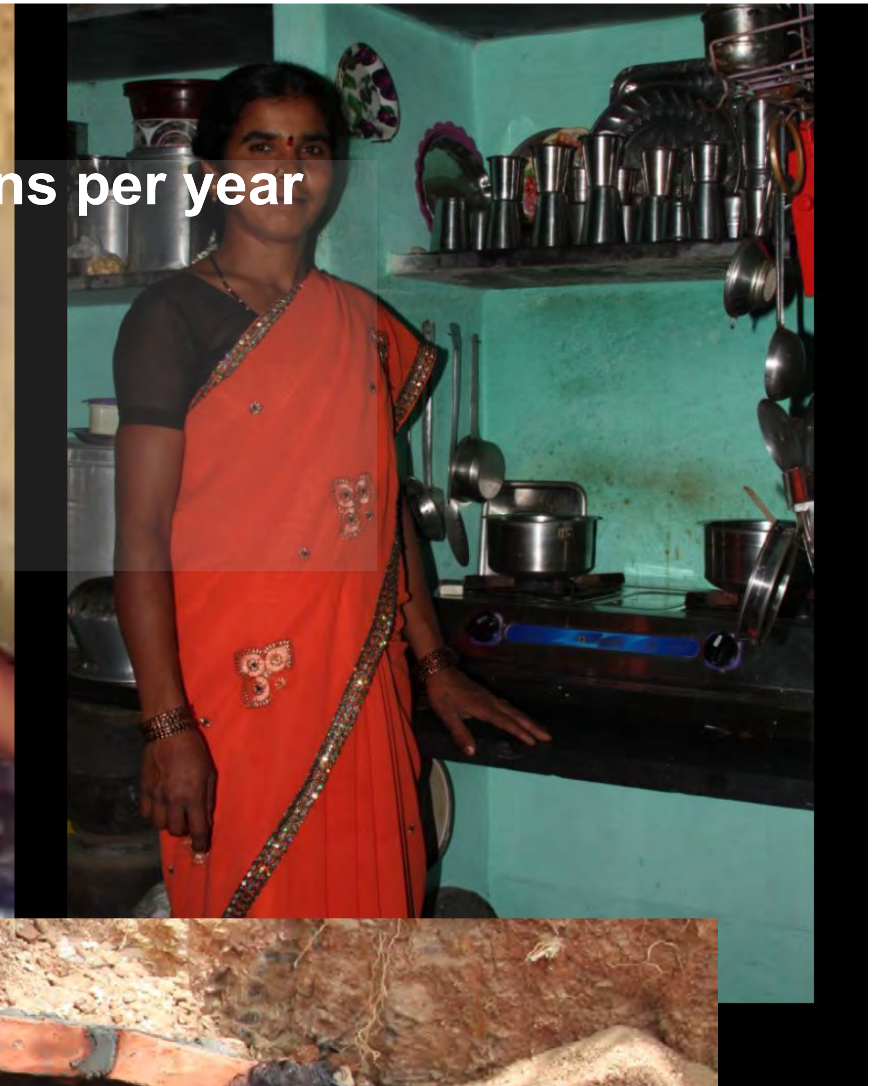
Biogas cookstoves

Unit serving a family of 5-6 → 1.5-3 tons per year

-Reducing indoor air pollution
-Improving household health

- opening the door for new income generation opportunities





Climate smart farming

Baseline surveys
New package

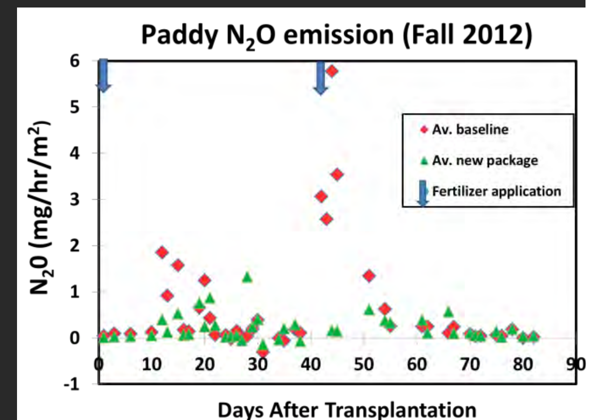
Plot GHG measurements

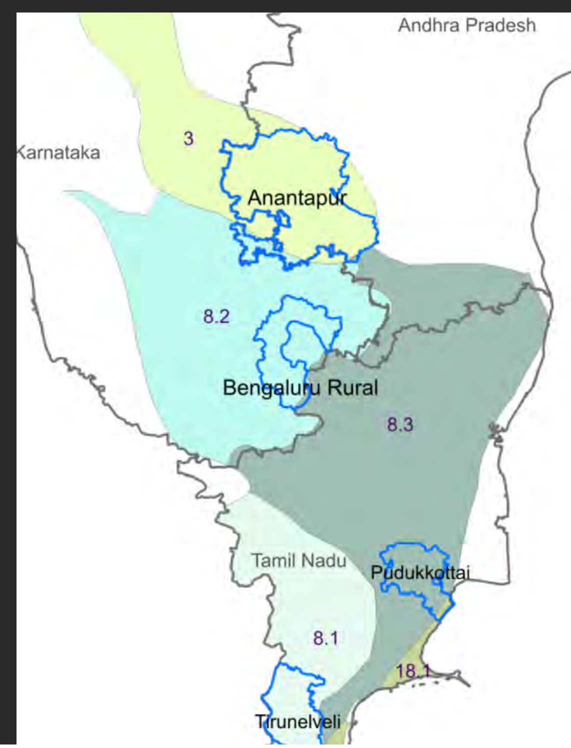
Large scale Modeling

+

Self reporting
Monitoring
Verification

Methodology





GHG EMISSION REDUCTION MEASUREMENTS

(not relying on IPCC Tier 1 emission factors)

Task at hand

- Farmer surveys/diaries for baseline conditions/practices
  - Fertilizer and manure, water management, pesticides
  - Soil qualities (T, pH), weather, treecover, cropping cycles
- New interventions “sustainable” practices by NGO partners
  - Multiple interests: yield, low external input, soil and water quality, crop rotations
- Sample collection
  - Choice of fields/farmers
  - Ensure replication
  - Design of gas collection chambers and sampling protocol
- Greenhouse gas emission measurements
  - Accuracy and precision of the gas chromatographs
  - Calibration and standards
  - Chamber graphs and seasonal rates
- Data analysis and modeling

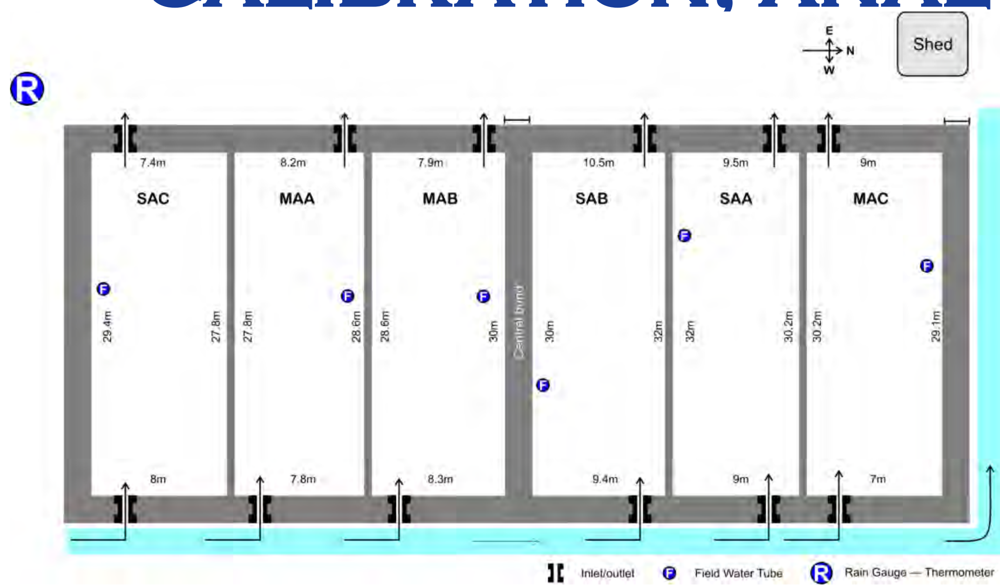
Challenge
Capacity building in rural India

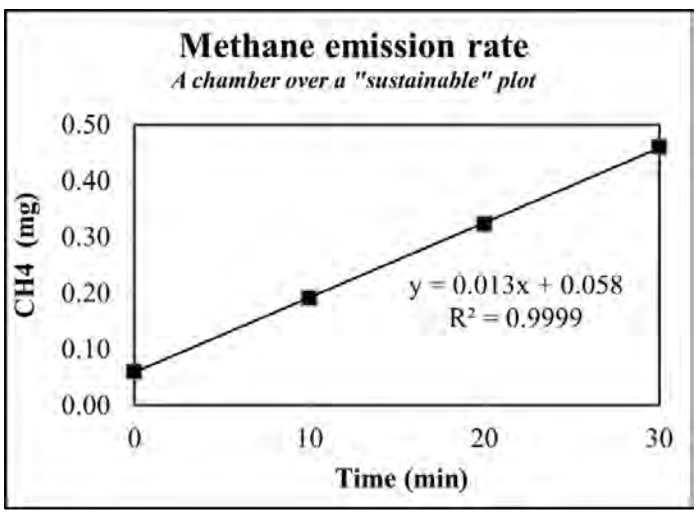
- Limited understanding among lab and field workers of
  - Climate change
    - “Its about ozone destruction”
    - “You can sell the air?”
  - Carbon markets
  - Importance of sampling, measurements and uncertainties
  - Modeling → Aggregation → Validation offset credits

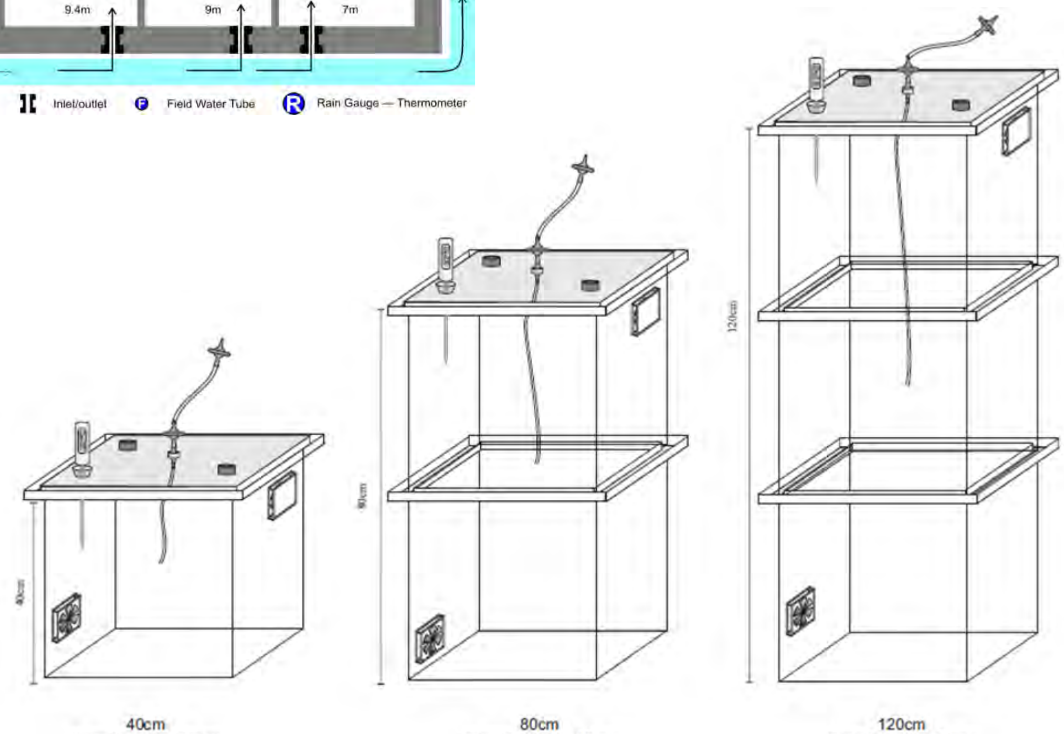
- Scientific/educational/cultural background
  - Staff retention
  - Gender gap & language barriers
  - Limited boundary between work/family issues
  - Efficiency and infrastructure

