Sustainable Intensification

- India
- Argent.
- IA
- China
- IPNI Global Maize
- Common R/T/E Themes
- Nepal
- Kenya
- CIMMYT Global Maize

- ○ Intra-project center
- ● Future inter-project center?
- — Current linkage
- --- Future linkage?

- What is it (practical context)?
- SI (EI) vs. "farmer practice"
- Tool kits, panacea packages & inference space
- Research needs ~ understanding the coupled natural resource - ag. mgmt. opportunities

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Complex Systems ~ Not all factors matter equally everywhere (space/time): drivers, pathways, feedbacks...

The CA Package

Zero Tillage

..... Long-term

Machinery ⋈ Minimum, sporadic, controlled

Advanced sowing

Soil compaction

Soil surface structure

Fertilizer placement

Weeds

Pests & diseases

+ Rotation

Water-logging

Leaching

Erosion

Soil water infiltration

SOM

Nutrient cycling

Seed Market

↓Soil T°

Immobilization

Variety, inputs

+ Mulch

Soil water content

Livestock, removed

Soil water evaporation

↓ Soil T° (spring crops)

Flood/furrow irrigation application

Seeding through residues

***Effects additive?
Multiplicative?***

Case Study: Evidence of CA Impacts on Yields

Sub-Saharan Africa and South Asia
Main CGIAR mandate crops

What do we know from the literature about effects in different systems?

What is still uncertain?

Priorities for future agronomic research and possible inter-disciplinary collaborations

