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
- 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
WHERE WE WORK ON AGRICULTURE

INDIA
- Andhra Pradesh
- Karnataka
- Tamil Nadu

VIETNAM
- An Giang Province
- Kien Giang Province

Where we work on agriculture
Feeding 9 billion in 2050
Long term nutritional security

By 2050 the world’s population will likely increase by more than 35 percent.

1 billion people — ▲ 35%

http://ccafs.cgiar.org/bigfacts2014/#
Yield Trends Are Insufficient to Double Global Crop Production by 2050

Effect of climate on agriculture

Limits of adaptation practices

- 40% yield decrease → changes associated with 2°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$_2$e (2010 & 2030)

Top 15 emitters in 2010, with growth to 2030

Total Food System
(with deforestation)

Food Waste (without deforestation)

Vietnam
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$_2$e (2010 & 2030)

Top 15 emitters in 2010, with growth to 2030

MMT CO$_2$

- **Total Food System (with deforestation)**
- **Food Waste (without deforestation)**

Vietnam
Agricultural CH₄ emissions: Why and how?
Agricultural N₂O emissions: Why and how?
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

CLIENTS
- Sectors
- Farmers
- Individuals
- Communities

RESOURCES
- International
- National
- Carbon Finance
  from Markets

INSTITUTIONS
- International
- National
- Sub National
- Local (NGO’s; communities)
Climate Smart Farming in India

Mitigating climate change and poverty = Low carbon rural development
ELECTRICITY & CLEAN COOK-STOVE GAP

Energy demand trajectories

Energy demand
Million tonnes of oil equivalent

- USA: 2,265 million tonnes of oil equivalent (5%)
- Russia: 833 million tonnes of oil equivalent (29%)
- China: 3,835 million tonnes of oil equivalent (69%)
- India: 1,464 million tonnes of oil equivalent (119% projected increase)
- Brazil: 421 million tonnes of oil equivalent (78%)

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
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
    - “It’s 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

Methane emission rate
A chamber over a "sustainable" plot

\[ y = 0.013x + 0.058 \]
\[ R^2 = 0.9999 \]

Time (min)

CH4 (mg)
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
Stackable Manual Chambers
Gas chromatograph
## Data Analysis and Storage

<table>
<thead>
<tr>
<th>ID</th>
<th>Temp. (°C)</th>
<th>Box Vol. (L)</th>
<th>Flux Vol. (L)</th>
<th>N₂O (ppmv)</th>
<th>CH₄ (ppmv)</th>
<th>N₂O (μg)</th>
<th>CH₄ (μg)</th>
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<tr>
<td>1</td>
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<td>0.553</td>
<td>22.916</td>
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**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$_2$O flux intensity

<table>
<thead>
<tr>
<th>Treatment</th>
<th>N input (kg/ha)</th>
<th>Dry pod yield (t/ha)</th>
<th>Farm profit (Rs./ha)$^a$</th>
<th>N$_2$O flux (kg N$_2$O-N/ha)</th>
<th>GHGI (Flux/yield) (tCO$_2$e/t)</th>
<th>Emission factor$^b$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Kharif (rainfed)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline (BP)</td>
<td>65.8</td>
<td>0.40 ± 0.05</td>
<td>-16,500</td>
<td>1.29 ± 0.31</td>
<td>1.59 ± 0.38</td>
<td>1.7%</td>
</tr>
<tr>
<td>Alternate (AP)</td>
<td>40.8</td>
<td>0.61 ± 0.03</td>
<td>3,800</td>
<td>1.01 ± 0.03</td>
<td>0.77 ± 0.02</td>
<td>2.1%</td>
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<tr>
<td><strong>Rabi (irrigated)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline (BP)</td>
<td>104.3</td>
<td>1.02 ± 0.18</td>
<td>36,800</td>
<td>1.88 ± 0.33</td>
<td>0.91 ± 0.14</td>
<td>1.6%</td>
</tr>
<tr>
<td>Alternate (AP)</td>
<td>42.4</td>
<td>1.38 ± 0.15</td>
<td>63,400</td>
<td>1.37 ± 0.41</td>
<td>0.47 ± 0.08</td>
<td>2.9%</td>
</tr>
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</table>

