CIMMYT Research on Crop Nutrition

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Part of CGIAR; founded in 1966
Mission: **Maize and wheat science for improved livelihoods**

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Afghanistan
Bangladesh
China
Colombia
Ethiopia
India
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Kenya
Mexico
Nepal
Pakistan
Turkey
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1,600 staff from over 50 countries
With >300 partners

Projects in over 40 countries

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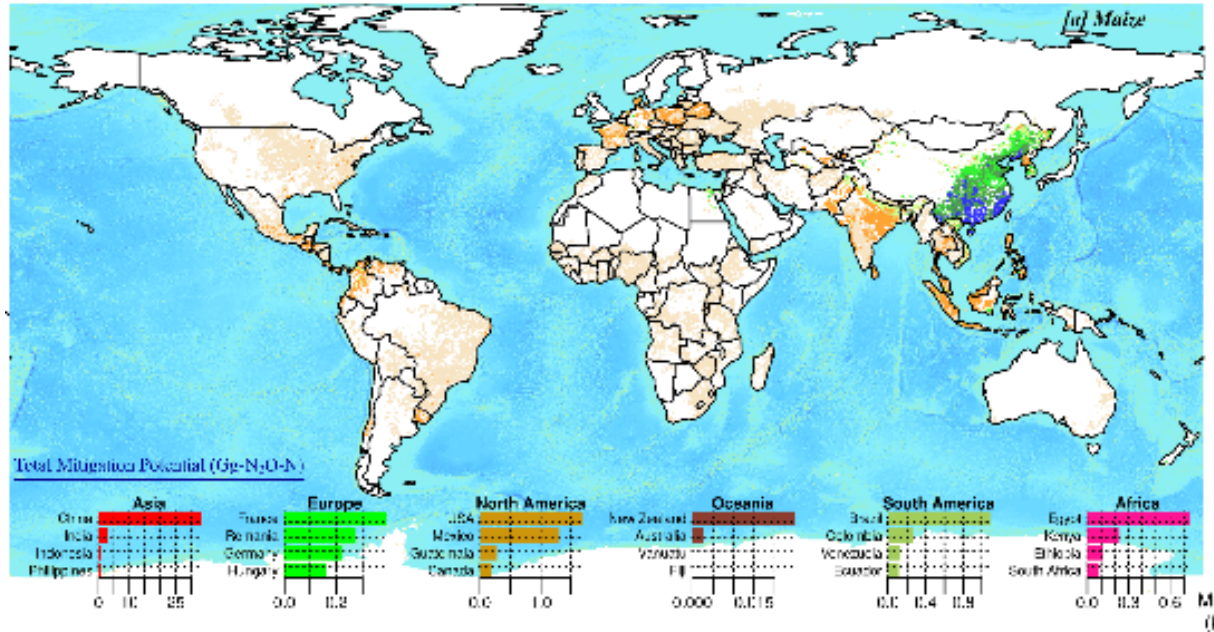
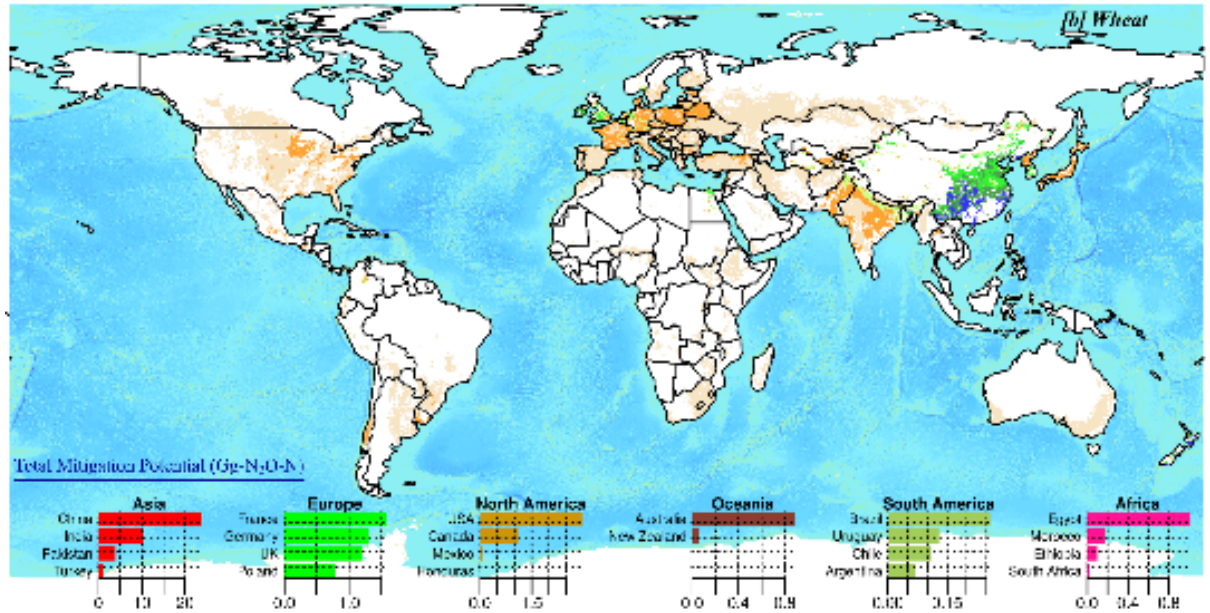
N_2O mitigation potential from global maize and wheat fields

Maize



Wheat



N_2O mitigation potential (kg-N_2O-N ha^{-1}) based on 75% reduction in excess N

Bar charts shows the annual total mitigation potential (Gg_N2O-N) of major countries.

(Tesfaye et al. 2021)

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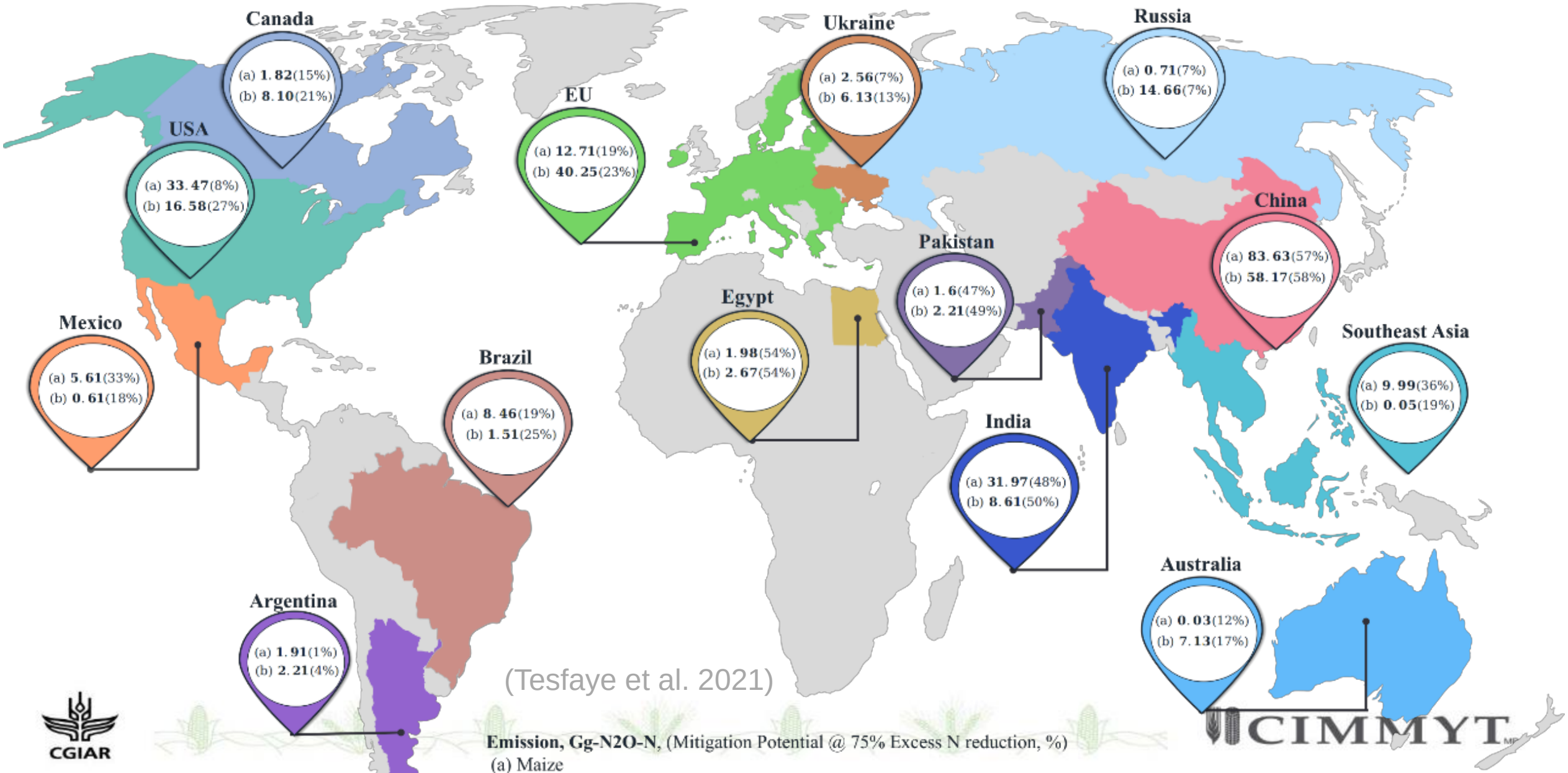
Total N_2O emission and % mitigation potential through reduction of excess N application in maize (a) and wheat (b) fields from major countries.