Existing Reviews
Surveys
On-farm /On-station Experiments

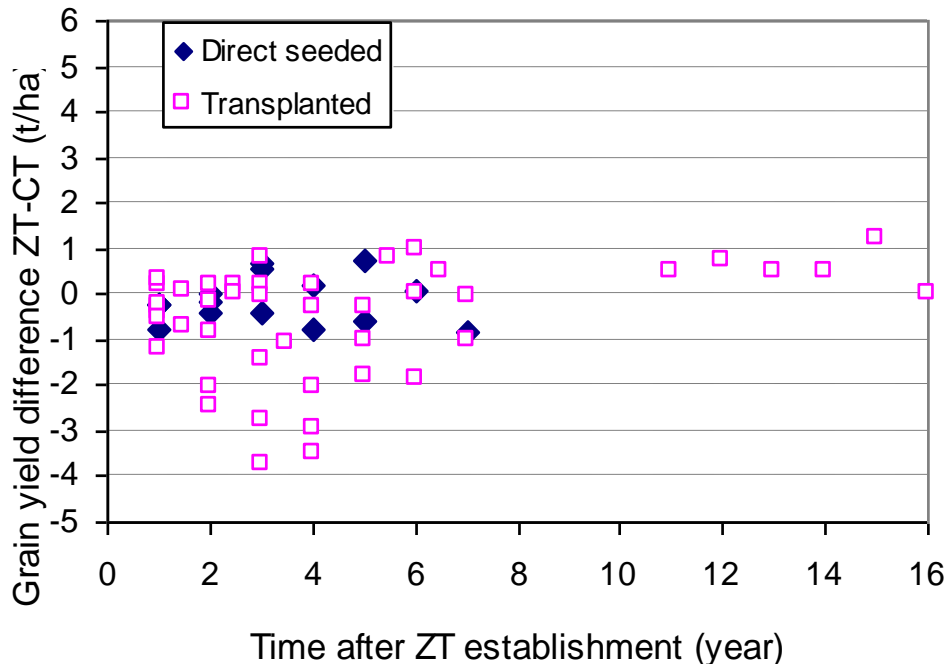