- Choosing domestic scientific advisors and collaborators

REPLICATES, SAMPLING DESIGN, CALIBRATION, ANALYSIS





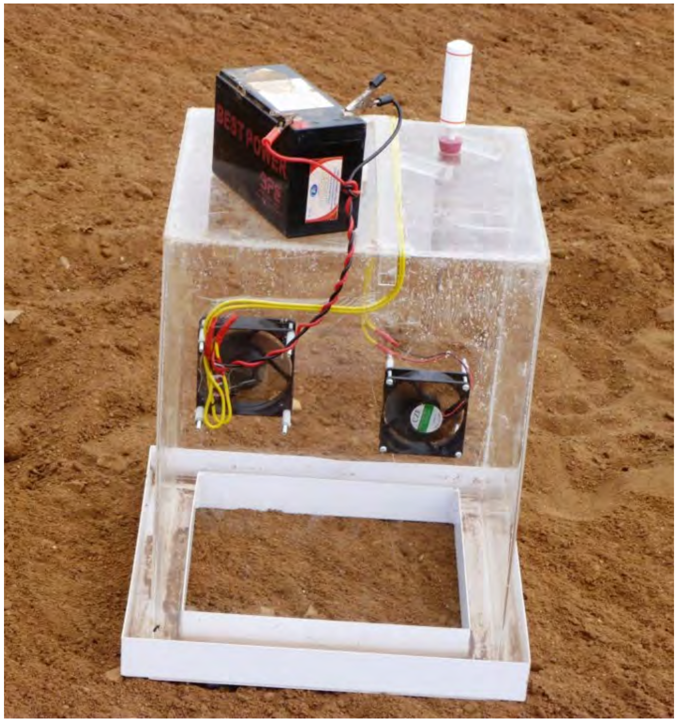


We started with Stories

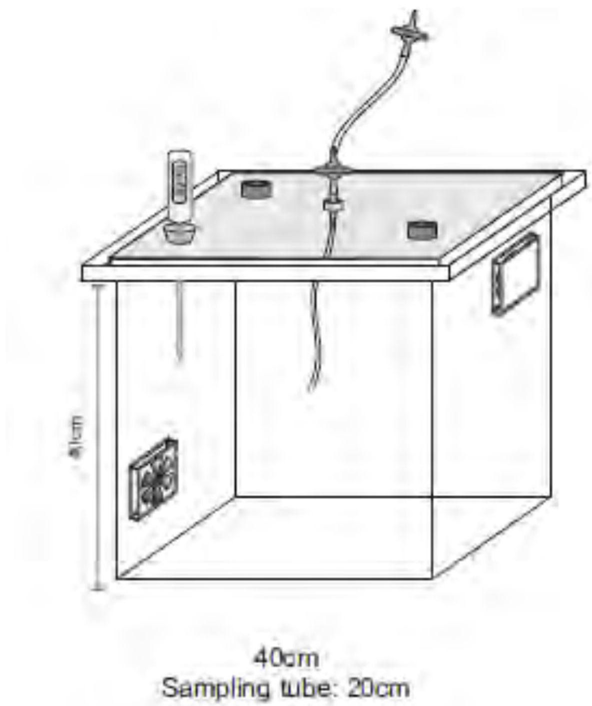
What brought you here?
What do you feel about our farming projects?
How can we change our training session?

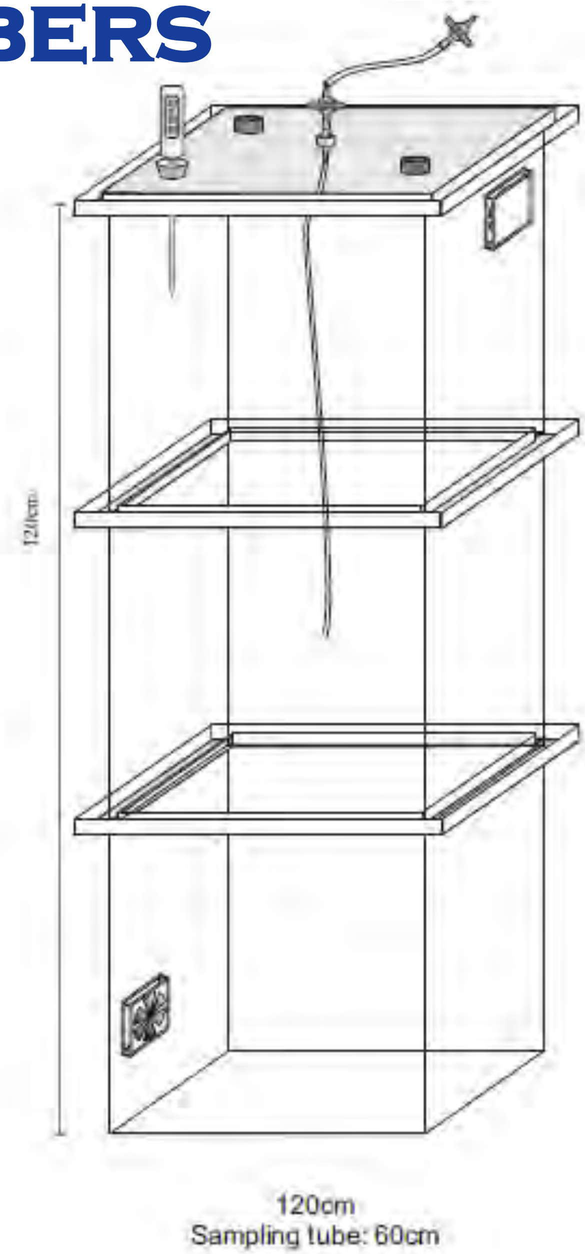
Rice GHG emission sampling

Photo: Dr. Tran Kim Tinh, Can Tho University



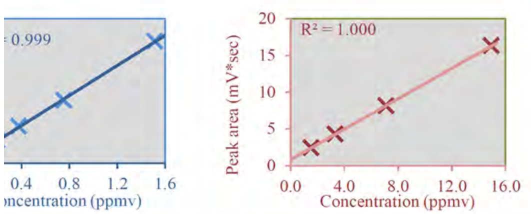
Stackable Manual chambers





Gas chromatograph

DATA ANALYSIS AND STORAGE



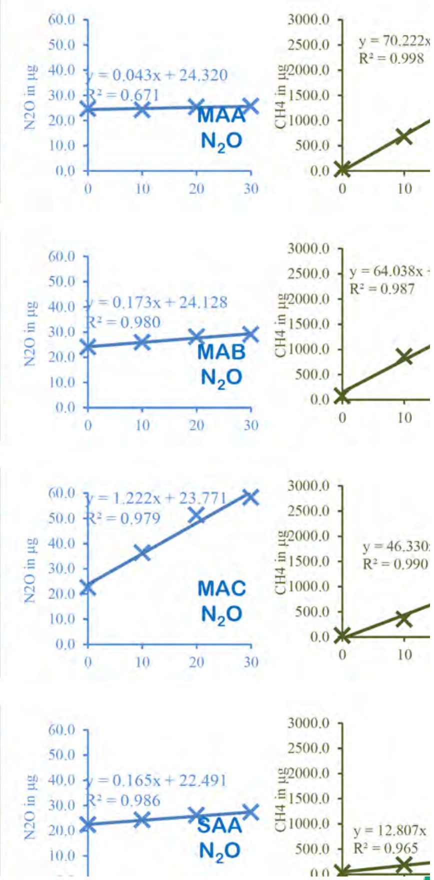
e ID	N_2O area	N_2O (ppmv)	CH_4 area	CH_4 (ppmv)
Run 01	281936	0.443	23888	1.535
Run 02	284478	0.448	22939	1.443
Run 03	289283	0.457	22038	1.356
Run 04	289388	0.457	22444	1.395
Run 05	284654	0.448	22663	1.416
Run 06	287388	0.453	23142	1.463
Run 07	288412	0.455	23098	1.458
Run 1	156850	0.202	24296	1.574
Run 1	255440	0.392	42714	3.351
Run 1	434271	0.736	81174	7.060
Run 1	843039	1.521	163055	14.958
	291148	0.461	25262	1.667
	293695	0.465	379508	35.837
	306657	0.490	765752	73.092
	311449	0.500	1194318	114.431
	280017	0.439	48246	3.884
	299794	0.477	459640	43.566
	324070	0.524	822787	78.594
	335482	0.546	1073892	102.815
	285467	0.450	24173	1.562
	436631	0.740	212563	19.734

MAA	Temp. (°C)	Box Vol. (L)	Plant Vol. (L)	N_2O (ppm)	CH_4 (ppm)	N_2O (µg)	CH_4 (µg)
0	27.0	33.0325	0.02	####	1.667	24.7	32.4
10	36.0			0.465	35.837	24.2	677.2
20	38.0	FWT Level (cm)	Sampler	0.490	73.092	25.3	1372.3
30	39.0	5	C.M	0.500	114.431	25.7	2141.5
	Syringe age		3	0.011	0.114	28.74	46814.56
	Analyzed after (h)		2	Above MDL	Above MDL	0.671	0.998

MAB	Temp. (°C)	Box Vol. (L)	Plant Vol. (L)	N_2O (ppm)	CH_4 (ppm)	N_2O (µg)	CH_4 (µg)
0	30.0	34.0225	0.02	####	3.884	24.0	77.1
10	32.0			0.477	43.566	25.9	859.0
20	36.0	FWT Level (cm)	Sampler	0.524	78.594	28.0	1529.6
30	38.0	5	C.M	0.546	102.815	29.0	1988.2
	Syringe age		3	0.011	0.114	115.47	42692.26
	Analyzed after (h)		2	Above MDL	Above MDL	0.980	0.987

MAC	Temp. (°C)	Box Vol. (L)	Plant Vol. (L)	N_2O (ppm)	CH_4 (ppm)	N_2O (µg)	CH_4 (µg)
0	28.0	31	0.02	####	1.562	22.5	28.4
10	34.0			0.740	19.734	36.3	352.2
20	38.0	FWT Level (cm)	Sampler	1.059	51.561	51.3	908.4
30	39.0	6	C.M	1.206	78.998	58.2	1387.4
	Syringe age		3	0.011	0.114	814.55	30886.76
	Analyzed after (h)		2	Above MDL	Above MDL	0.979	0.990