(Tesfaye et al. 2021)

Emission, Gg-N2O-N, (Mitigation Potential @ 75% Excess N reduction, %)
(a) Maize
(b) Wheat

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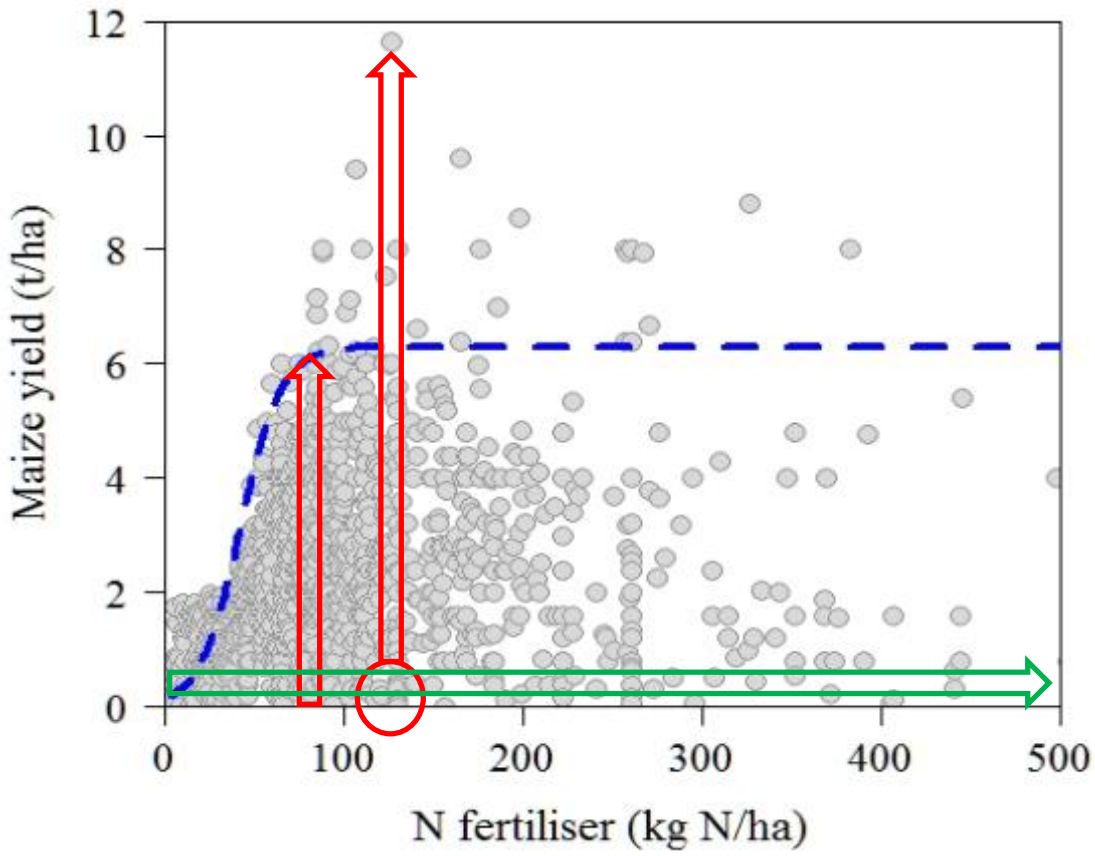
Crop Nutrition & Agronomic Context

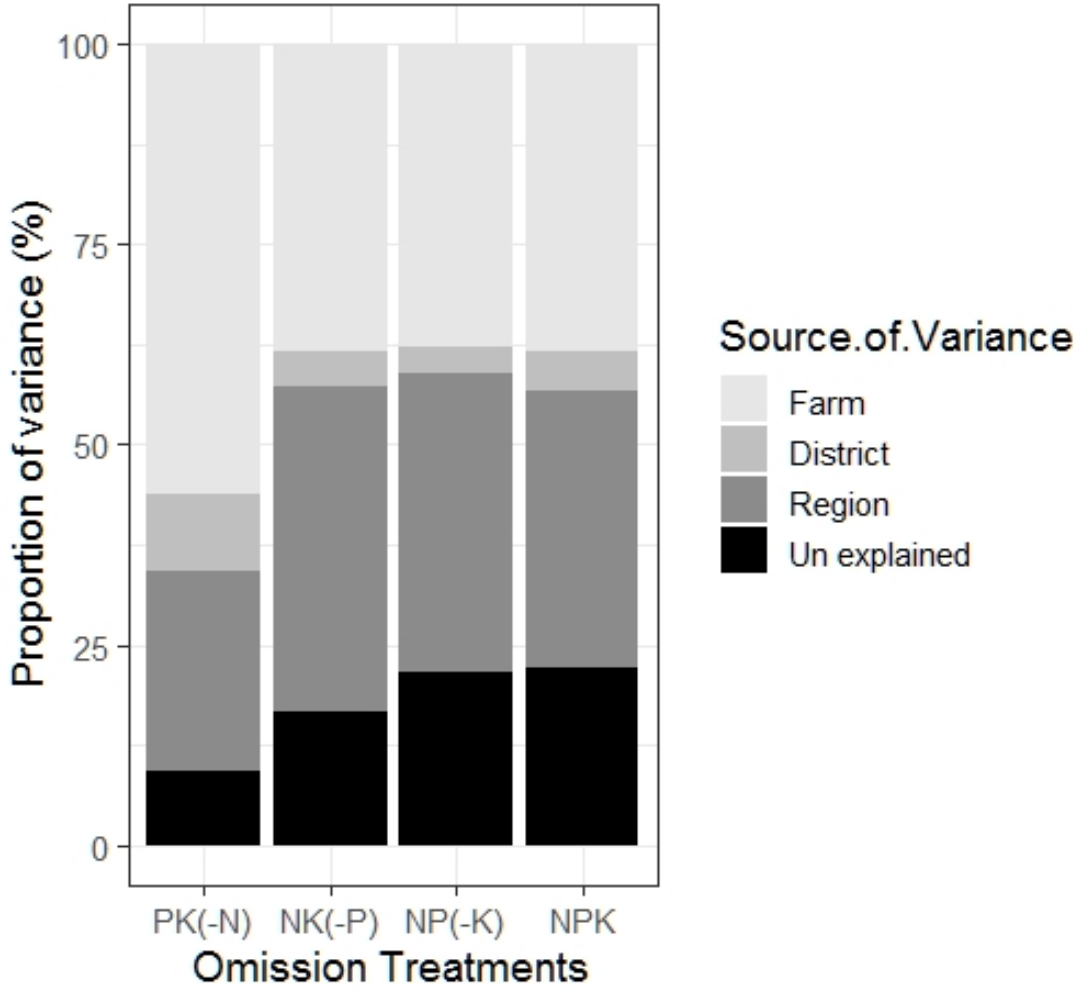
Smallholder maize production systems in Ethiopia

- Result of Agricultural Panel Survey (APS) in Ethiopia (N = 1400).
  - Extreme variability
    - Spatially, temporally
    - Variability in responses to input
    - Discourages adoption / scaling
  - These differences cannot be explained by differences in fertilizer supply alone



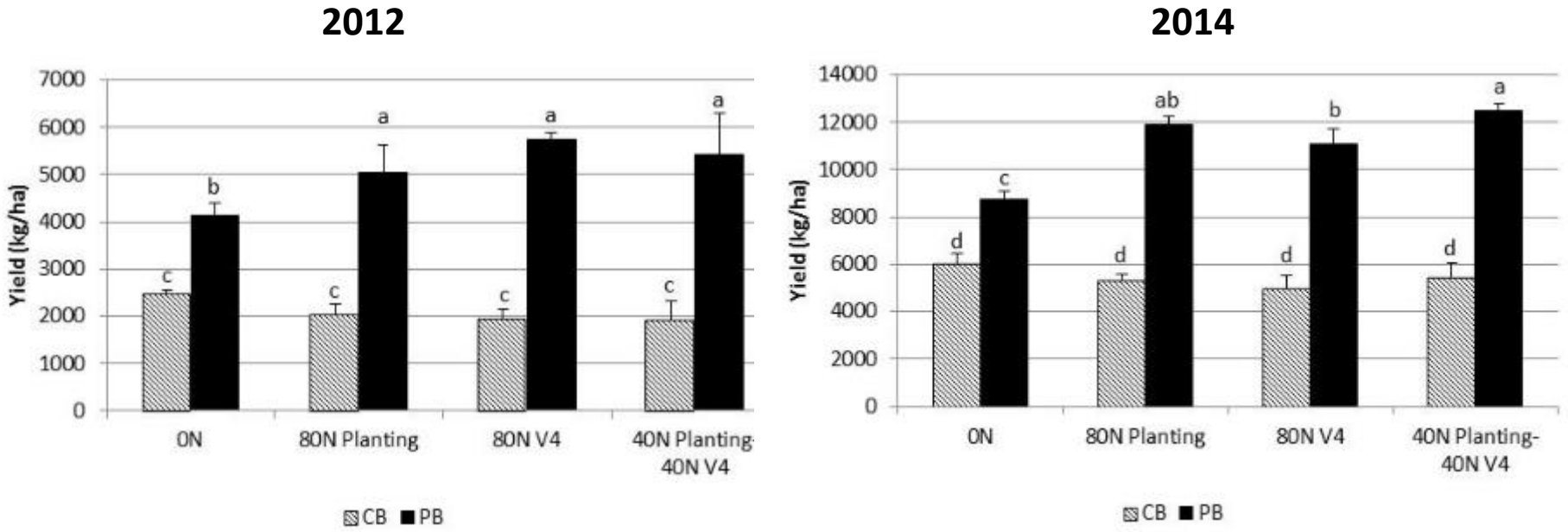
Is there a scale effect?

- Most variance in yield responses to N, P or K is explained at farm level
- What level of aggregation? (Kebele, district, zone, region etc.)



Fertilizer recommendations depend on other agronomic practices

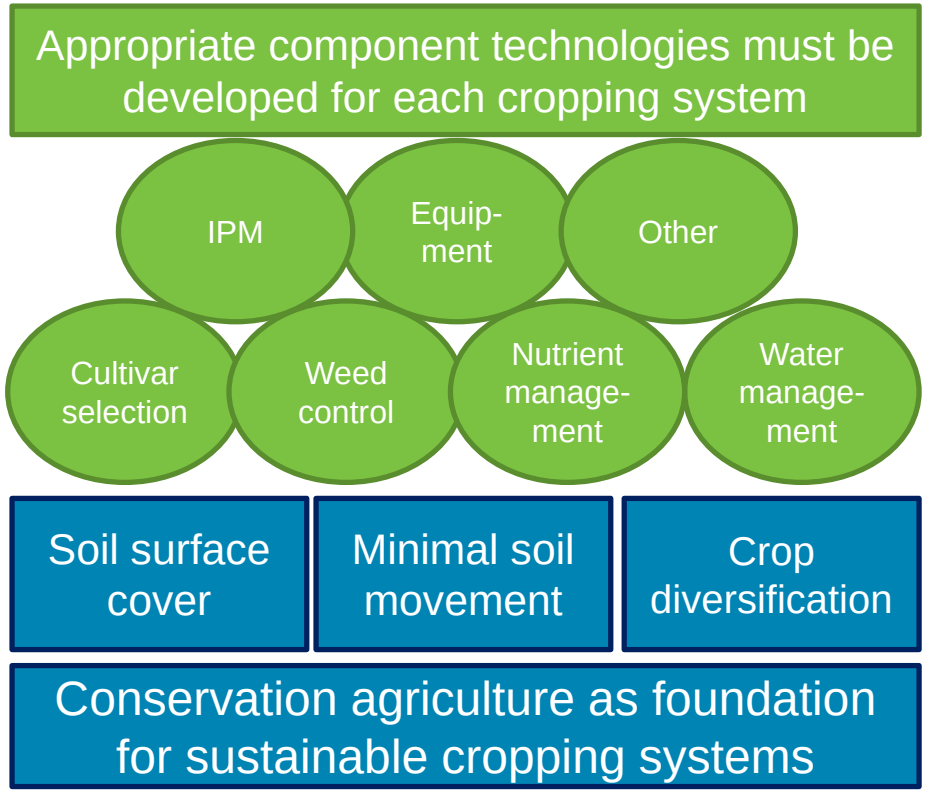
- Maize yield in rainfed N fertilization experiment in Central Mexico:
  - Under CB (conventional tillage): low yields, fertilizer does not increase yield
  - Under CA:
    - Without fertilizer yield higher than under CB
    - Fertilizer application increases yield