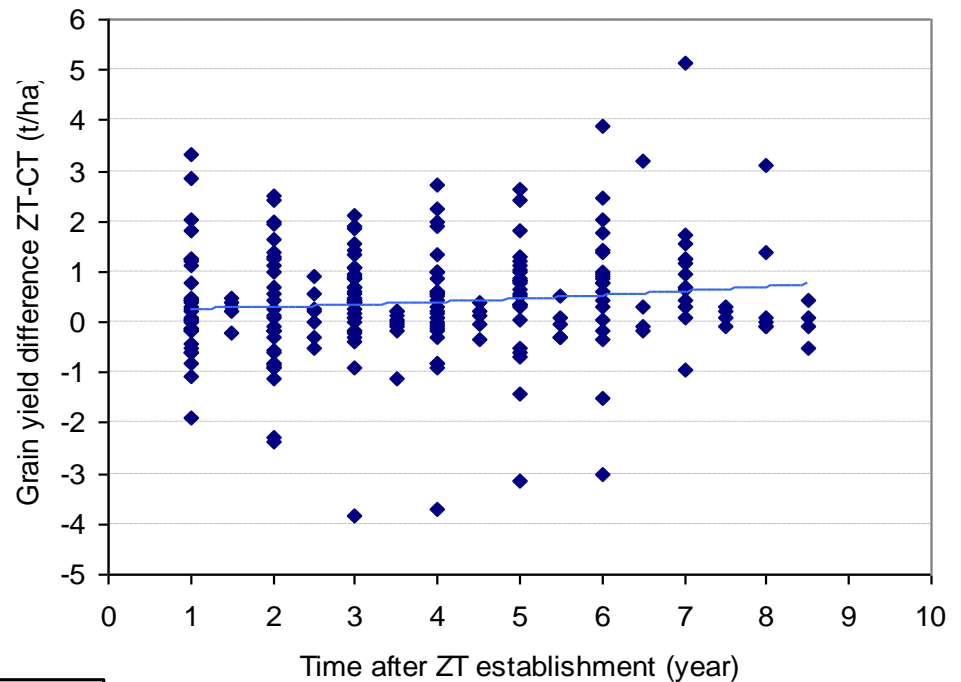# Critical drivers
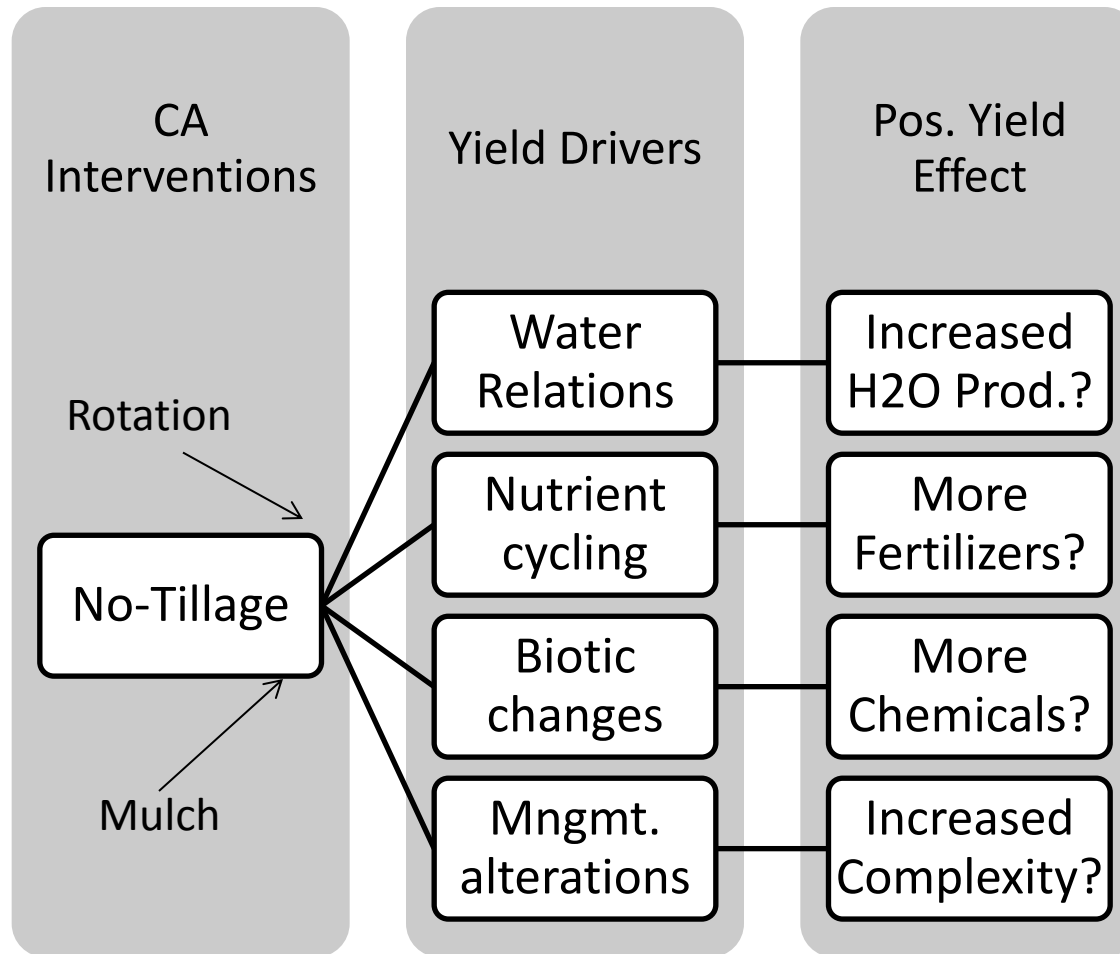
Evidence of ZT impacts on yields