SAA	Temp. (°C)	Box Vol. (L)	Plant Vol. (L)	N_2O (ppm)	CH_4 (ppm)	N_2O (µg)	CH_4 (µg)
0	31.0	30.82	0.03	####	1.614	22.3	28.9
10	34.0			0.497	10.442	24.3	185.2
20	35.0	FWT Level (cm)	Sampler	0.537	19.511	26.1	345.0
30	37.0	6	M.M	0.563	22.916	27.2	402.6
	Syringe age		3	0.011	0.114	110.03	8537.98



Results
India low carbon peanut farming

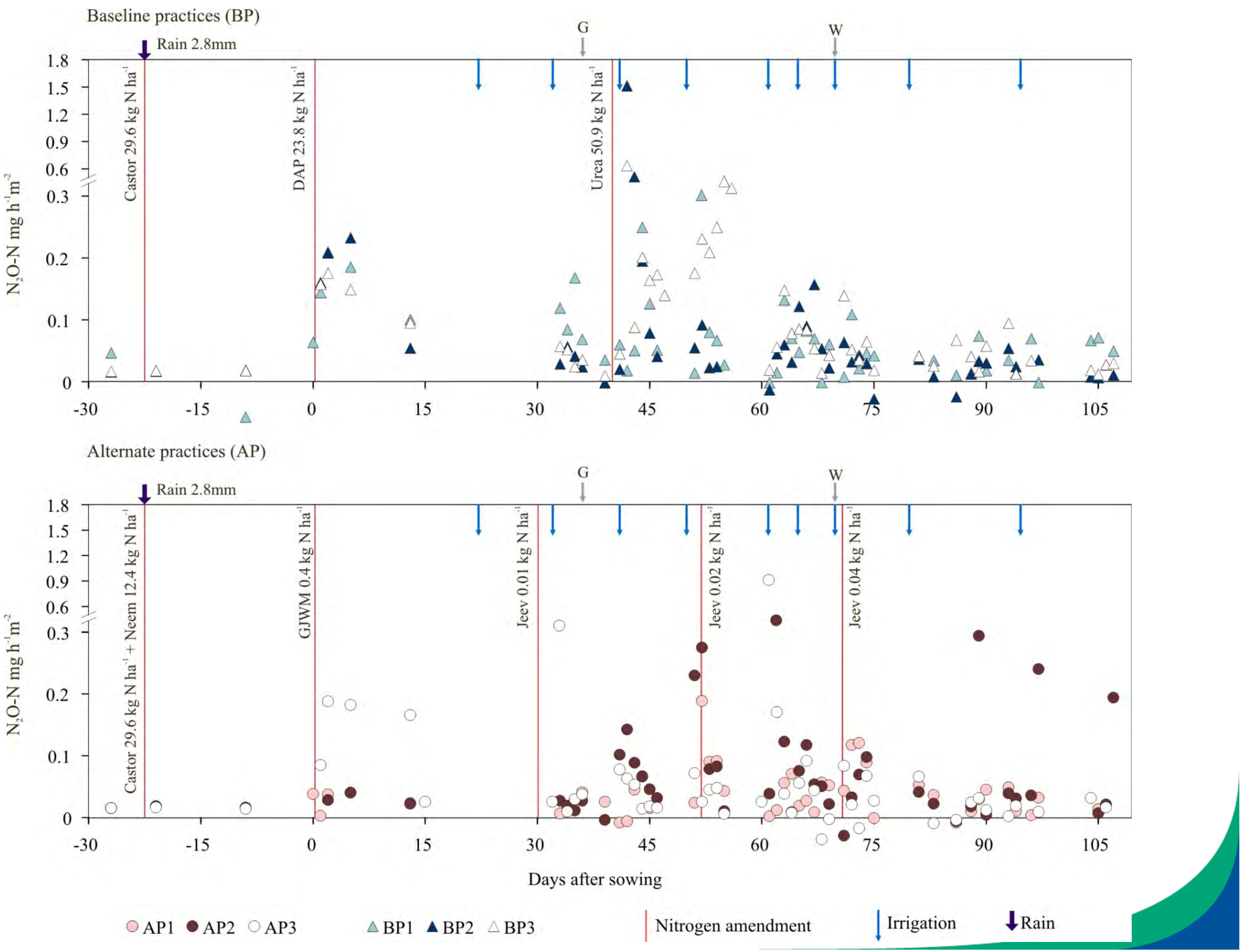
- 40-60% total N use reduction
- Adaptation (drought-hit year): 35-50% yield increase
- Mitigation: 50% decrease in GHG emission intensity
- Poverty alleviation: 70-120% higher farm profit

2012-2013 Groundnut yield, farm profitability, N_2O flux intensity

Treatment	N input (kg/ha)	Dry pod yield (t/ha)	Farm profit (Rs./ha)[a]	N_2O flux (kg N_2O-N/ha)	GHGI (Flux/yield) (tCO_2e/t)	Emission factor[b]
Kharif **(rainfed)**						
Baseline (BP)	65.8	0.40 ± 0.05	-16,500	1.29 ± 0.31	1.59 ± 0.38	1.7%
Alternate (AP)	40.8	0.61 ± 0.03	3,800	1.01 ± 0.03	0.77 ± 0.02	2.1%
Rabi **(irrigated)**						
Baseline (BP)	104.3	1.02 ± 0.18	36,800	1.88 ± 0.33	0.91 ± 0.14	1.6%
Alternate (AP)	42.4	1.38 ± 0.15	63,400	1.37 ± 0.41	0.47 ± 0.08	2.9%

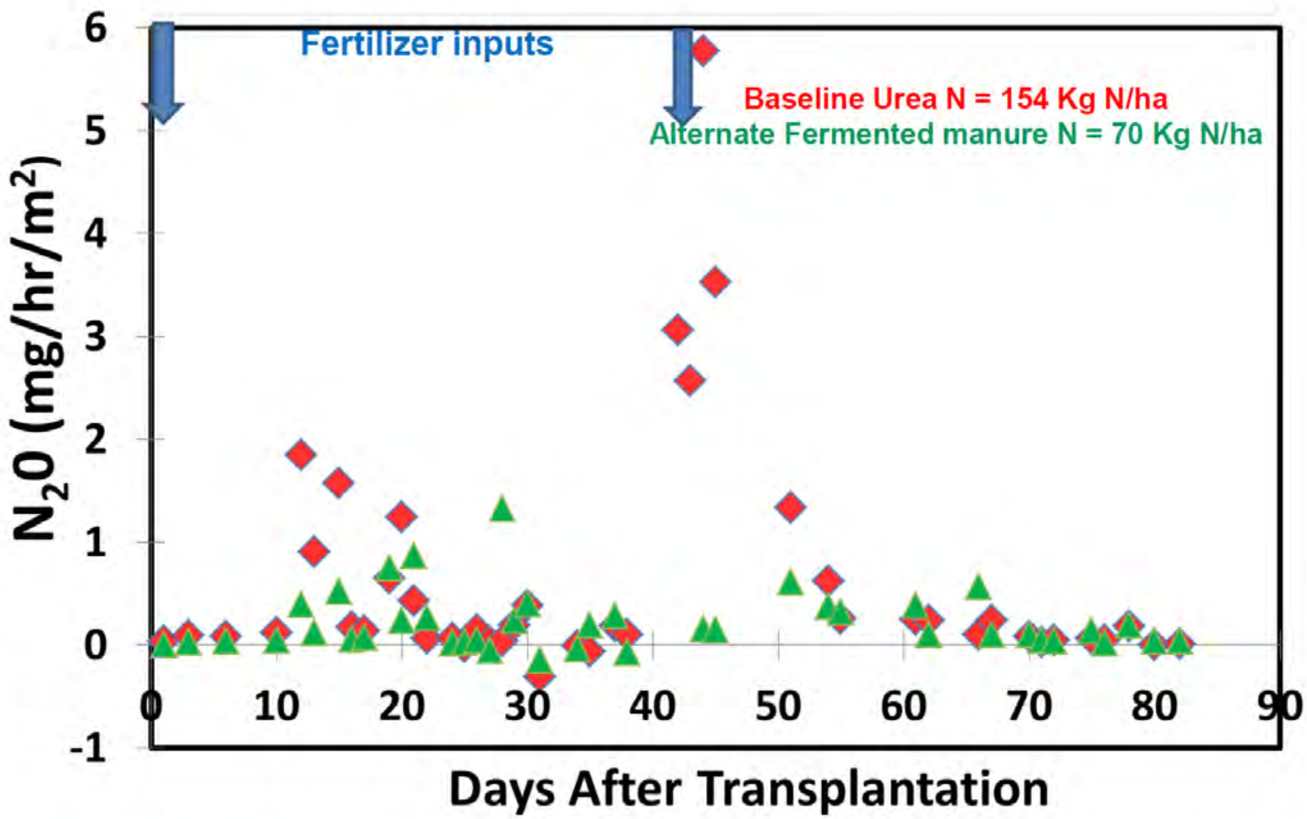
[a] *Net return pooled. See supporting tables 4.1-4.5 for more details*

[b] *EF = (Seasonal N_2O flux - background N_2O flux)/N input; Assuming background flux to be 0.16 kg N_2O-N/ha; see text for more discussion*



Baseline practices (BP)
Rain 2.8mm
G
W
Castor 29.6 kg N ha-1
DAP 23.8 kg N ha-1
Urea 50.9 kg N ha-1
N2O-N mg h-1m-2
Alternate practices (AP)
Castor 29.6 kg N ha-1 + Neem 12.4 kg N ha-1
GJWM 0.4 kg N ha-1
Jeev 0.01 kg N ha-1
Jeev 0.02 kg N ha-1
Jeev 0.04 kg N ha-1
Days after sowing
AP1 AP2 AP3
BP1 BP2 BP3
Nitrogen amendment
Irrigation
Rain

Fig. 1 Seasonal N_2O emissions: Rice
(Anantapur, Andhra Pradesh, AEZ 3.0)



Baseline practices (BP) (Average of 3 replicates)**:** 154 Kg N/ ha as 2 Urea or DAP applications, chemical pesticides, irrigation every 2nd day (not permanently flooded)

Alternate practices (AP) (Average of 3 replicates)**:** 70 Kg N/Ha as manure (FYM & fermented liquids); Neem cake as pesticide; Irrigation every 3-5th day (AWD)