Conservation agriculture

- Definition: farming system that promotes
  - minimum soil disturbance (avoid tillage),
  - maintenance of a permanent soil cover (residues or cover crop),
  - diversification of plant species (intercropping or rotation)

- CA as foundation for sustainable agriculture



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Conservation agriculture affects N cycling

- Study in long-term experiment in Ciudad Obregon
  - Initiated in 2005 in Ciudad Obregón, Mexico
  - Furrow irrigation
  - Focus on 3 tillage-straw systems with wheat (winter) – maize (summer) rotation
    - CTB: conventionally tilled beds
    - PB-straw: permanent raised beds with residue retention
    - PB-burn: permanent raised beds with residue burning
  - N balance: winter 2013/14
  - ^{15}N study: established summer 2014

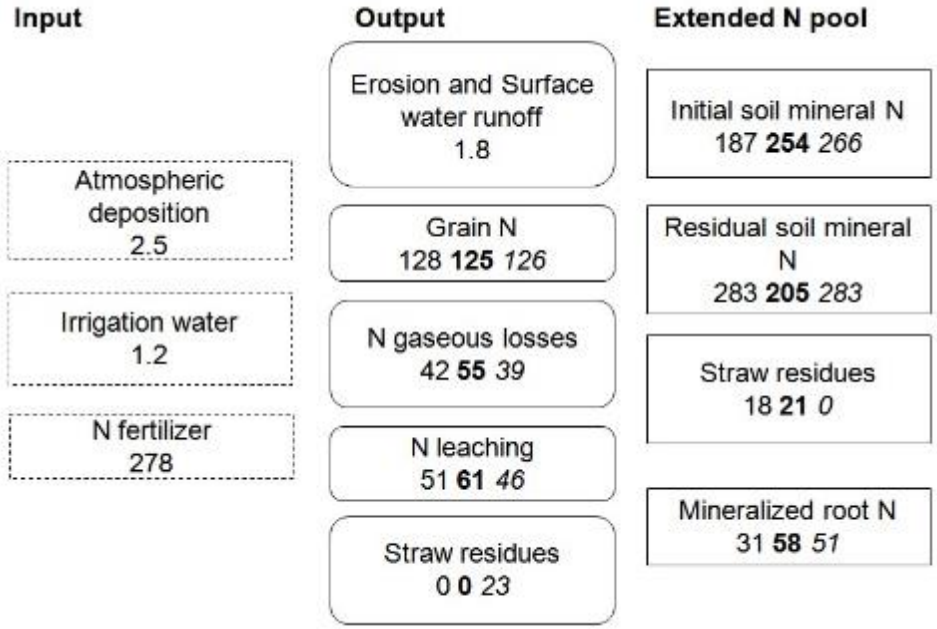
Conservation agriculture affects N cycling

- N balance (input-output)

  +59 kg N ha^{-1} in CTB,

  +39 kg N ha^{-1} in PB-straw,

  +46 kg N ha^{-1} in PB-burn

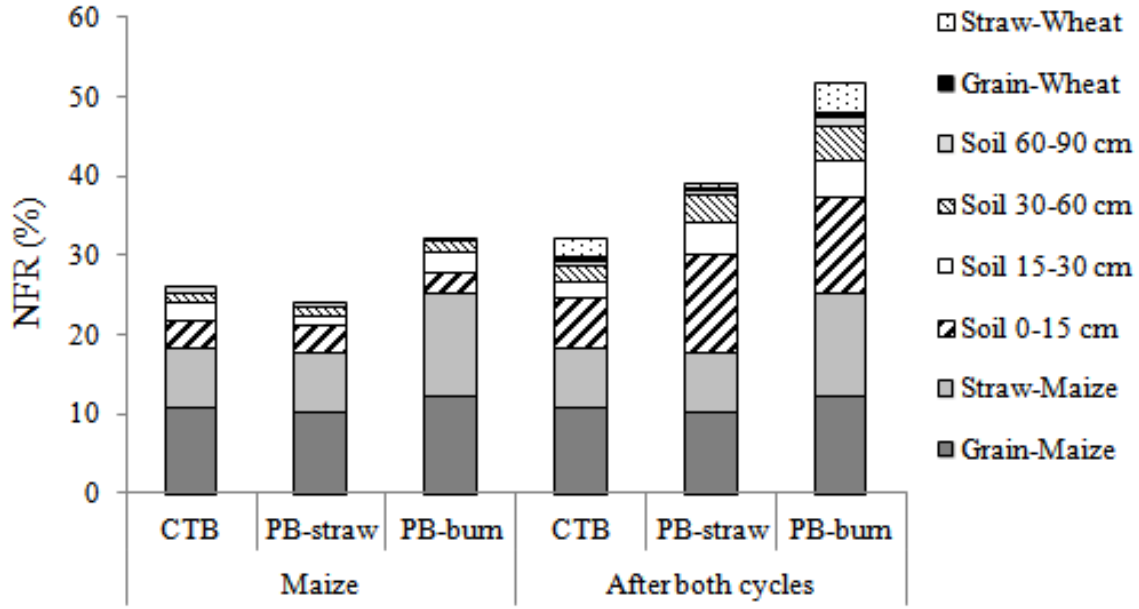


Legend: CTB, **PB-straw,** *PB-burn*

(Grahmann et al. 2018)

- ^{15}N study: N fertilizer recovery

  After two crops: NFR highest for PB-burn (52%), followed by 39% in PB-straw and lowest at 32% in CTB



(Grahmann et al. 2019)

CIMMYT research focus

- Our objectives:
  - Maximize overall utility rather than yield
  - Minimize use of external inputs
  - Reduce environmental impact of agriculture
- Strategy for nutrient management in maize and wheat systems:
  - Starting from limiting factors
  - Tillage, crop establishment, crop residues
  - Diversification, where possible including legumes,
  - N management tools, techniques and strategies
  - GHG mitigation work for all these practices

Nutrient Expert

Nutrient Expert: a decision support tool for precision nutrient management in maize, wheat and rice in South Asia

IPNI, CIMMYT, NARS collaboration in South Asia

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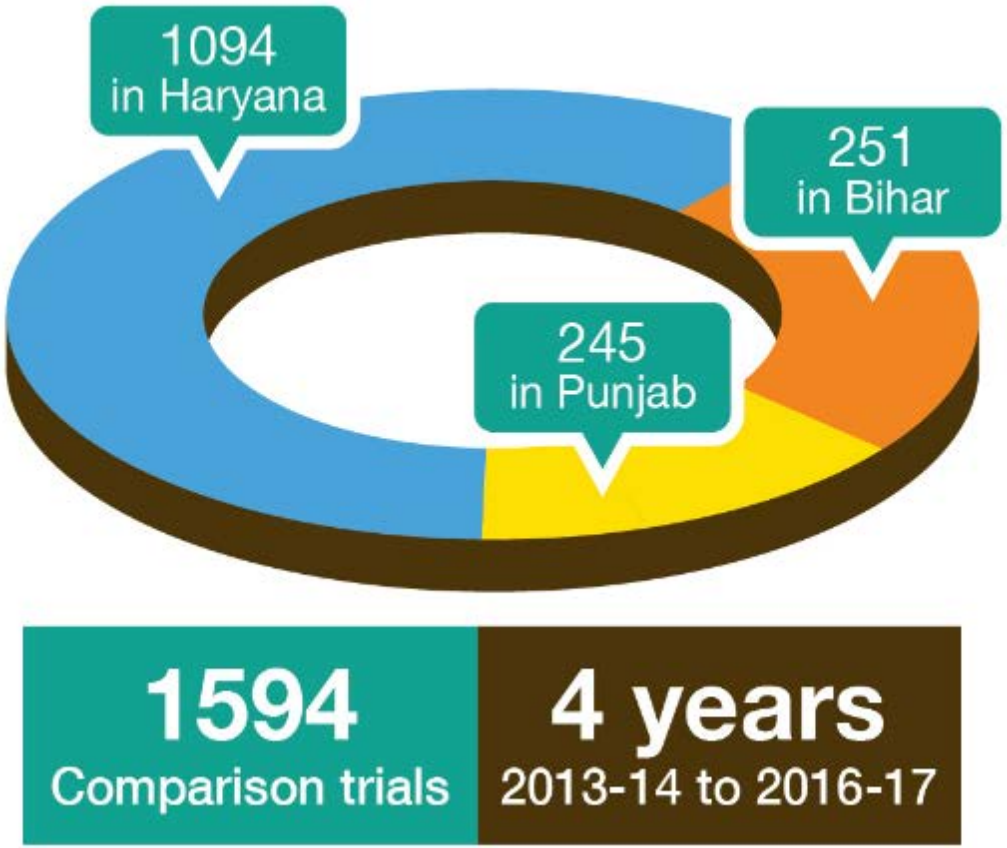
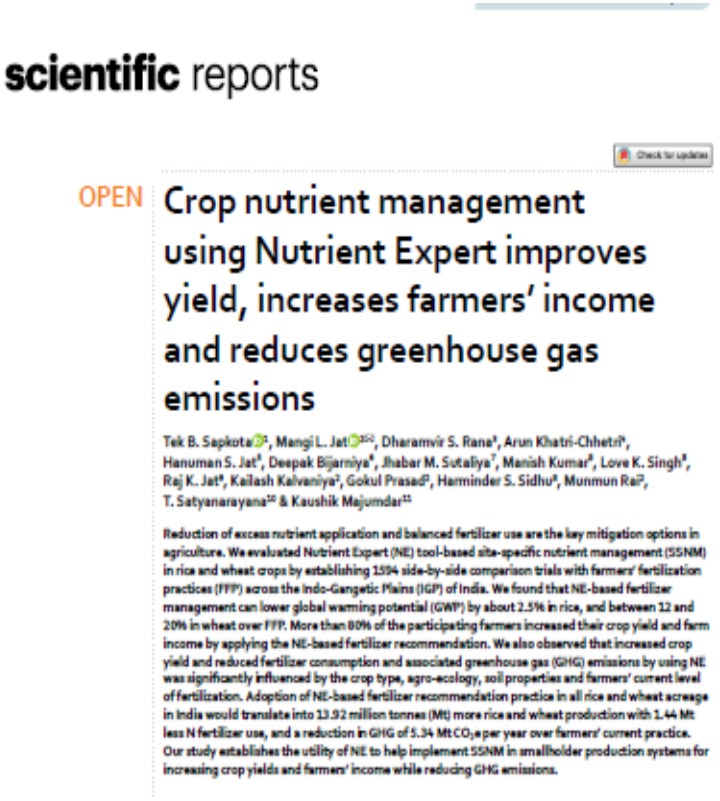
Nutrient Expert vs Farmers' Practice in IGP





scientific reports

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Crop nutrient management using Nutrient Expert improves yield, increases farmers' income and reduces greenhouse gas emissions