Search SCI publications

	SSA	SA
Maize	23	7
Rice	5	8
Wheat	5	19
Sorghum	5	1
Cowpea	11	-
Millet	3	3
Cassava	4	-

Maize: 12 with at least 3-years data

Zero tillage & yield gains / stability

Can we untangle the inference space to increase probability of rapid/positive outcomes?
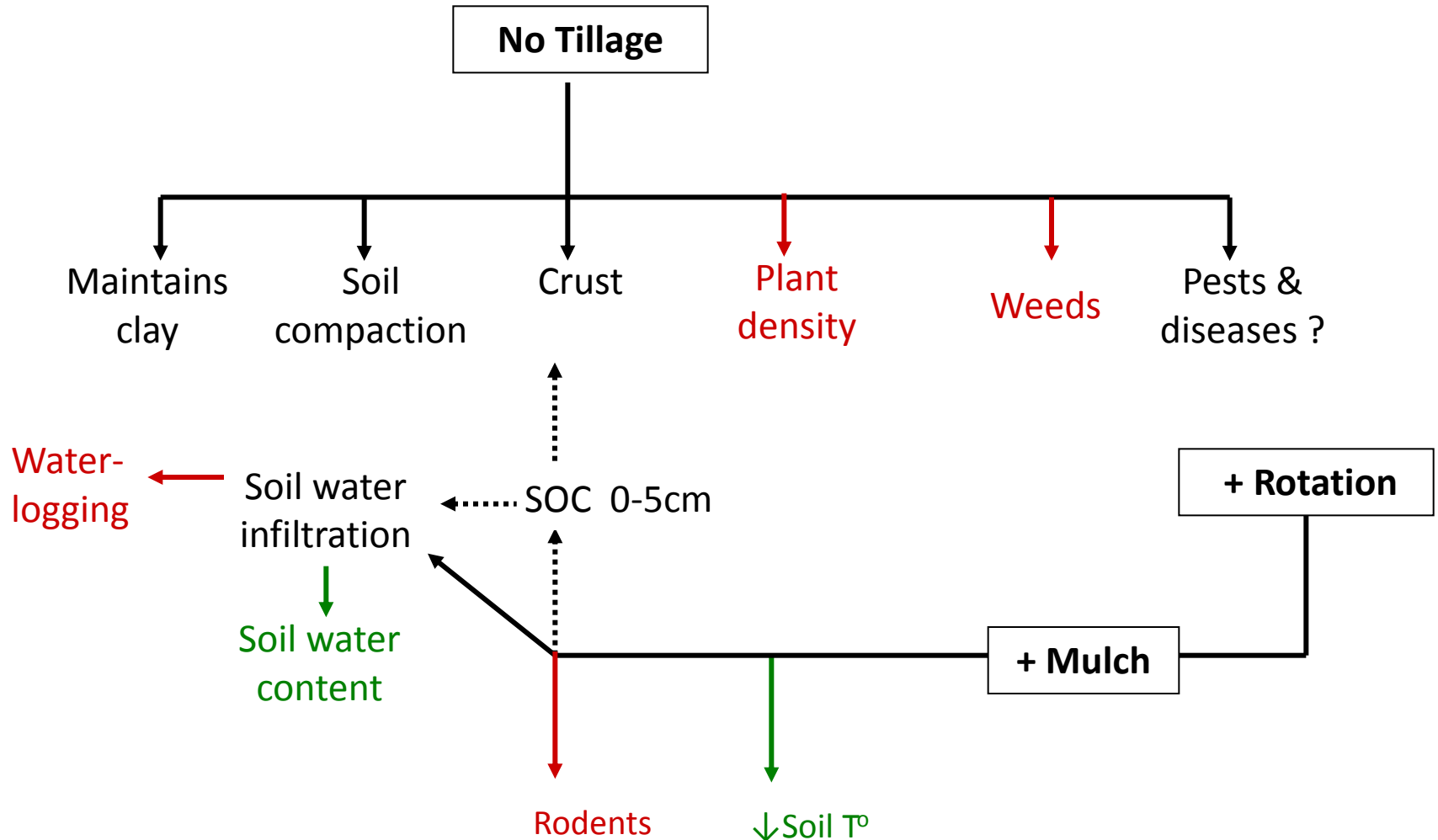