$a$ Net return pooled. See supporting tables 4.1-4.5 for more details

$b$ EF = (Seasonal N$_2$O flux - background N$_2$O flux)/N input; Assuming background flux to be 0.16 kg N$_2$O-N/ha; see text for more discussion
**Fig. 1 Seasonal N₂O emissions: Rice**
(Anantapur, Andhra Pradesh, AEZ 3.0)

![Graph showing N₂O emissions over days after transplantation.]

- **Baseline practices (BP)** (Average of 3 replicates): 154 Kg N/ha as 2 Urea or DAP applications, chemical pesticides, irrigation every 2\textsuperscript{nd} 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 3-5\textsuperscript{th} day (AWD)
Agricultural Mitigation Potential

India - Rice
- 35 million tons CO$_2$e/year (EPA 2014)
- >125 million tons CO$_2$e/year (Our internal estimate)

Photos: Hong Tin, Can Tho University
Fig. 2 Seasonal N$_2$O emissions: Millet
(Bangalore, Karnataka, AEZ 8.2)$^5$

Three treatment replicates are shown in three different shades of grey

Baseline practices
Urea N = 296 Kg N/ha

Alternate practices
Organic N = 74 Kg N/ha

Temperature maximum
Temperature minimum
Rainfall
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) =

\[(31 \times \text{Methane}) + (298 \times \text{Nitrous Oxide}) \text{ minus } (3.66 \times \text{Soil Carbon})\]

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.
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) =

\((31 \times \text{Methane}) + (298 \times \text{Nitrous Oxide}) \text{ minus } (3.66 \times \text{Soil Carbon gain})\)

- Antagonism between N\(_2\)O & CH\(_4\) wrt water management is known; but
  - unlike CH\(_4\), 70-90% N\(_2\)O emitted within 4-7 days. Once a week measurements misleading.
  - measurements should capture N\(_2\)O 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\(_2\)O 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 CH₄ and N₂O

• 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
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).

Carbon dioxide emissions, 2010
The top 15 emitters account for 75% of emissions

- China: 22%
- United States: 16%
- European Union: 11%
- Russia: 5%
- India: 5%
- Indonesia: 5%
- Brazil: 4%
- Japan: 3%
- Int'l marine: 2%
- South Korea: 2%
- Next five: 7%
- Rest of world: 18%
Yields – CCAC 2014
There are more people living inside this circle than outside of it.
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

\[ y = 0.0526x - 0.0902 \]

\[ R^2 = 0.9981 \]

<table>
<thead>
<tr>
<th>( \text{N}_2\text{O (ppmv)} )</th>
<th>( \text{CH}_4 \text{ (ppmv)} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.197</td>
<td>1.535</td>
</tr>
<tr>
<td>0.393</td>
<td>3.352</td>
</tr>
<tr>
<td>0.795</td>
<td>7.152</td>
</tr>
<tr>
<td>1.615</td>
<td>15.682</td>
</tr>
</tbody>
</table>
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

139 gallons of water are required for a 16-ounce cup of coffee.

29 gallons of water are required for a 4-ounce glass of wine.

67 gallons of water are required for an 8-ounce glass of orange juice.

13 gallons of water are required for one tomato.

449 gallons of water are required for a 100-gram chocolate bar.

2,036 gallons of water are required for one pound of beef.
Effects on Agriculture
SLCPs, a threat to agricultural productivity

SLCPs, especially tropospheric O₃, 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:

- O₃
- BC AND CO-POLLUTANTS
- 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)

Approximate share of global crop losses from WHEAT + RICE + MAIZE + SOYBEAN year 2000

Latin America and Caribbean
N. America and Europe
Africa
S. W. and Central Asia
NE and SE Asia and Pacific
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.