Tek B. Sapkota[1], Mangi L. Jat[1,2✉], Dharamvir S. Rana[3], Arun Khatri-Chhetri[1], Hanuman S. Jat[1], Deepak Bijarniya[4], Jhabar M. Sutaliya[3], Manish Kumar[5], Love K. Singh[5], Raj K. Jat[6], Kailash Kalvaniya[3], Gokul Prasad[3], Harminder S. Sidhu[6], Munmun Rai[7], T. Satyanarayana[10] & Kaushik Majumdar[11]

Reduction of excess nutrient application and balanced fertilizer use are the key mitigation options in agriculture. We evaluated Nutrient Expert (NE) tool-based site-specific nutrient management (SSNM) in rice and wheat crops by establishing 1594 side-by-side comparison trials with farmers' fertilization practices (FFP) across the Indo-Gangetic Plains (IGP) of India. We found that NE-based fertilizer management can lower global warming potential (GWP) by about 2.5% in rice, and between 12 and 20% in wheat over FFP. More than 80% of the participating farmers increased their crop yield and farm income by applying the NE-based fertilizer recommendation. We also observed that increased crop yield and reduced fertilizer consumption and associated greenhouse gas (GHG) emissions by using NE was significantly influenced by the crop type, agro-ecology, soil properties and farmers' current level of fertilization. Adoption of NE-based fertilizer recommendation practice in all rice and wheat acreage in India would translate into 13.92 million tonnes (Mt) more rice and wheat production with 1.44 Mt less N fertilizer use, and a reduction in GHG of 5.34 Mt CO_2e per year over farmers' current practice. Our study establishes the utility of NE to help implement SSNM in smallholder production systems for increasing crop yields and farmers' income while reducing GHG emissions.

(Sapkota et al. 2021)

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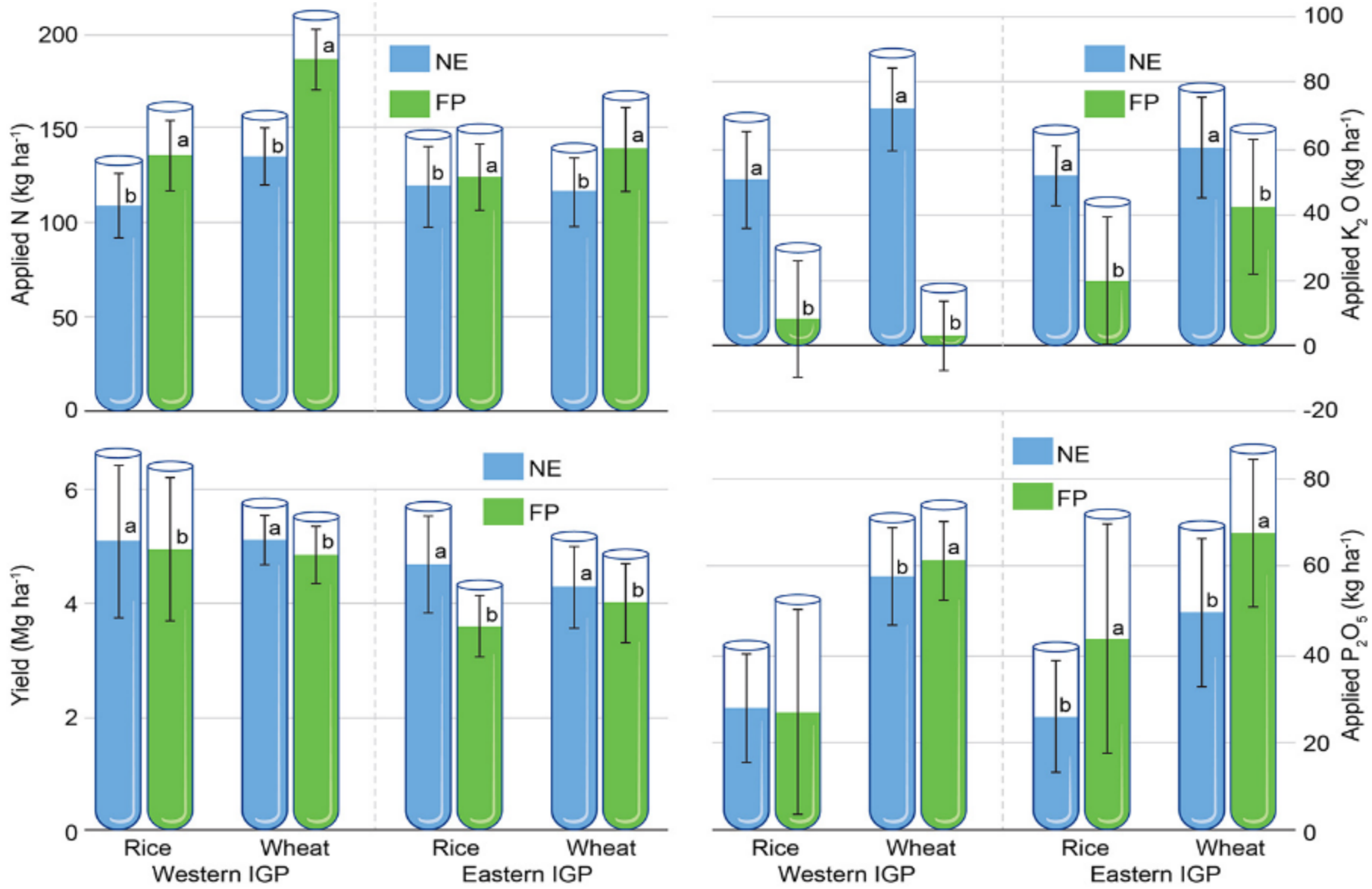
Fertilizer input & Yield (NE vs FP)

Applied N

Applied K_2O

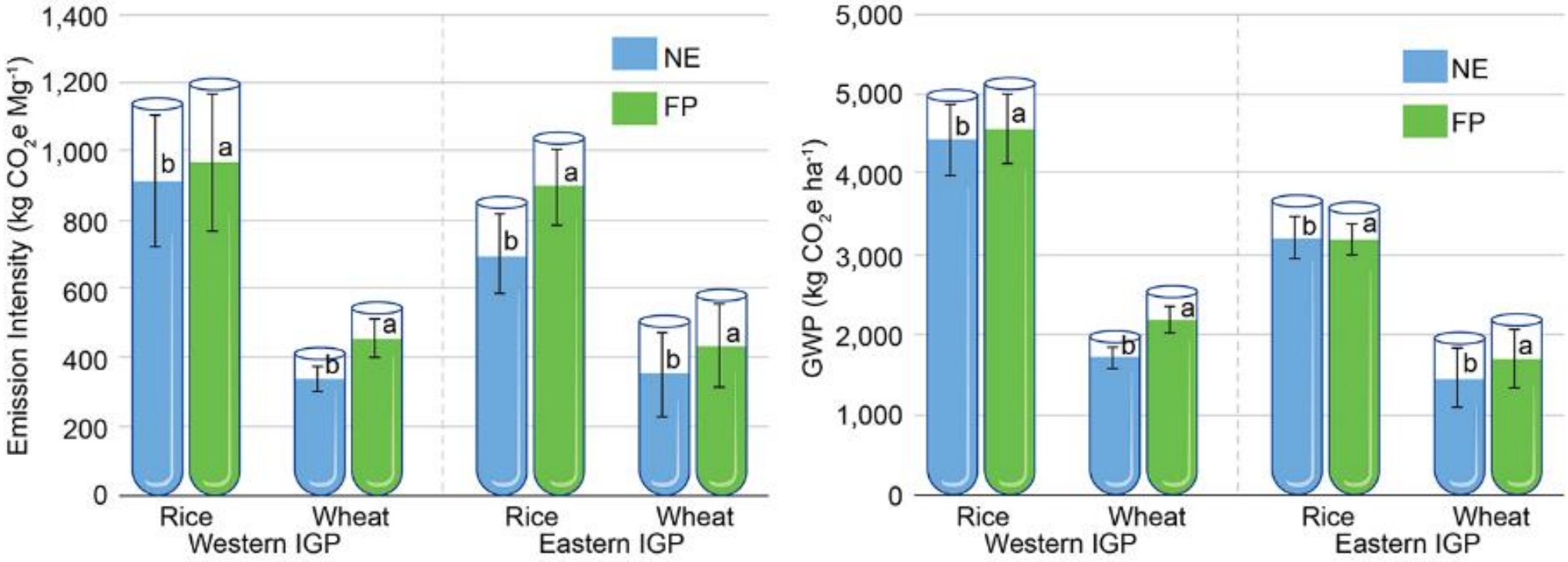
Yield

Applied P_2O_5



(Sapkota et al. 2021)