Maize

Not really ~ In its present state, science is not comprehensive enough to untangle confounded biophysical drivers, ES benefits, etc.

Rice

Brouder & Macpherson
In review

Maize: observed effects, not necessarily linked to higher GY; observations of other system impacts (ES) largely qualitative or lacking in quantitative rigor.

Advantage	Attribute	Mechanism	Benefit Realized (grain vs. vegetation)?
What is the problem to be solved & what is the unique advantage of a perennial system vs. other CA tools?	Longer growing season	Better light interception efficiency	Yes, **if** canopy closes quickly (& HI is high)
		Higher nutrient use efficiency, lower environmental loss /fert. require	Yes, **if** uptake is more synchronous w/ ephemeral nutrients
Better Productivity on Marginal Land (shallow soils?)	Deeper rooting depths	Better water productivity	Yes, **if** soils have deep H2O storage & subsurface soils hospitable
Is temperate zone (cellulosic crop) inference space relevant to SSA?	Greater root mass	Reduced soil erosion	Yes, **if** adequate surface cover when erosion potential high
		Better C sequestration	Yes, **if** adequate N, P, S

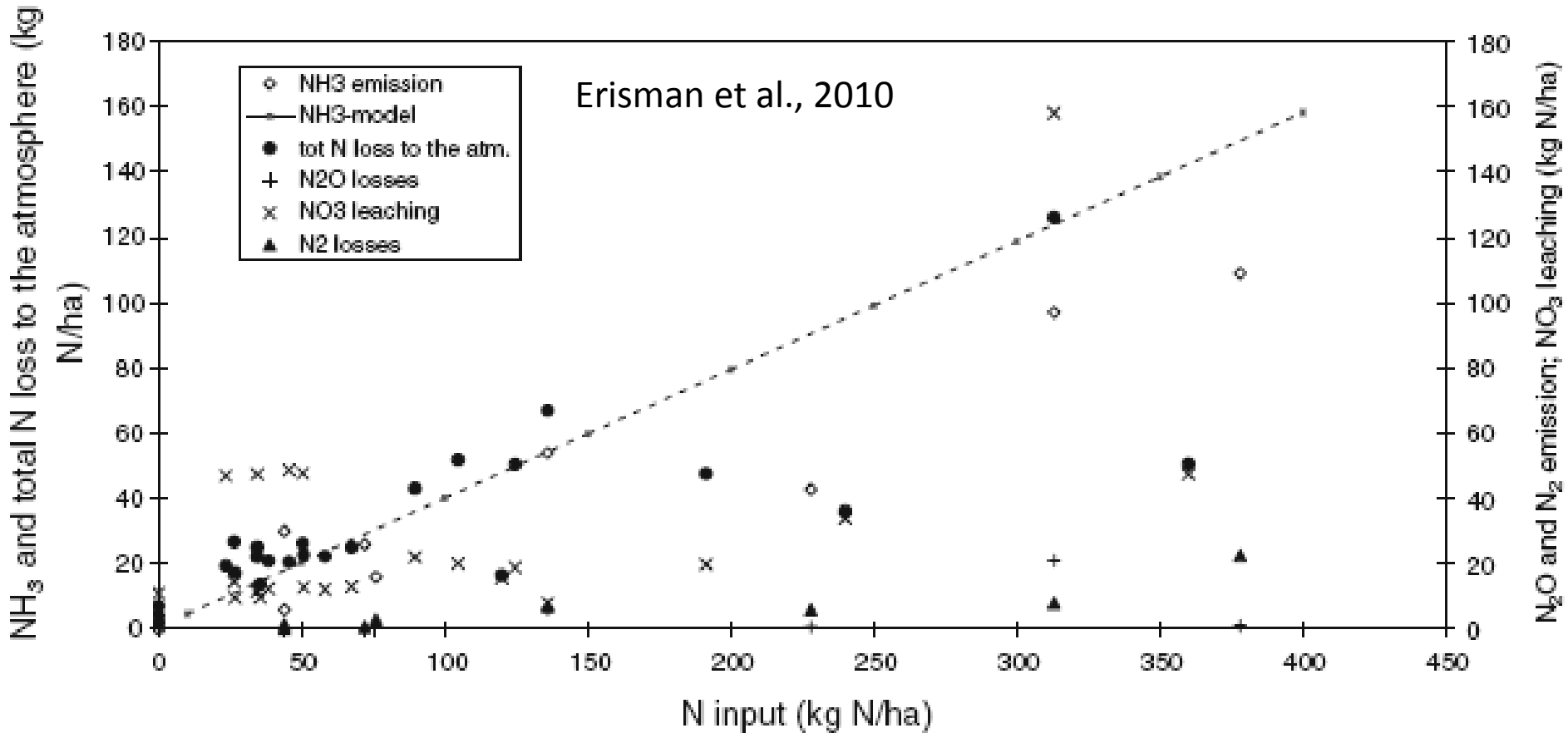# Stable Organic Matter has constant C:N:P:S ratio (slide courtesy of Kirkegaard, 2012)