AGRICULTURAL MITIGATION POTENTIAL

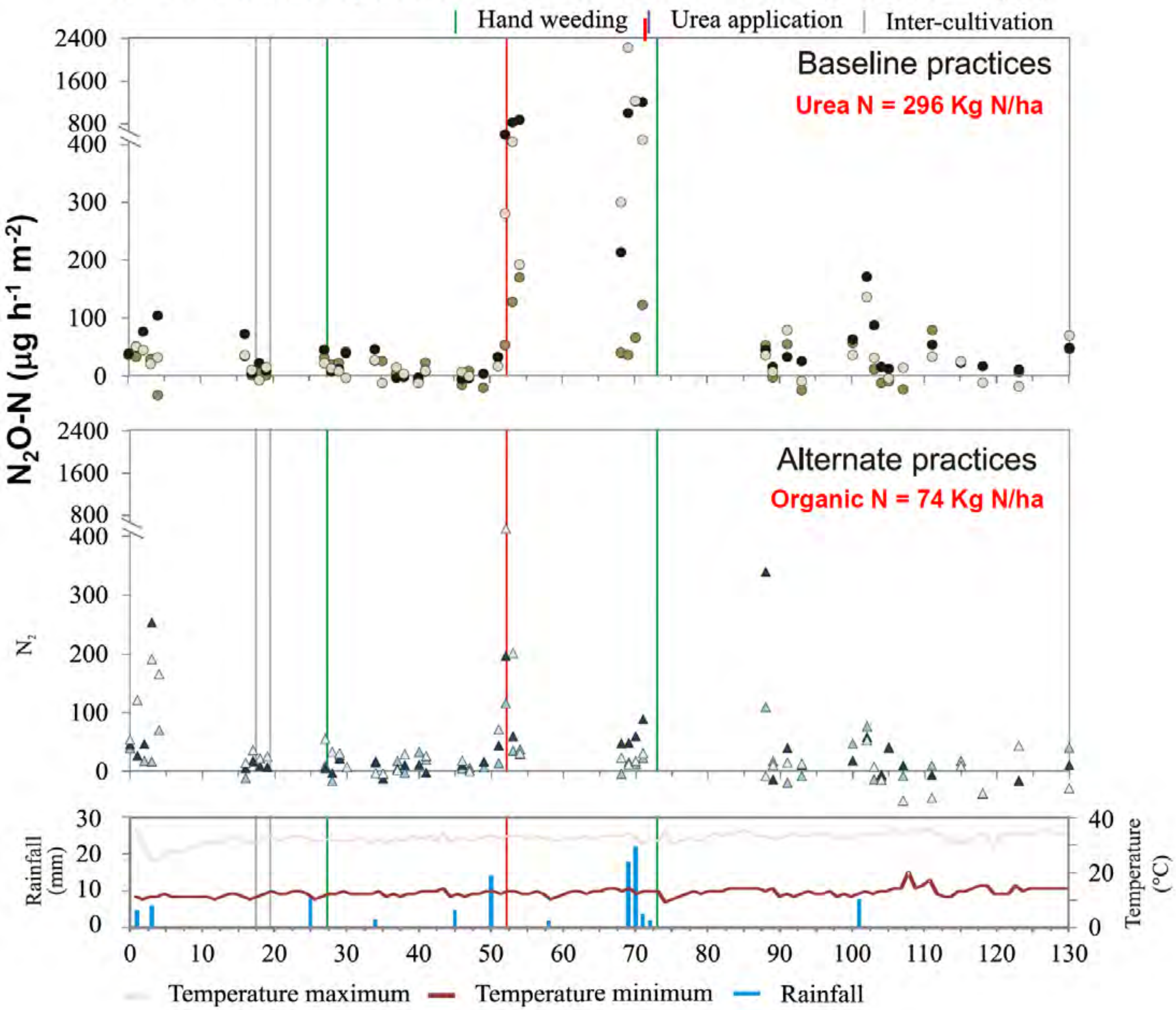
India - Rice

- 35 million tons CO_2e/year (EPA 2014)
- >125 million tons CO_2e/year (Our internal estimate)

Fig. 2 Seasonal N_2O emissions: Millet

(Bangalore, Karnataka, AEZ 8.2)[5]

Three treatment replicates are shown in three different shades of grey



Progress

- Pre-ante farmer surveys for baseline determination

  (and post-ante diaries to monitor/reporting followed practices)
  - Yield
  - Economic indicators
  - Fertilizer, water management, pesticides

- Alternative "sustainable" practice package
  - Interests: yield, economic benefit, low external inputs, soil/water/climate health

- Greenhouse gas emission reduction estimation
  - Field sampling
  - Laboratory measurements using gas chromatographs

- Data compilation analysis
- Tier 2 or 3 modeling
- Methodology and certification

Barriers and challenges

Net Global Warming Potential (100 year time scale) =

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

Correct baseline determination

- Fertilizer, yields, weather, soil, energy, water use, economics, demographics

Practical alternate technologies & State of the science

- Timing of organic matter addition (during dry season vs. rice)
- Timing of synthetic fertilization (one time vs. multiple)
- 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

Linking Ag standards within state/country/region to International market (GHG standards)

- Modeling
- Monitoring, reporting and verification
- Lifecycle analysis and ecosystem services

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.

Kritee
kritee@edf.org

Twitter @KriteeKanko

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Ongoing challenges

- State of the Science (trade-offs)
- Capacity building
  - GHG measurements
  - Data collection and processing
  - Baseline demographic, economic and agronomic data
- Scaling up and integrating different activities across a landscape
  - Modeling for market linkages
  - Compost protocol for Soil C sequestration + Rice Protocol for methane
  - Crop-animal farming cycle
  - Health, water, ecosystem services

GHG Emission Science: 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
  - unlike CH_4, 70-90% N_2O emitted within 4-7 days. Once a week measurements misleading.
  - measurements should capture N_2O peaks (0-4 days after critical events)

- 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

- Measurement common but require daily careful calibration
  - Use of only 1-2 points for calibration → faulty results
  - Use of 2-3 samples from a chamber → misleading emission rates

GHG Emission Science: Requirements

- Simultaneous N, C and Water management for least GWP
    - (e.g., N addition just before flooding)

- Standard operating protocols for
    - Soil organic and inorganic C measurement ***(NEW)***
    - Emission rate calculation (>3 points on conc. *vs.* time graph*)*
    - Frequency of gas sampling for capturing nitrous oxide peaks
    - Calibration by using at least 3 standards each for CH_4 and N_2O

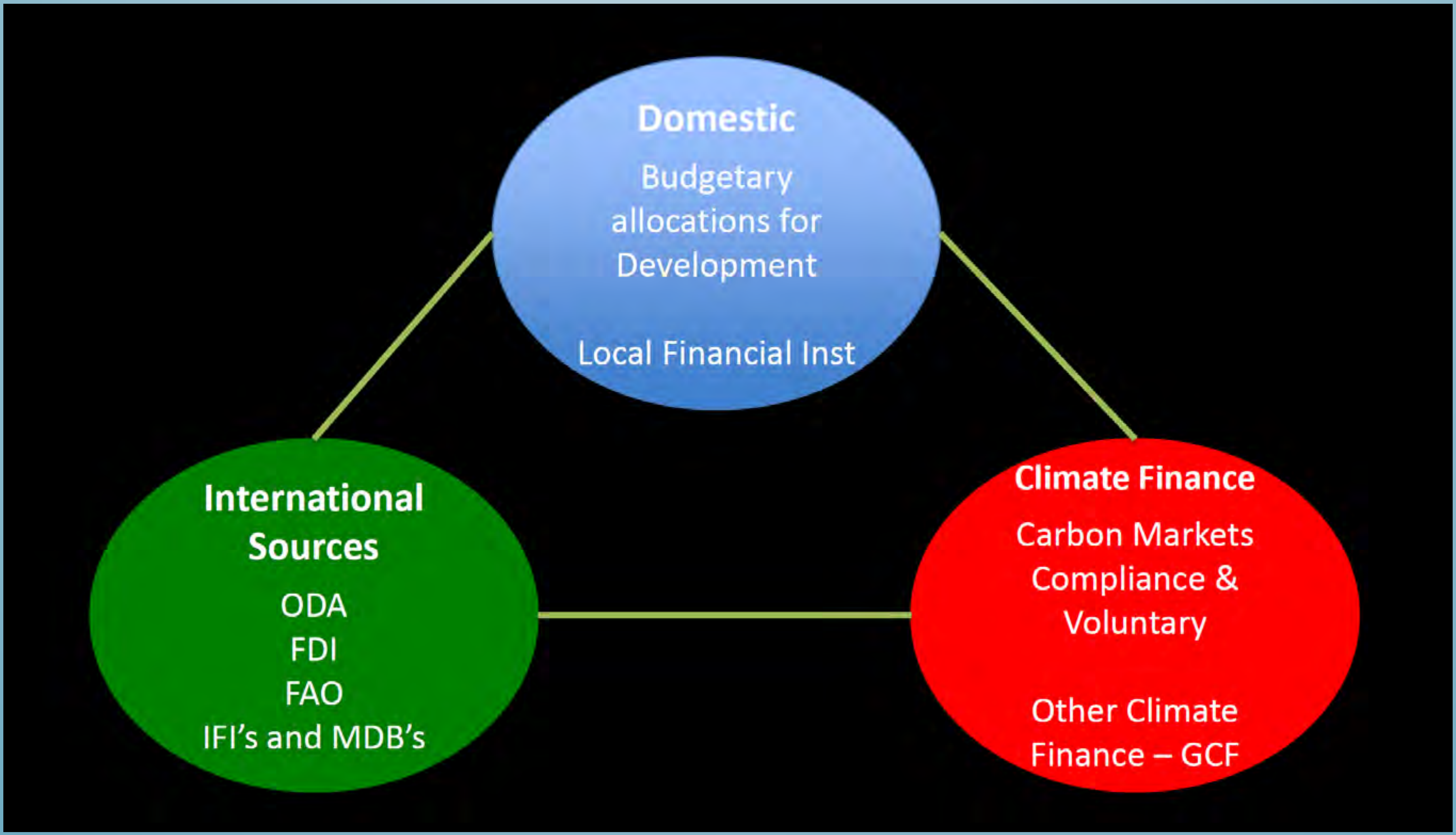
- Water level monitoring by field water tube
  – especially near static chambers

- Detailed below & aboveground biomass yield estimation

- Detailed energy/water use assessment

Other measurements

pH, rain, max min temperature, humidity, daily field water tube data


Domestic
Budgetary allocations for Development
Local Financial Inst
International Sources
ODA
FDI
FAO
IFI's and MDB's
Climate Finance
Carbon Markets Compliance & Voluntary
Other Climate Finance – GCF