Nutrient Expert vs Farmers' Practice Environmental Footprints

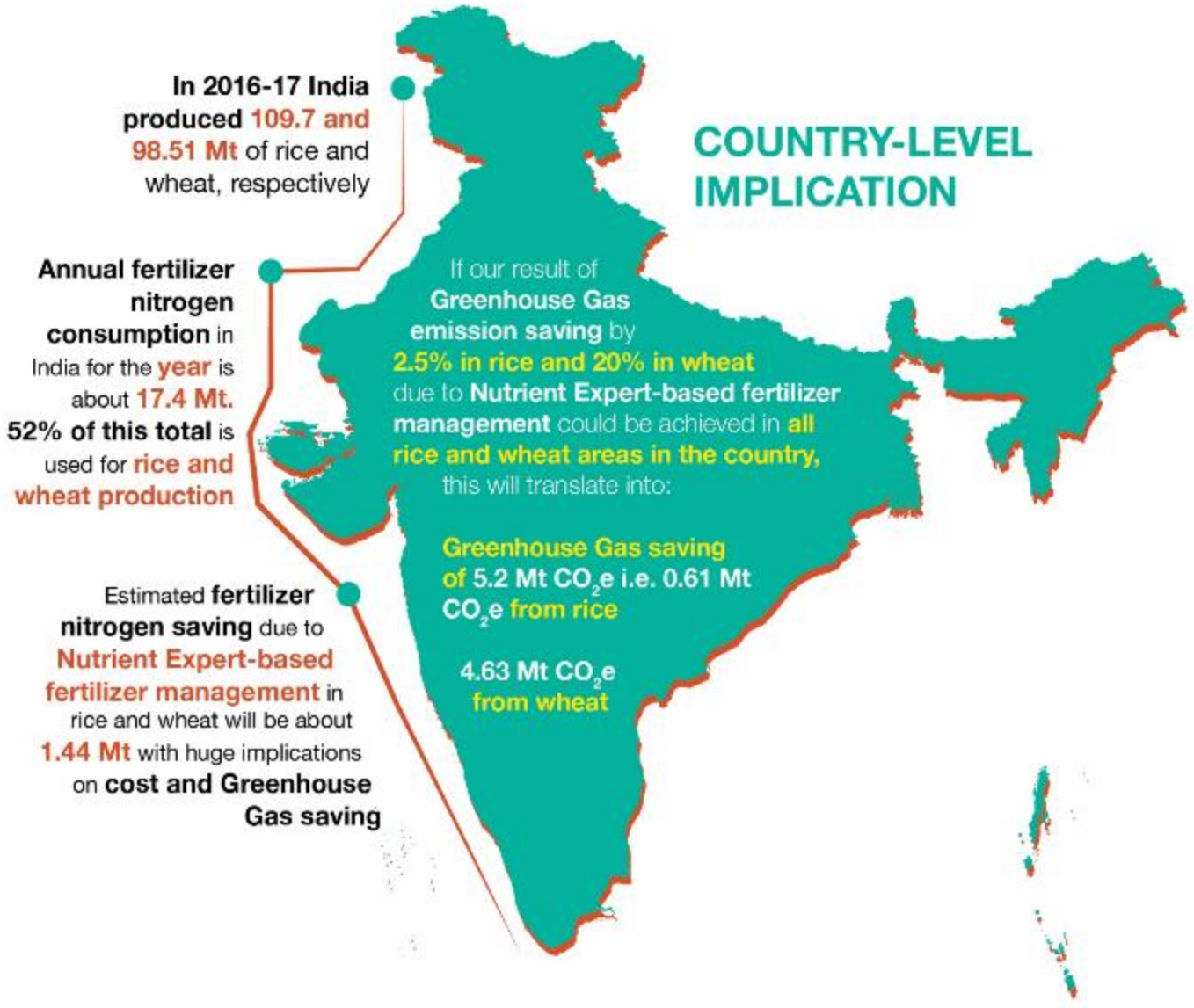


Compared to FP, NE-based fertilizer management lowered GWP by

- about 2.5% in rice
- between 12 and 20% in wheat

(Sapkota et al. 2021)

NE benefit over farmers' fertilizer practice



Adoption of NE in rice-wheat system in India provides 13.92 Mt extra grain with 1.44 Mt less fertilizer N use and 5.34 Mt CO_2e GHG reduction per year
(14 million cars off the road per year)

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Experiences with Nutrient Expert in Ethiopia

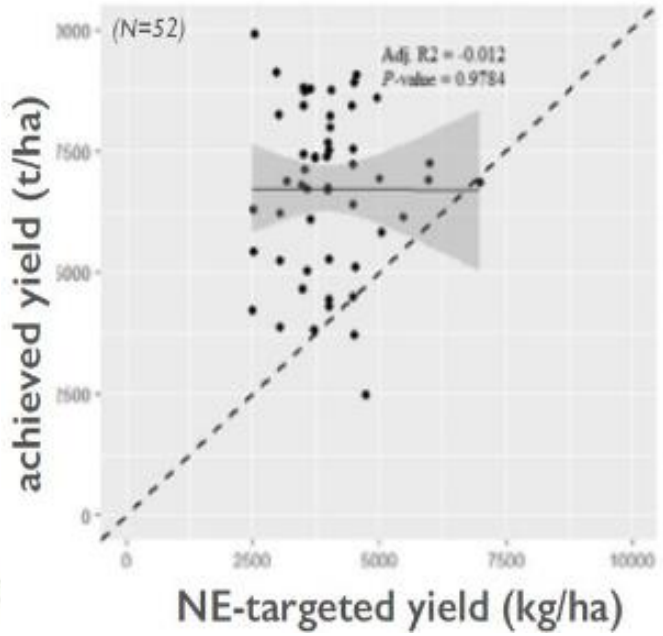
- Site-specific fertilizer advisory is needed
- But, how can we incorporate site-specific factors in fertilizer advisory?
- Assumptions
  - The DST-prototype Nutrient Expert® was ‘technically ready’
  - Its design would require only minor adjustments to user, advice needs and the specific institutional settings

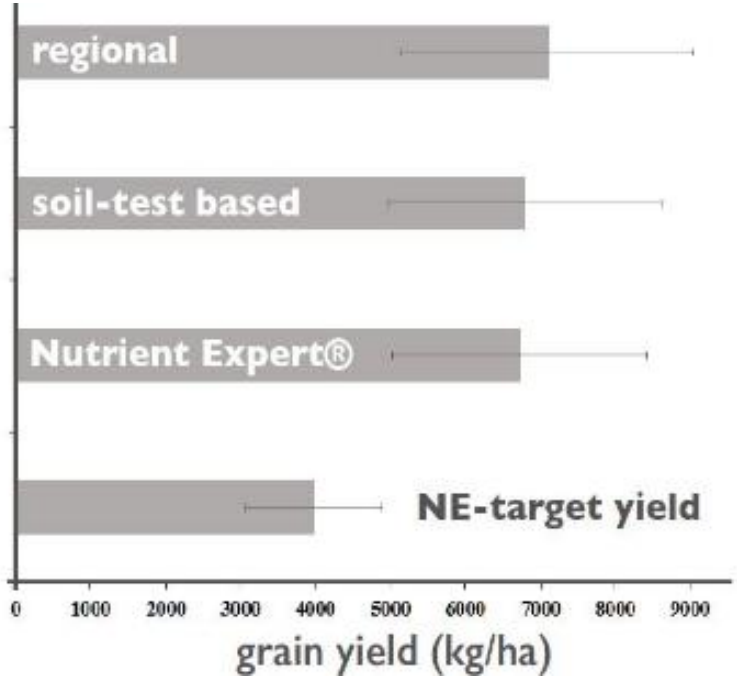
Experiences with Nutrient Expert in Ethiopia

Performance trials:

- Yields on average 70% higher than targeted yield
- Yields not correlated with the NE-targeted yield
- NE advice did not lead to superior yield over regional (blanket) fertilizer recommendation
- NE: higher N-rates, similar yields: economic benefits?

Recommendation method	N (kg/ha)	P_2O_5 (kg/ha)	K (kg/ha)
Nutrient Expert®	125	54	36
Regional	102	69	0
Soil-test based	120	28	2