Minimum

- 500+ international and 100+ Australian soils

- 1000 kg C requires 92 kg N, 18 kg P, 14 kg S
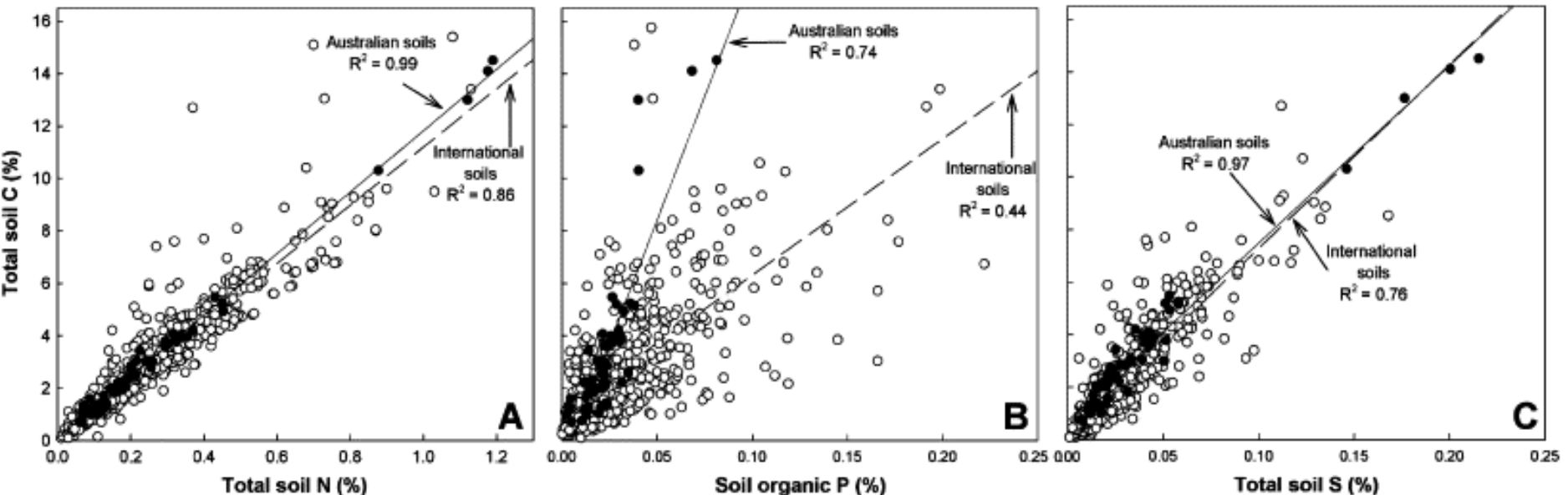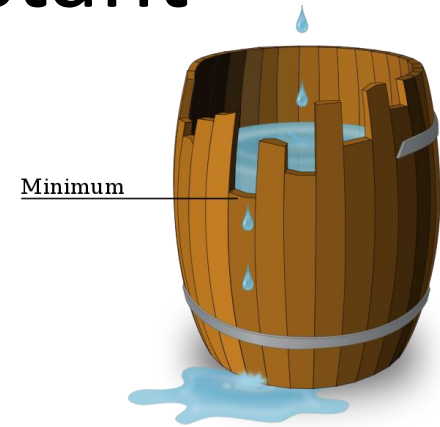
Kirkby et al (2011) Geoderma 162, 197-208

Meta-analysis of multiple paths for N loss

Erisman et al., 2010

What we know is very limited:
1) N uptake scales with biomass (↑ biomass *may* ↑ **N inputs**)
2) Higher N applications *can* ↑ **N loss**; *will* ↑ **variation in N loss**