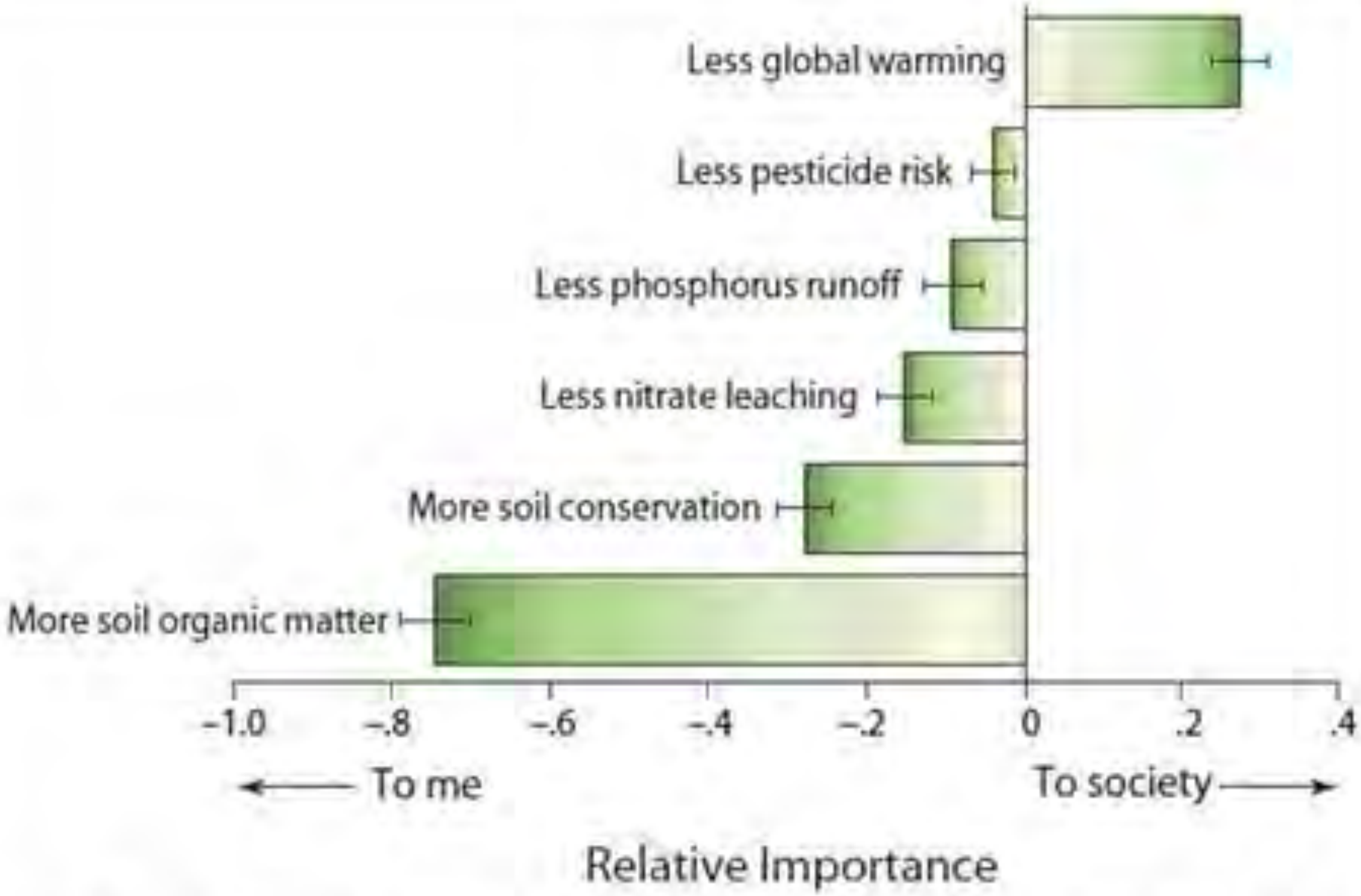
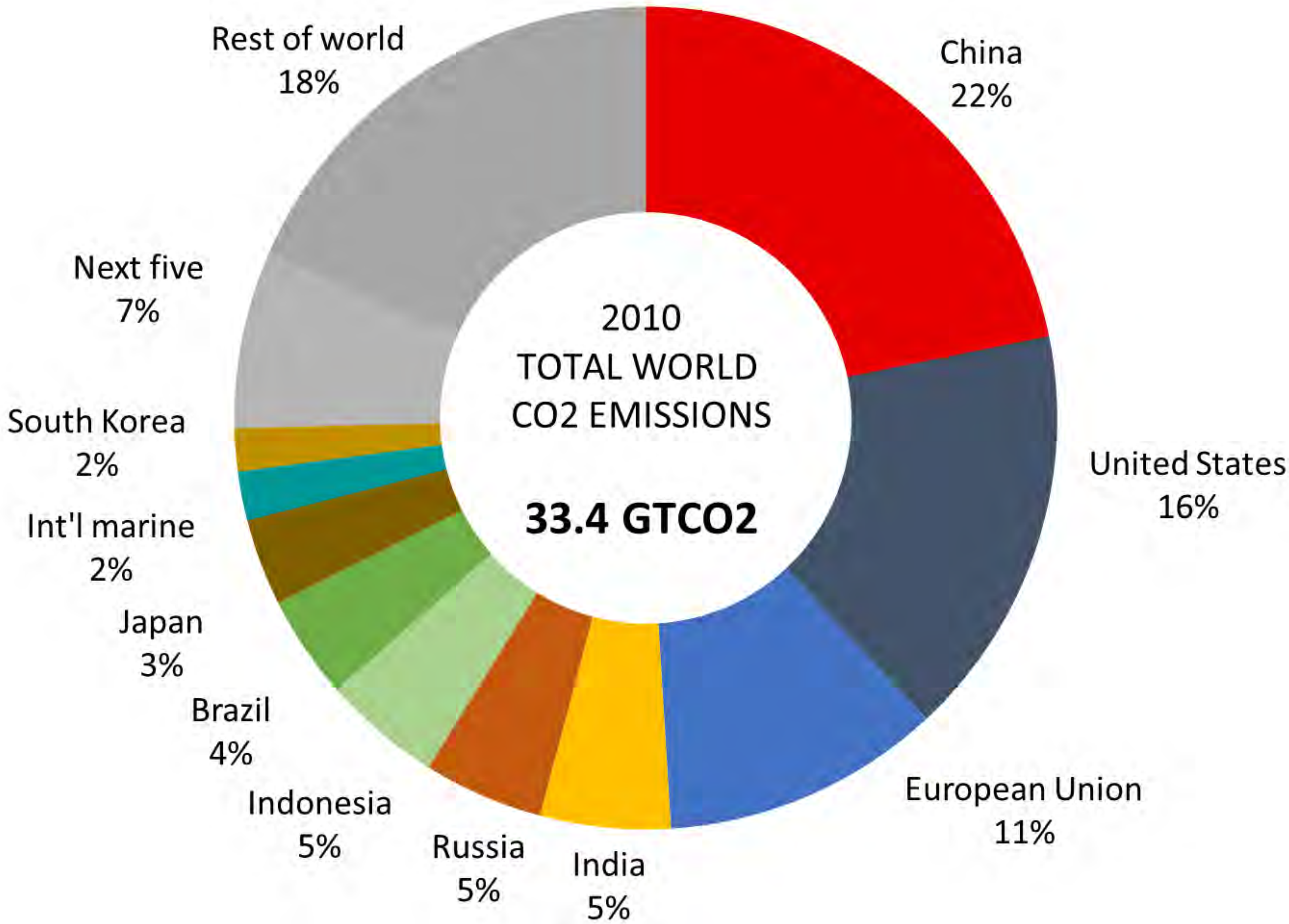


Figure 7. The relative importance to Michigan farmers and to society (as ranked by the farmers) of various environmental benefits potentially provided by agriculture. Source: Adapted from Swinton and colleagues (2014a).

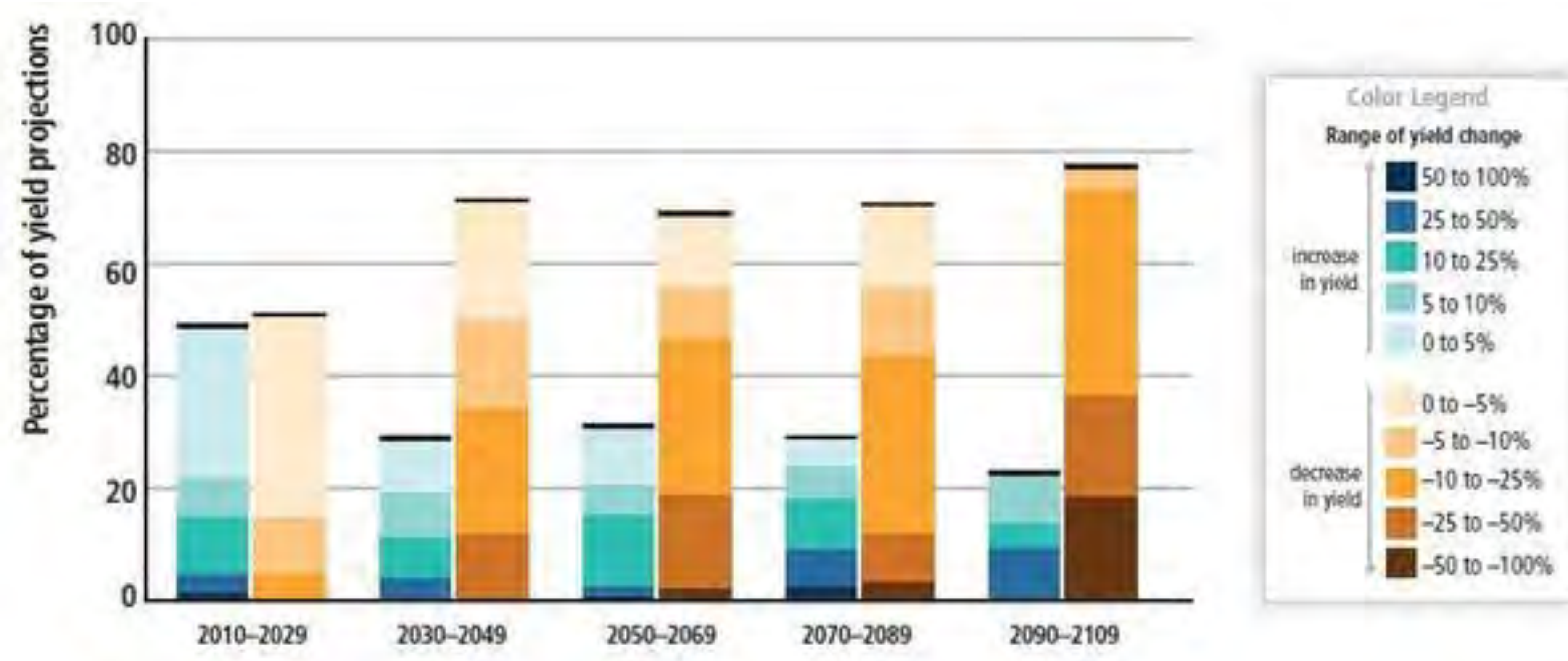
From: Robertson et al, 2014. Farming for Ecosystem Services: An Ecological Approach to Production Agriculture. Bioscience doi: 10.1093/biosci/biu037