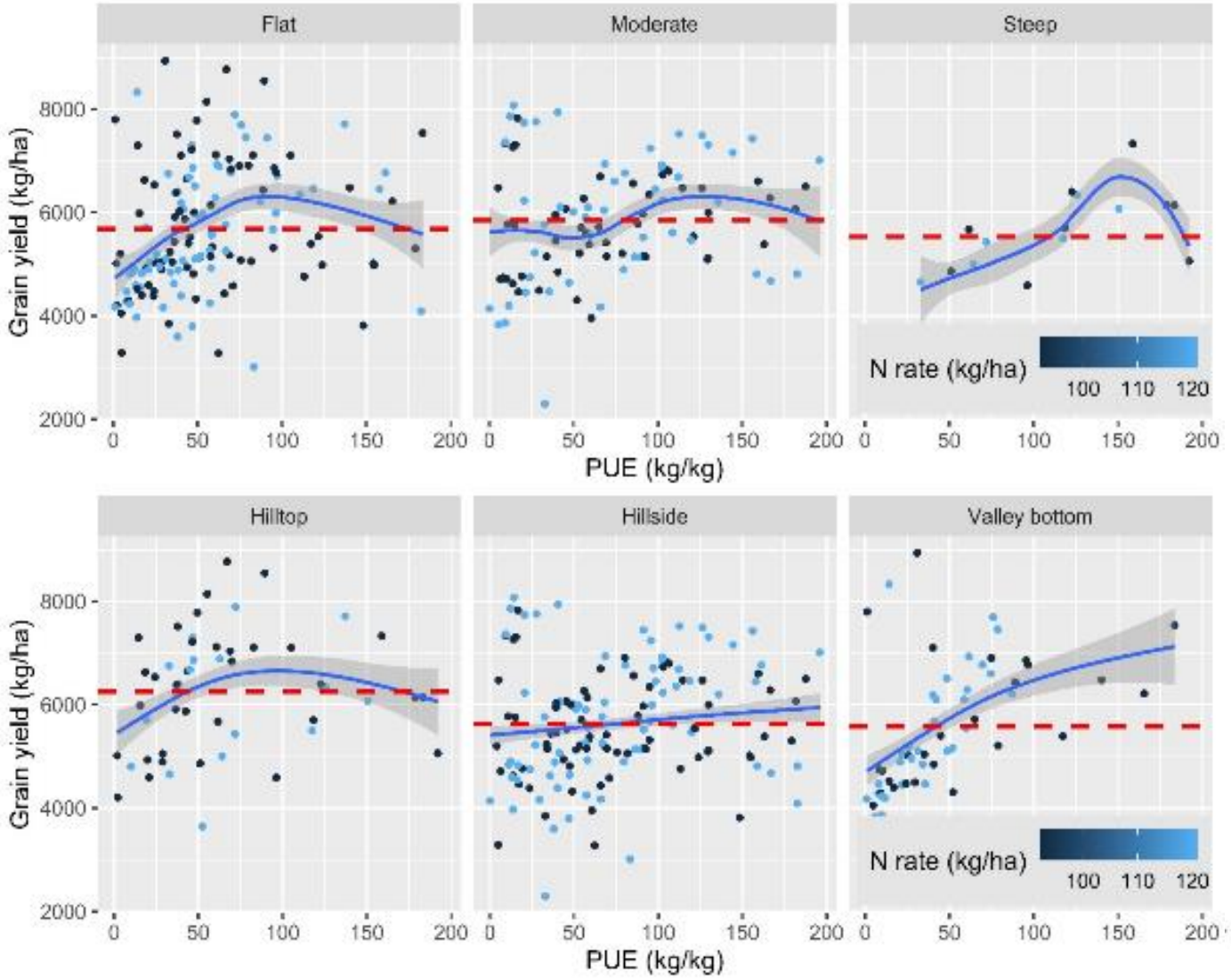
Field-specific factors… Biophysical

- Response of maize to

  NP fertilizer varied with

  – Slope

  – Landscape position



Way forward

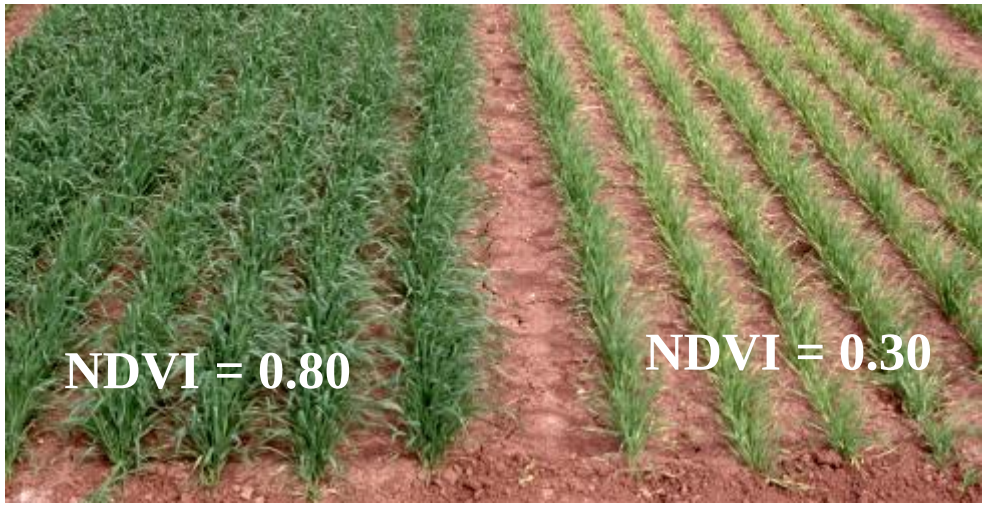
- Site-specific NM with decision support tools is realistic in the digital era
- Understanding farmer practice (e.g. plant spacing, manure use, etc.)
- Tool design principles:
  - Investment-based (not target yield)
  - Balanced use (N:P ratio)
  - Stronger focus on site-specific management practices and field conditions (key to crop response to nutrients)
  - Cautions with yield prediction

Remote-sensing-based Fertilizer Recommendations

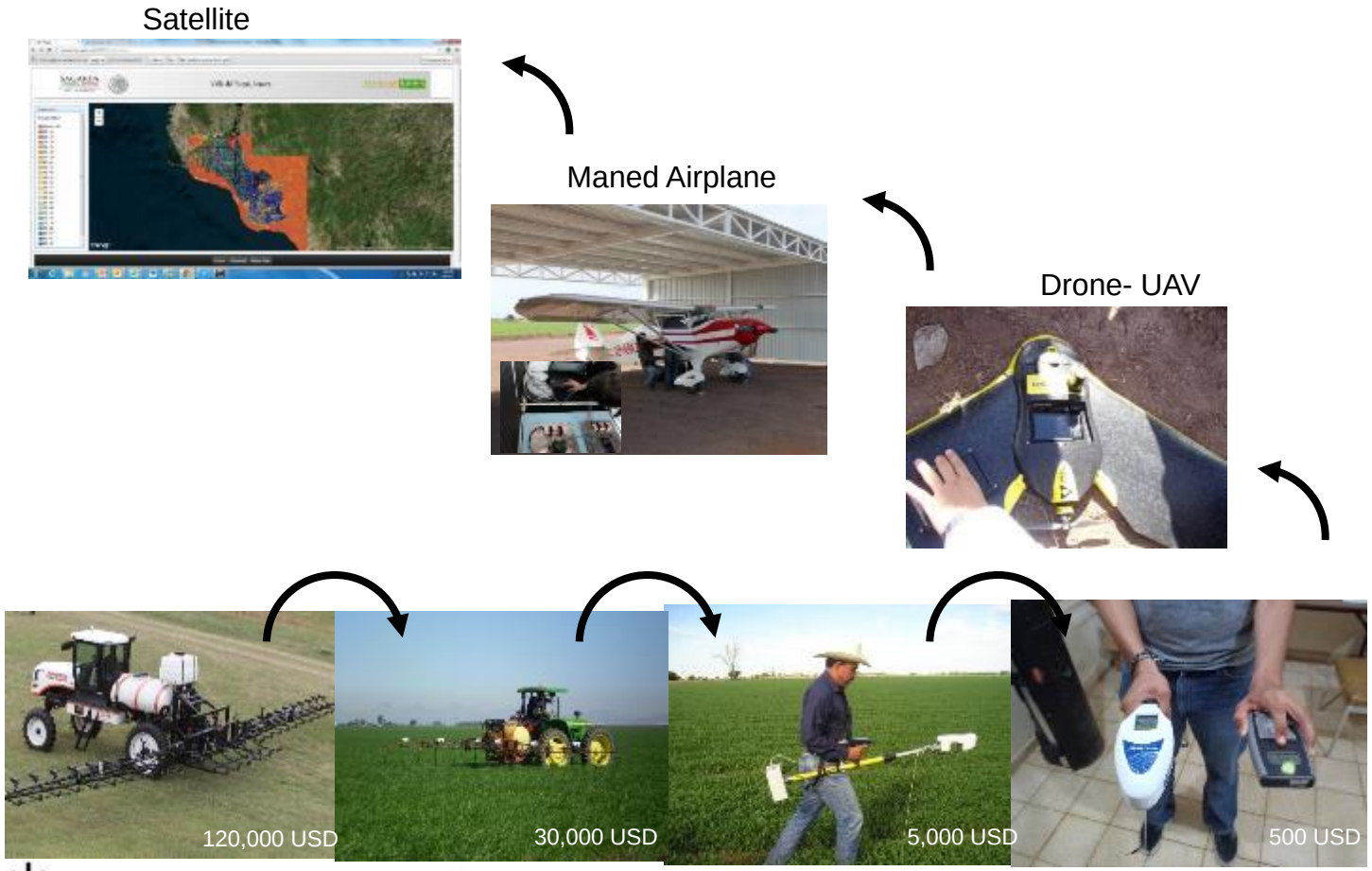
Optical sensors to determine rate

- General principle:
  - Diagnostic tool to identify site specific N needs
  - Compare N rich strip (without N shortage) with rest of the field before second fertilization, to determine needed N

N Rich Strip N Diagnostic Area



Sensor technology for N management: different scales and costs



In Mexico:

- Algorithm originally developed with GreenSeeker
- Validated with different tools, showing good correlations between recommendations based on different tools
- Most successful for scaling with larger farmers: drone-based recommendations

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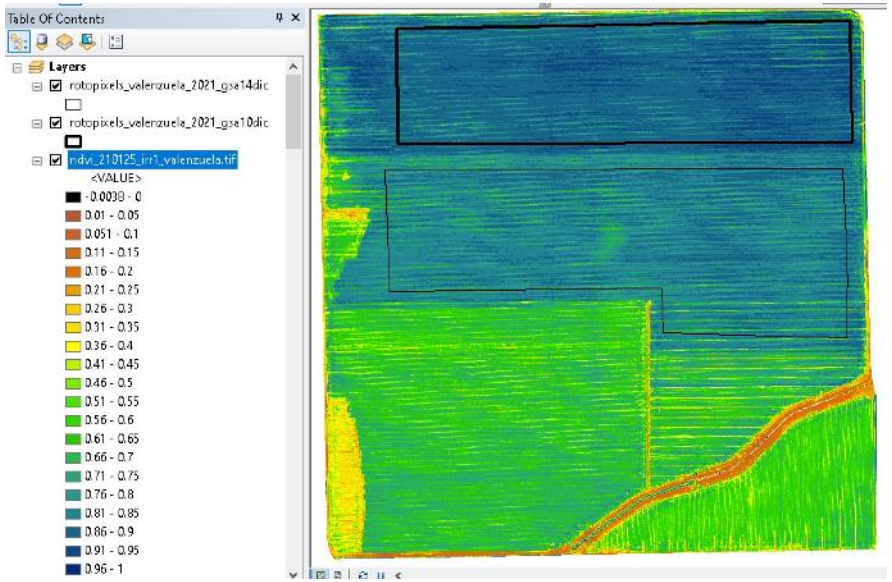
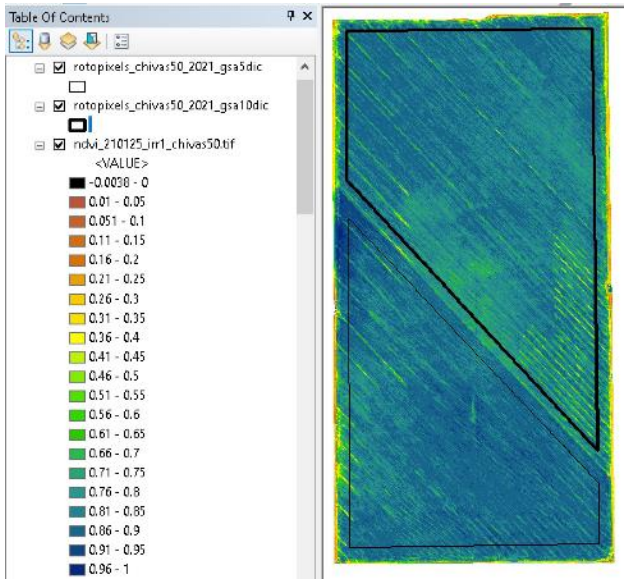
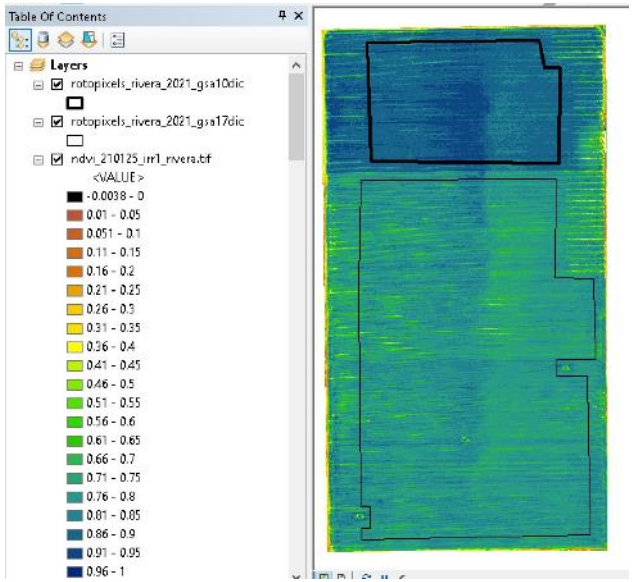
Sensor technology – drones

- Experience in Yaqui Valley, Mexico
  - Service provided by several private companies, based on available algorithm
  - Potential for differential rate application (aprox. 15 cm resolution)







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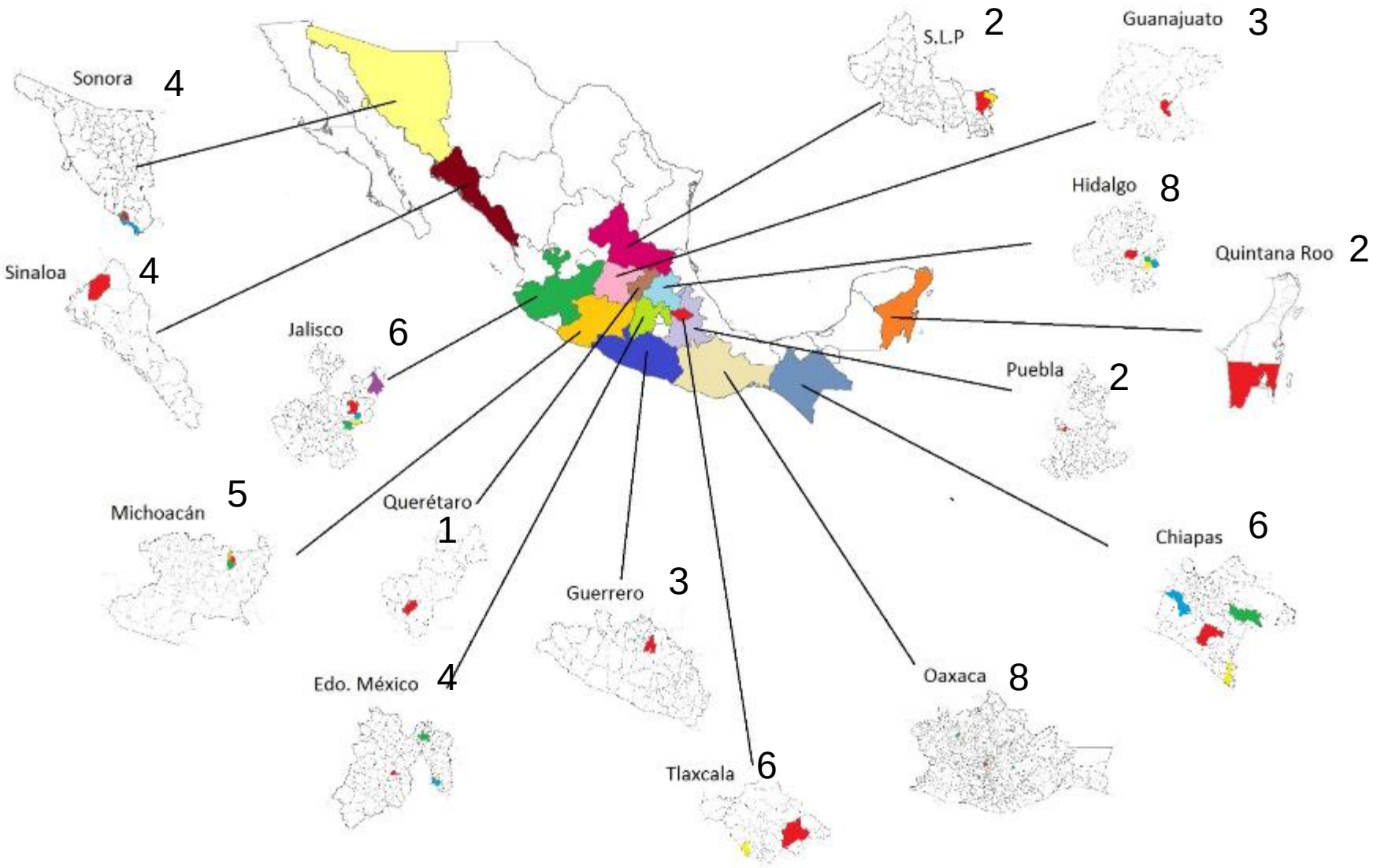
GreenSeeker sensor for precision N management in South Asia

- Research started in 2005 (CIMMYT/RWC-ICAR-PAU-Oklahoma State University, USA)
- Calibration curves (South Asia adapted) developed and validated for wheat, rice and maize
- Hand held GreenSeeker sensors are being used by extension agents and farmers (using android phone based urea calculator)
- Over 500 hand held GreenSeekers in use now

(Bijay-Singh et al., 2011; 2015)

Omission Trials

Network of 64 omission trials 2011-2013 in maize in Mexico



Treatments

- Complete fertilization: N – P – K – Zn – B
- 5 trts with omission of one element
- Control: without fertilization
- In subset:
  - Farmer practice
  - Trt with Fe and S

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Main nutrients limiting maize production in different regions in Mexico

Technology layering

Technology layering for sustainable intensification (CA+ Diversification+ Precision Water & N)

Scenarios	Grain yield (t ha^{-1})			Irrigation water use (mm ha^{-1})		
	Rice/ Maize	Wheat	System	Rice/ Maize	Wheat	System
Conv RW system-Flood	7.04a	5.68b	13.36b	1886a	435a	2321a
CA- RW system-Flood	5.87b	6.47a	13.06b	1447b	385a	1832b
CA- RW system+ SDI	6.30b	6.70a	13.75a	785c	207b	992c
CA- MW system- Flood	7.14a	6.51a	14.38a	110d	372a	482d
CA -MW system + SDI	7.48a	6.59a	14.81a	85d	198b	283e


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Re-designing irrigated intensive cereal systems through bundling precision agronomic innovations for transitioning towards agricultural sustainability in North-West India

- SDI=subsurface drip irrigation
- Has potential for at least 50 mha
- SDI system saved fertilizer N by 20% under CA systems

(Jat et al. 2019; Sidhu et al. 2019)

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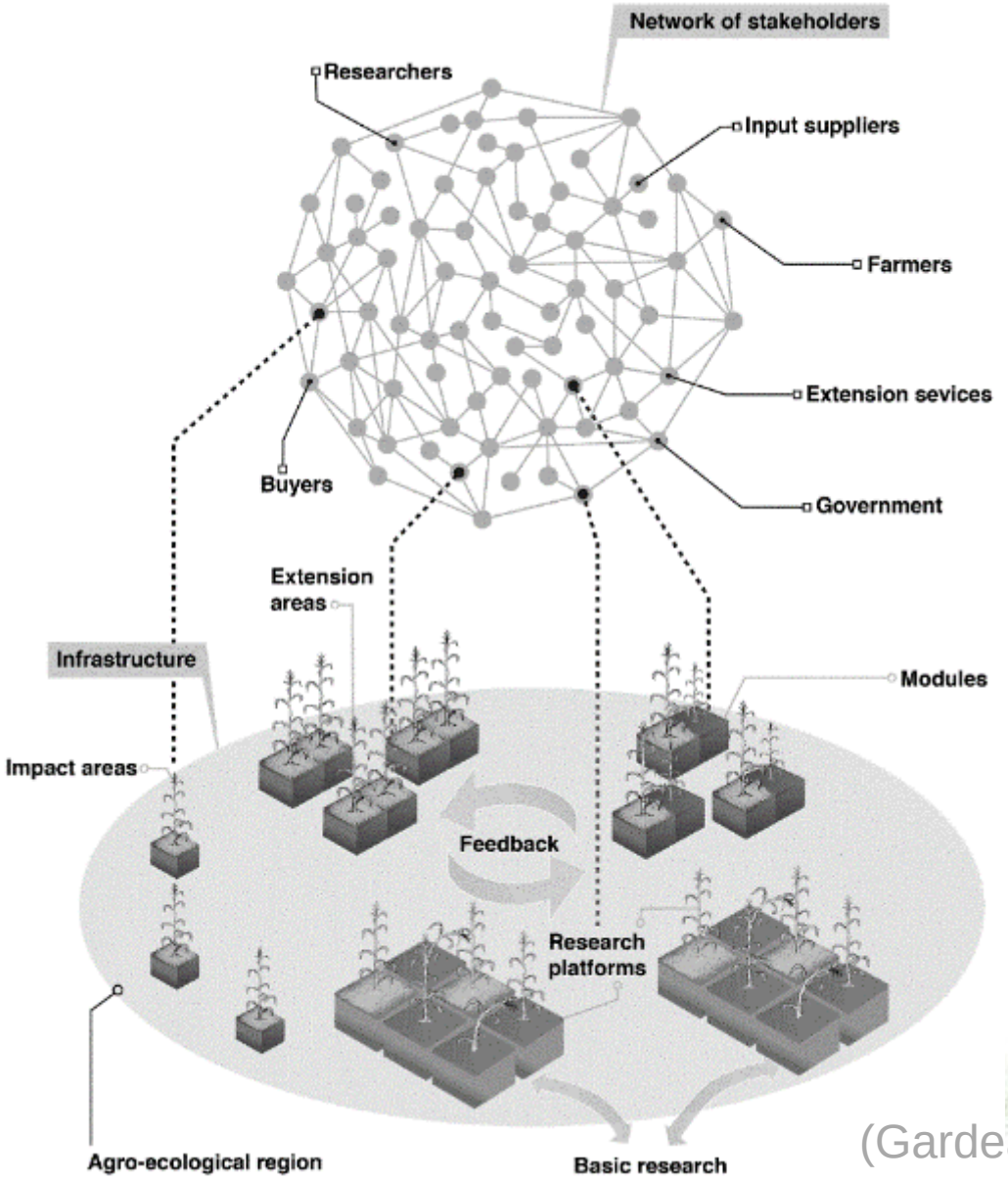
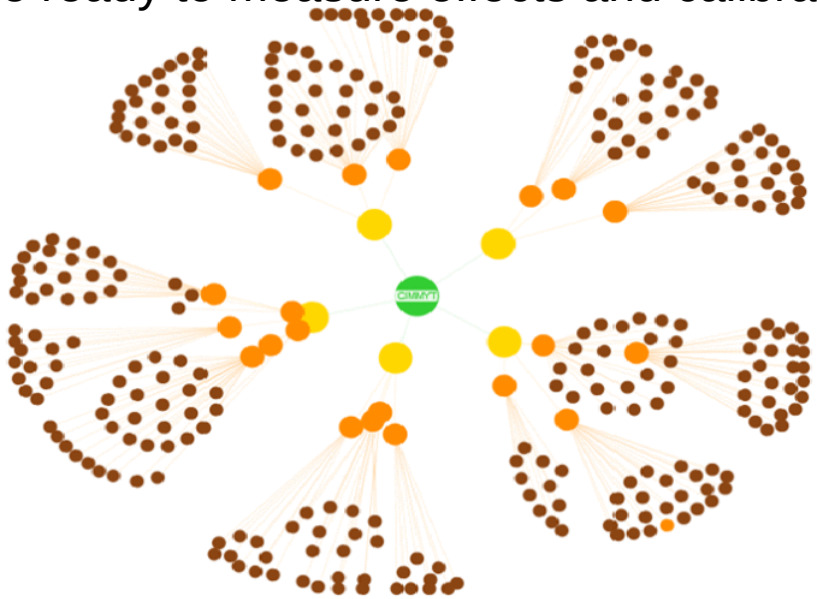
Innovation Systems and Farmer Data