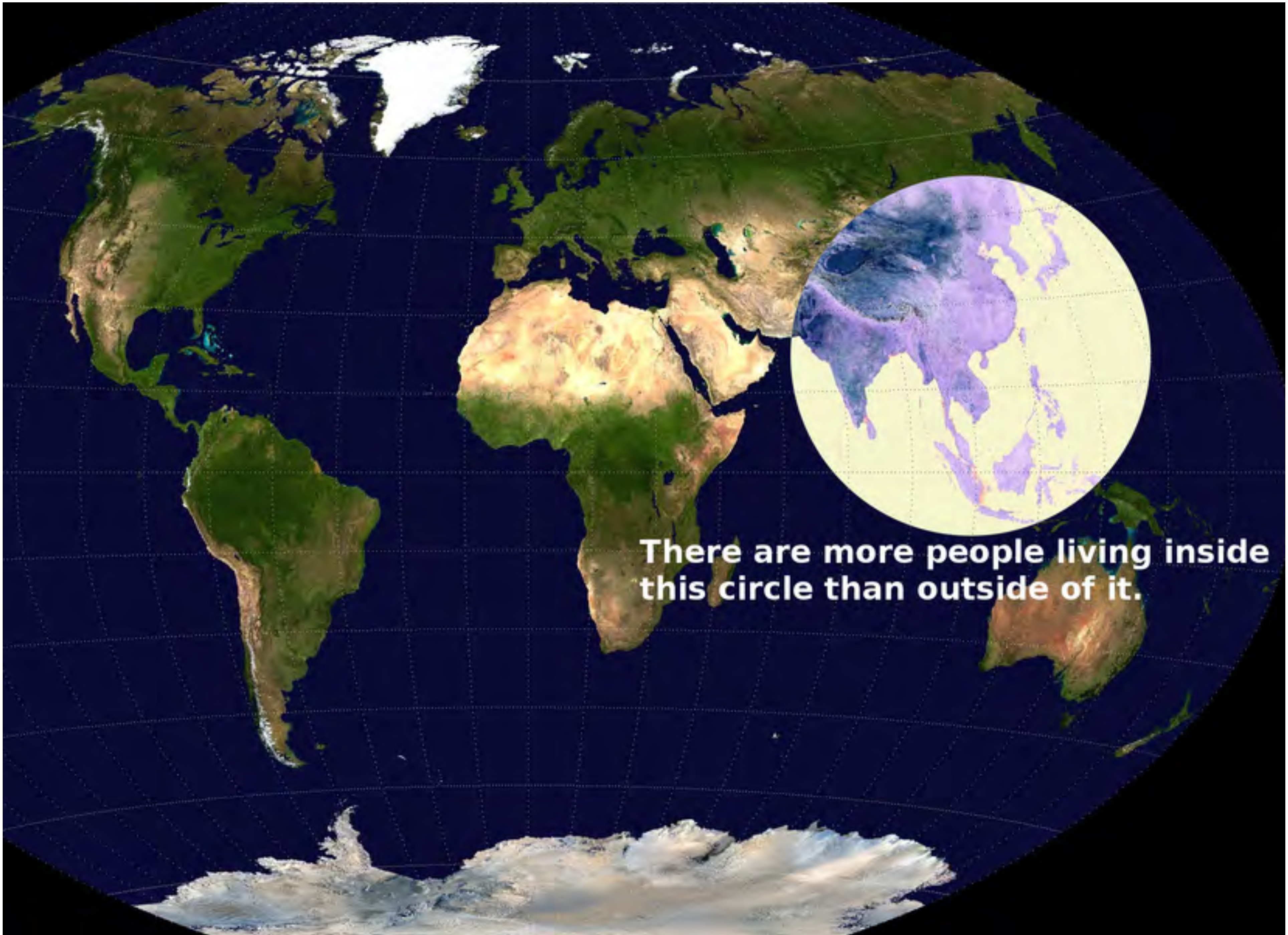
Carbon dioxide emissions, 2010

The top 15 emitters account for 75% of emissions



Yields – CCAC 2014

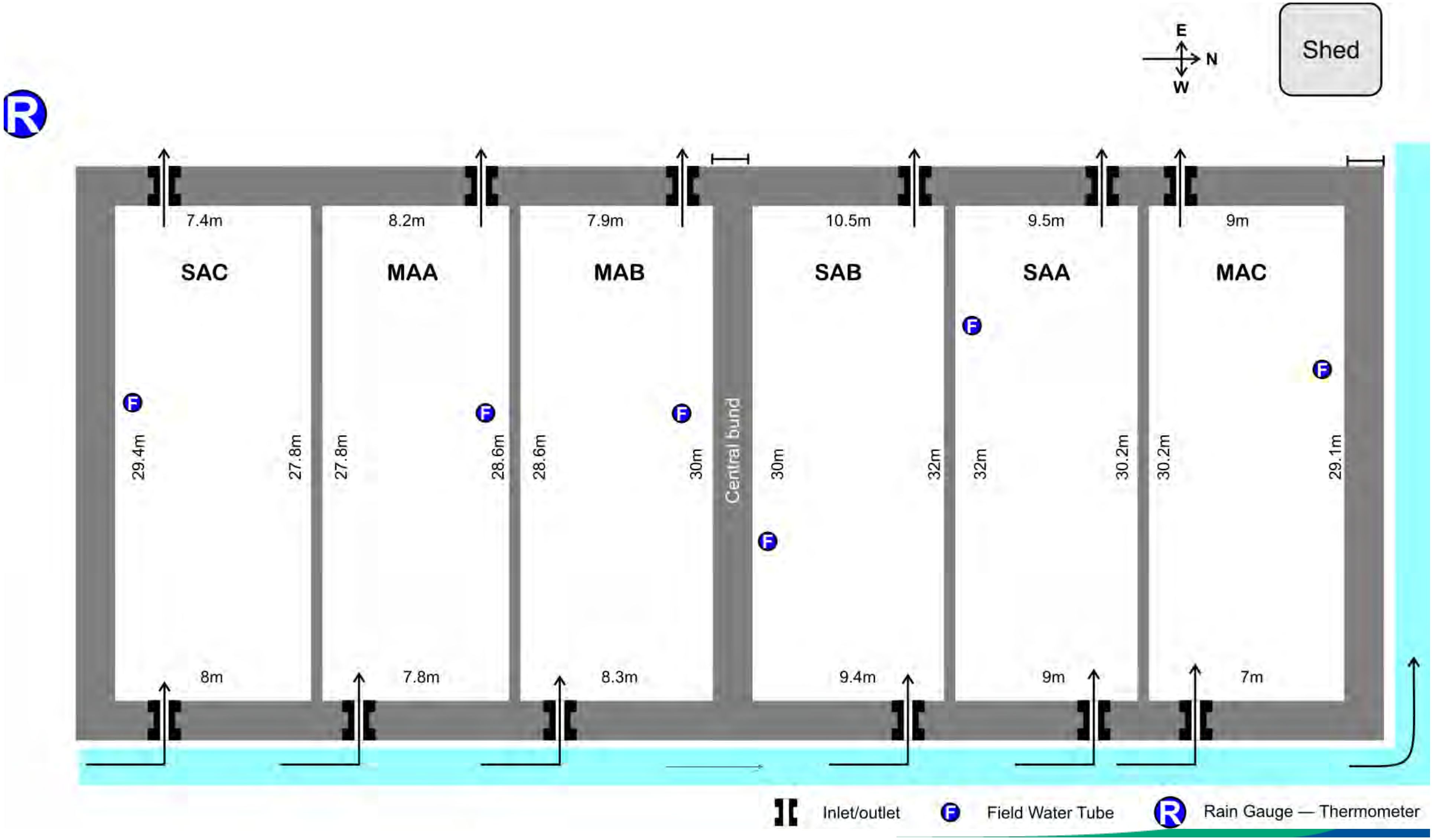




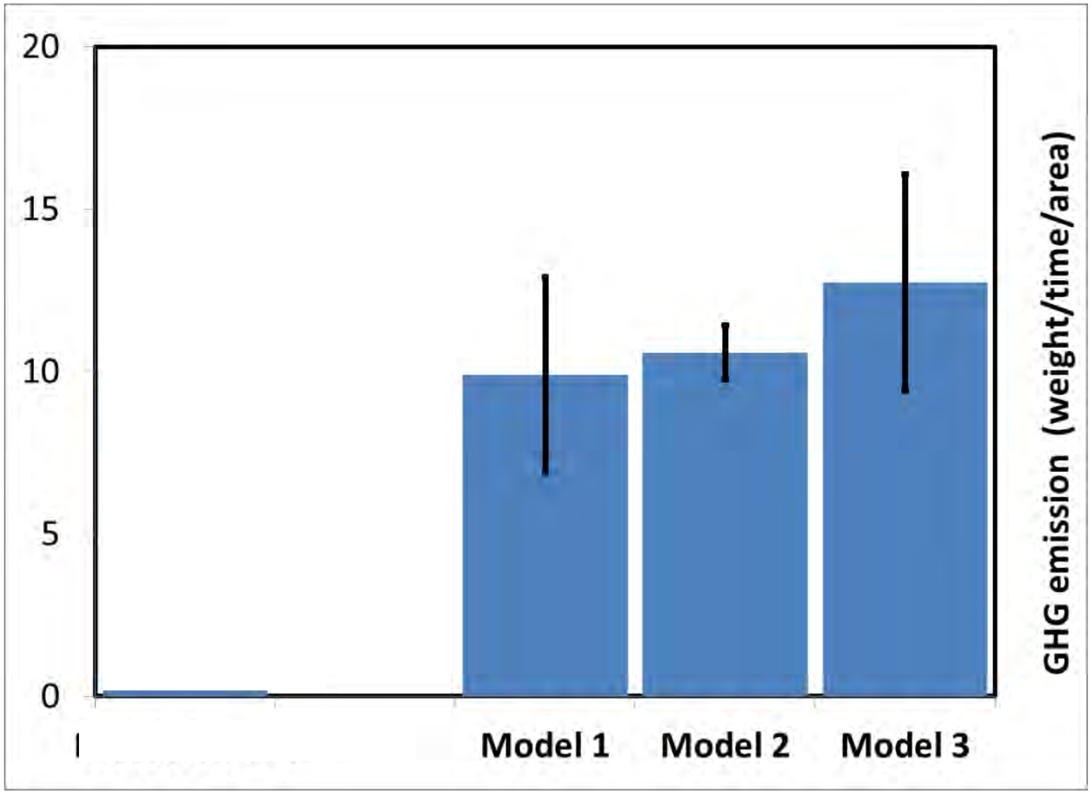
Valerie Pieris / Via reddit.com

Baseline (MA) and Alternative (SA) plots

Three Replicates: Random plot design or random chamber placement



Putting model uncertainties into perspective

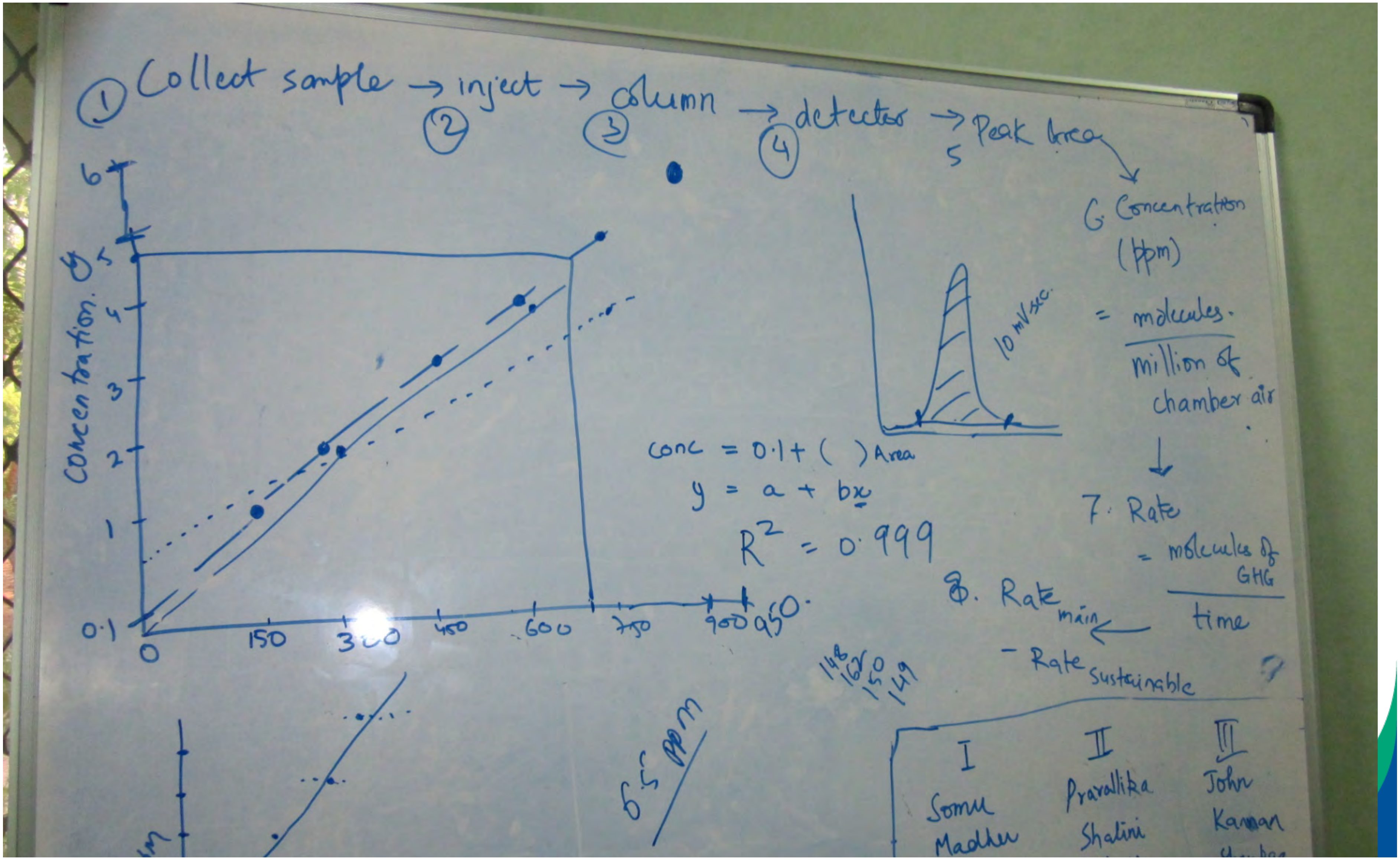


Technical Achievements (and Challenges)

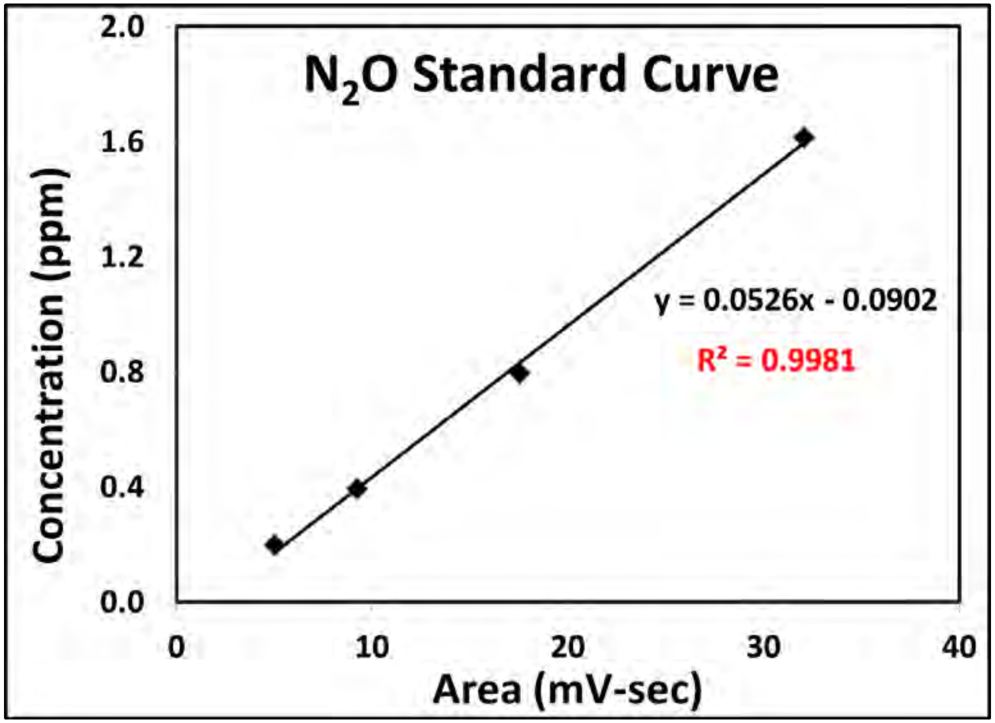
- Same day analysis @GC RSD <3 % (Sample storage for bad days, N2O leaks)
- Minimum detection limit for daily emission rate (poor R^2)
- Extrapolation of half hour measurement to daily rate (diurnal curve)
- Area under the curve (seasonal emission rates)
- Outliers among replicate chambers, absence of replicates
- Absence of uniform leveling
- Hard to maintain water level in drylands
- Fallow land sampling schedule: Unclear!
- Weekly 4 point sampling for 30-45 minutes except for these events
  - Rain/Irrigation (3-4 days)
  - Fertilizer/manure (3-4 days)
  - Pesticide
  - Weeding

Training session in the Lab

Clarifying the process: Sampling to GHG emission rates

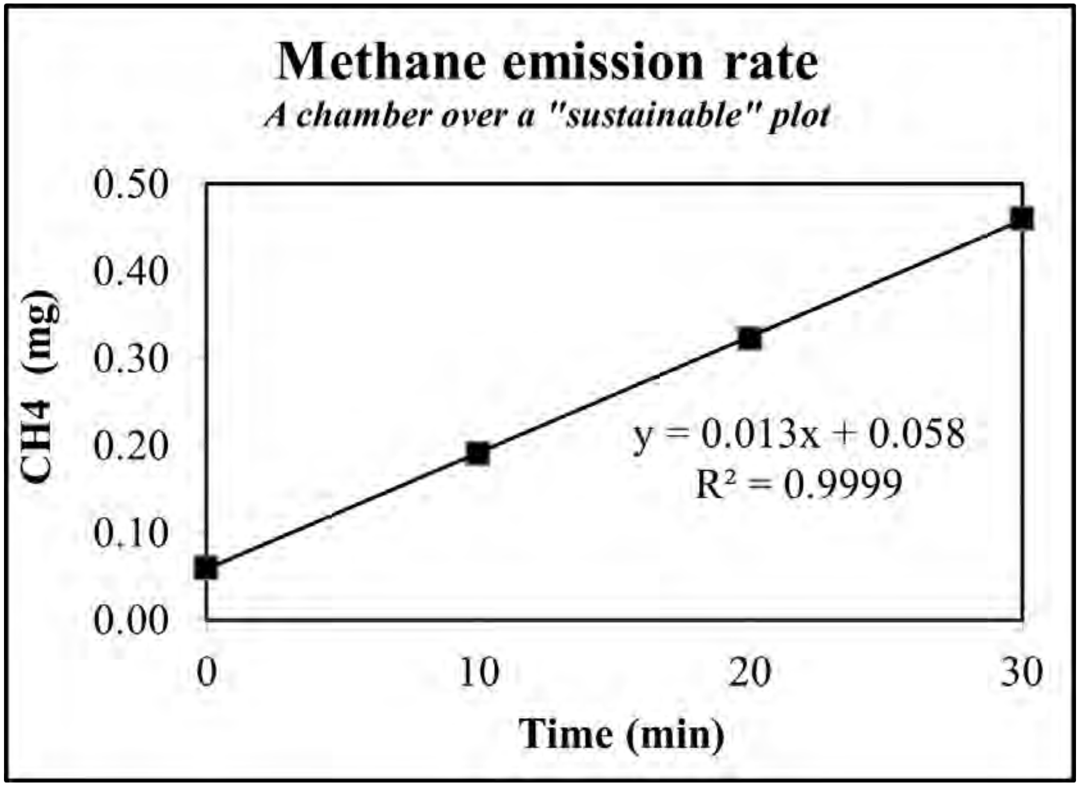


Multi-point calibration curves for GC



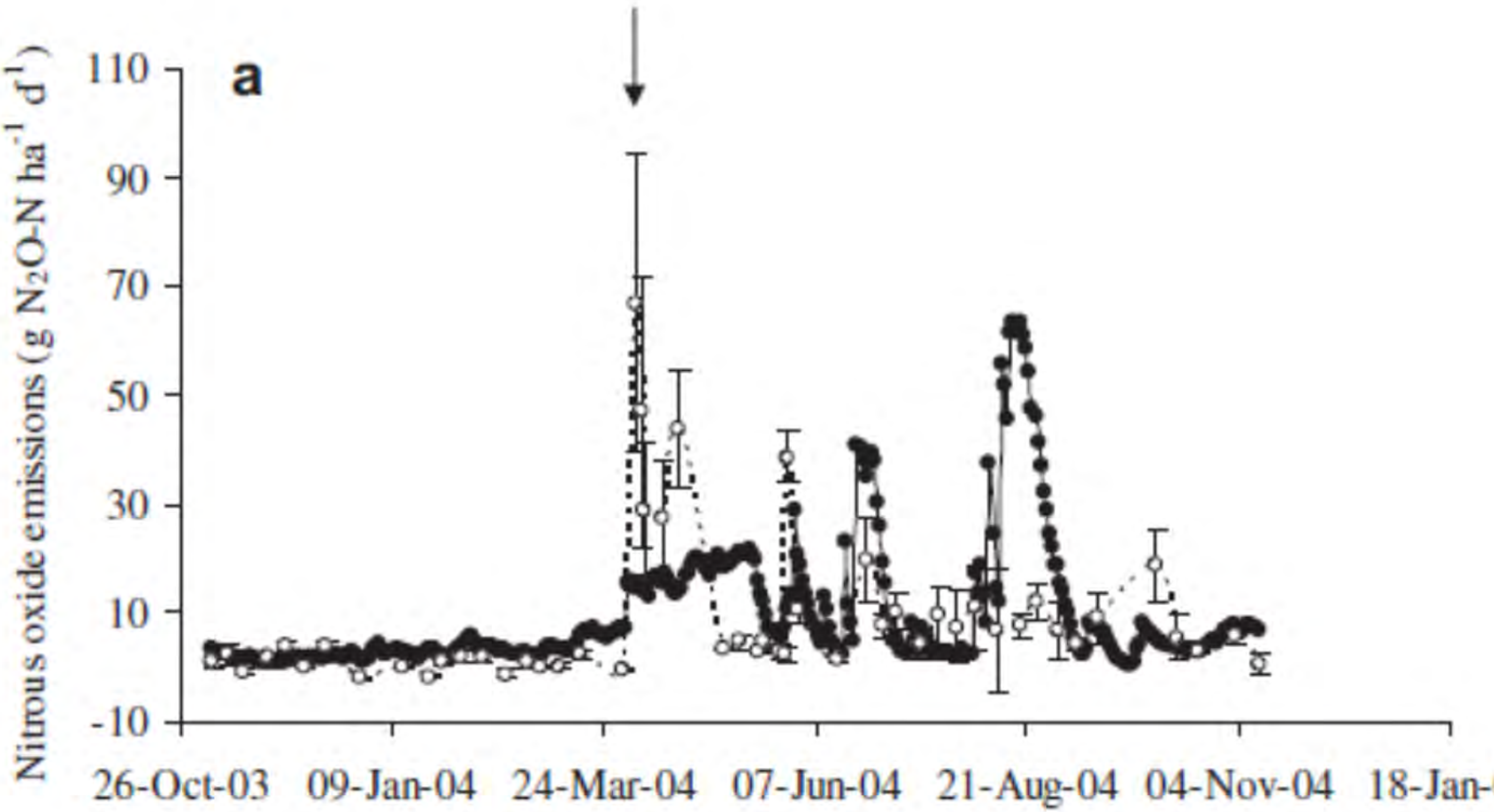
N_2O (ppmv)	CH_4 (ppmv)
0.197	1.535
0.393	3.352
0.795	7.152
1.615	15.682