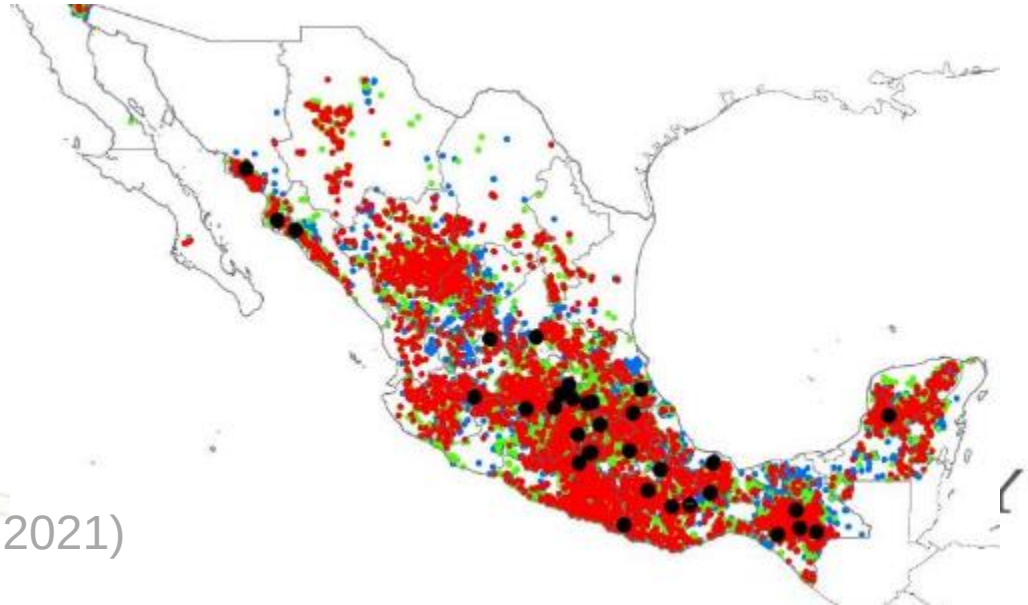
Knowledge hubs for innovation in agri-food systems



Infrastructure ready to measure effects and calibrate models



Hub managers
Coordinators
Trainers
Extension agents
Farmers



(Gardeazabal et al. 2021)

How does e-Agrology work?

AGRODATA data collection

Reaching
1,322,177 ha with
218,577 farm logs

data curation & integration

pre-processing & descriptive analytics

tidy datasets

training machine learning models

cluster analysis
predictive models
understanding trends

prescriptive analytics

AGROTUTOR

AGROPULSE

extension services and network validation

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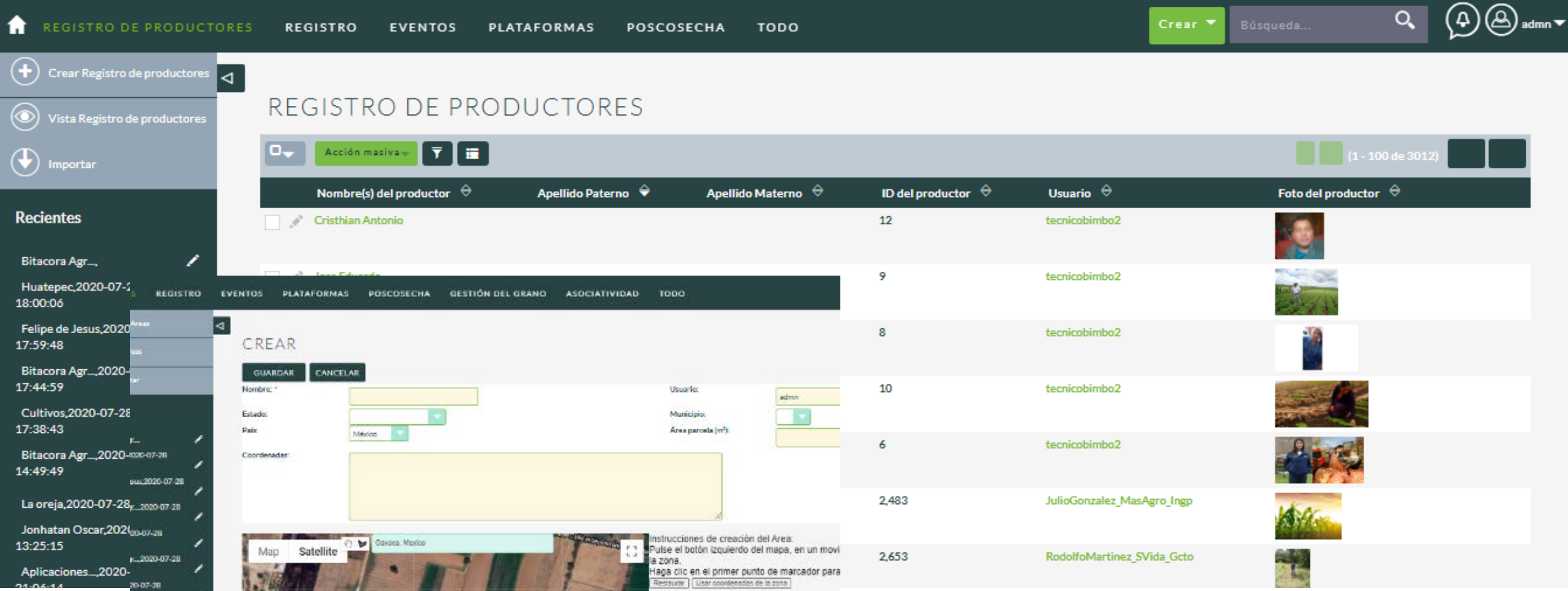

AGRODATA data collection

Future: connection with **Excellence in Agronomy,** especially to strengthen advisory

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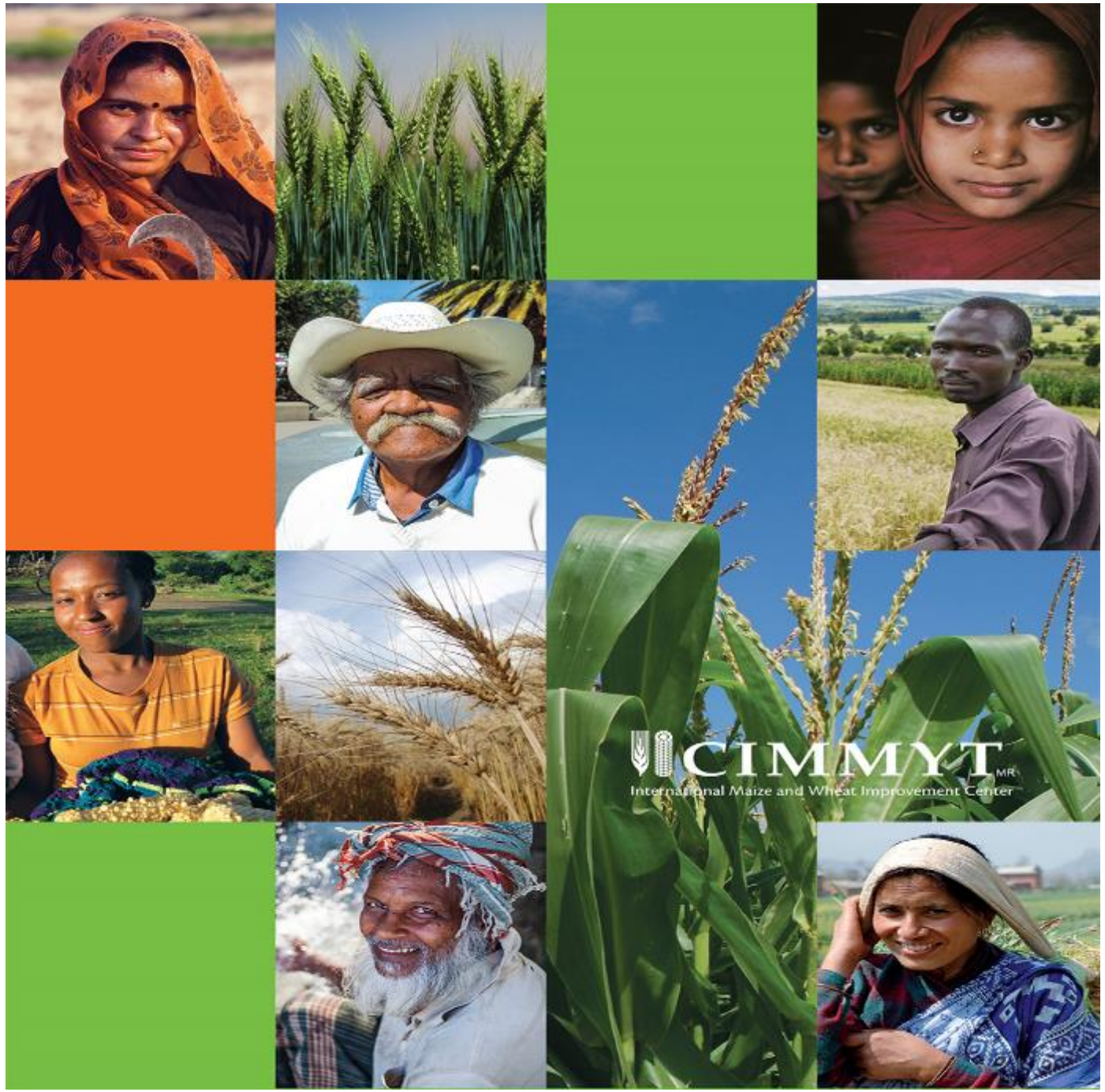

Thank you for your interest!

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