Chamber graph and minimum detection limit



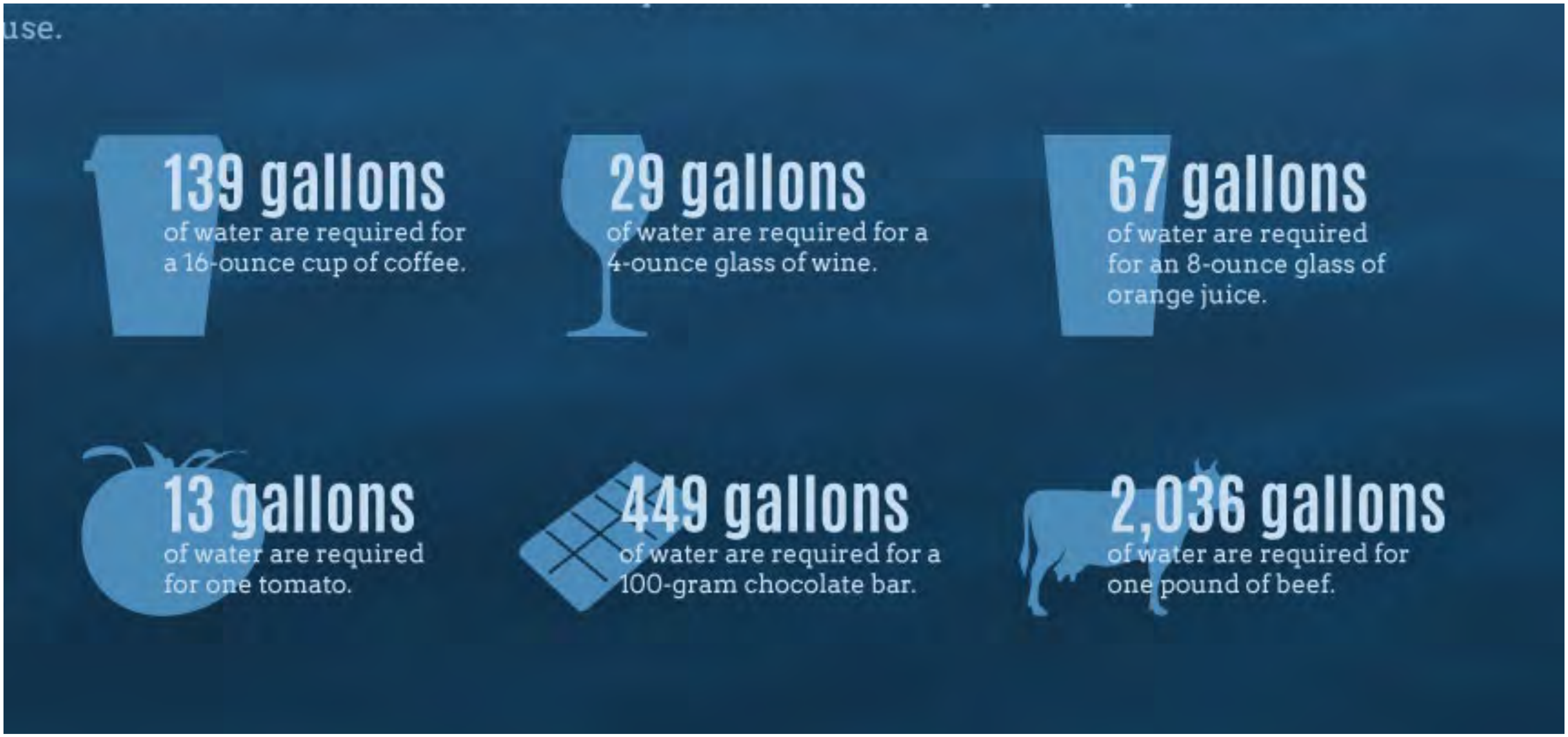
Linear increase in GHG concentration inside the chamber

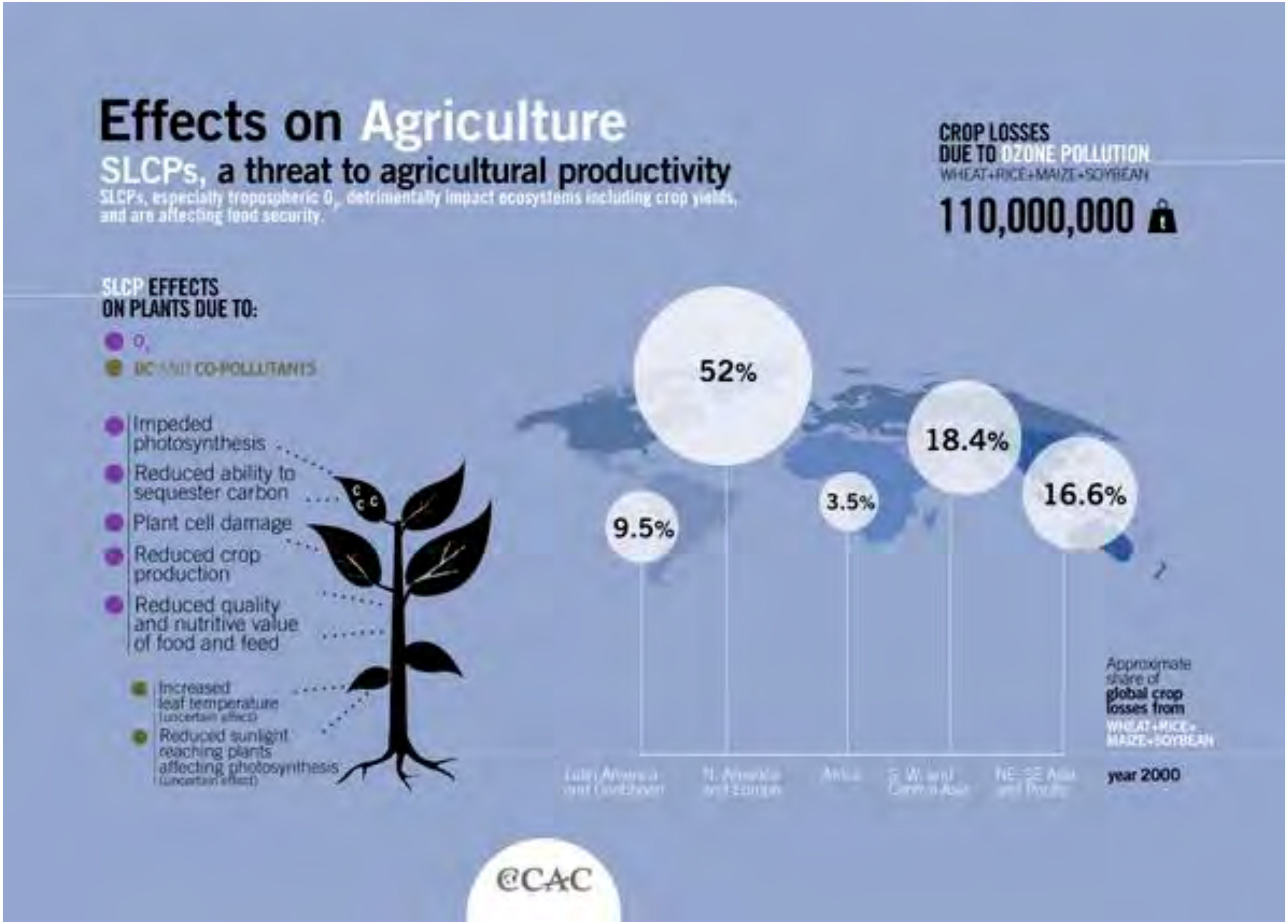
Forcing models to conform to ….what?



(Abdalla et al, 2011)

Water footprint of agriculture





Effects on Agriculture
SLCPs, a threat to agricultural productivity
SLCPs, especially tropospheric O_3, detrimentally impact ecosystems including crop yields, and are affecting food security.
CROP LOSSES DUE TO OZONE POLLUTION
WHEAT+RICE+MAIZE+SOYBEAN
110,000,000
SLCP EFFECTS ON PLANTS DUE TO:
O_3
Impeded photosynthesis
Reduced ability to sequester carbon
Plant cell damage
Reduced crop production
Reduced quality and nutritive value of food and feed
Increased leaf temperature (uncertain effect)
Reduced sunlight reaching plants affecting photosynthesis (uncertain effect)
52%
18.4%
16.6%
9.5%
3.5%
Approximate share of global crop losses from WHEAT+RICE+MAIZE+SOYBEAN
year 2000
CCAC


Annual income spent on food
Malnutrition
< 5%
5-10%
10-20%
20-30%
30-40%
> 40%
not in survey
Canada
US
Mexico
Guatemala
Dominican Republic
Costa Rica
Venezuela
Colombia
Ecuador
Peru
Brazil
Bolivia
Chile
Argentina
Uruguay
Ireland
UK
Norway
Sweden
Finland
Denmark
Netherlands
Lithuania
Latvia
Estonia
Russia
Poland
Belarus
44%
Ukraine
Czech Republic
Slovakia
Hungary
Portugal
Spain
France
Italy
Croatia
Macedonia
Romania
Bulgaria
Greece
Turkey
Israel
Georgia
Kazakhstan
Uzbekistan
Azerbaijan
48.5%
Turkmenistan
China*
Japan
S Korea
Taiwan
Hong Kong
Tunisia
Morocco
Algeria
Egypt
Jordan
Kuwait
Bahrain
Qatar
UAE
Saudi Arabia
Iran
Pakistan
India
Thailand
Vietnam
Philippines
Malaysia
Singapore
Indonesia
Kenya
Nigeria
Cameroon
S Africa
Australia
New Zealand
A map of the world based on food costs as a percentage of income compared with incidence of juvenile malnutrition.
The size of the country represents the percentage spent on food. The darker the color, the higher the rate of malnutrition.