Most resource use efficiencies are coupled; greatest RUE/SI opportunities may be indirect...
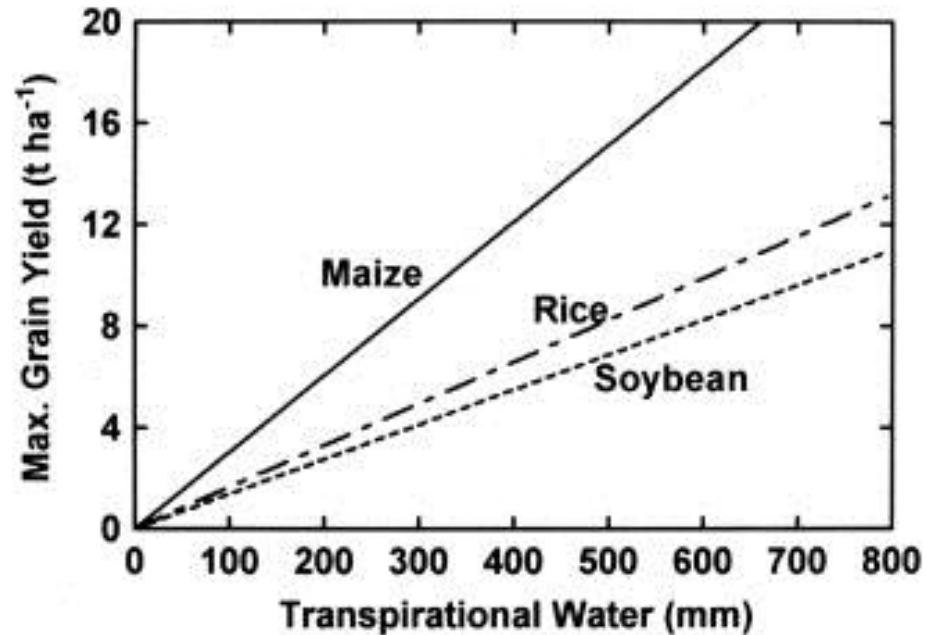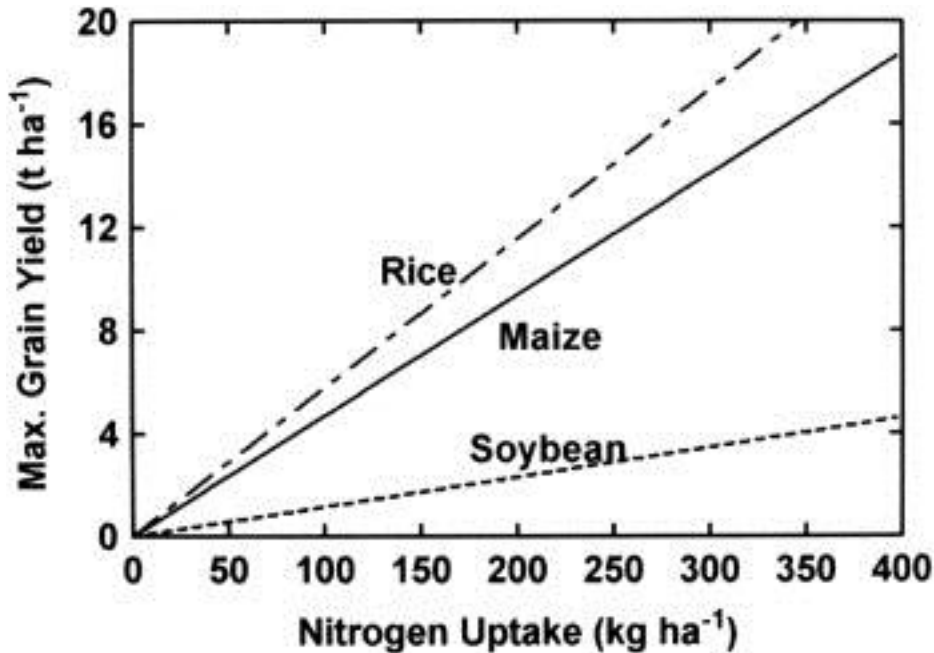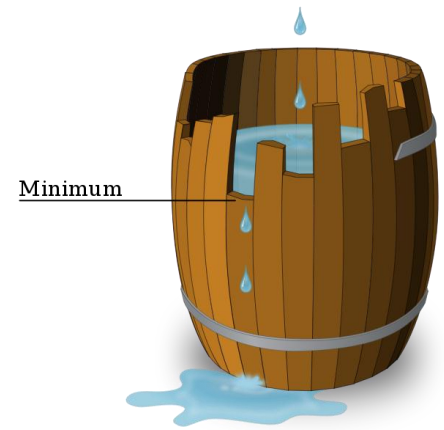
Minimum

Sinclair and Rufty, 2012

Study Quality Very High...

Reviews

On-Station Experiments

On-Farm Trails

Systematic Reviews

A priori research protocol

Quantitative (Meta-analysis)

Publication bias, Sensitivity Analysis Explored

Valid Exp Design

Assess. of covariates

Variance measures

Surveys

A priori Exp. Design

Appropriate QA / QC mechanism

Variance measures

Co-variates assessed

Realistic deployment environ.

Valid survey instrument

Explanatory variables included

Low attrition

High data yield

Real World Cond.

Poor Exp Design

No variance measures

Covariates not assessed

Measurement bias

Data form reported incorrect or unclear

Selection Bias

Performance Bias

Measurement Bias

Attrition

No variance measures

Incorrect data form reported

Low quality instrument

Poor / no explanatory variables assessed

High attrition w/o analysis

One or more forms of bias

Incorrect data form reported

Qualitative / Subjective Reviews

Methods not repeatable

Inclusion / Exclusion Criteria not given
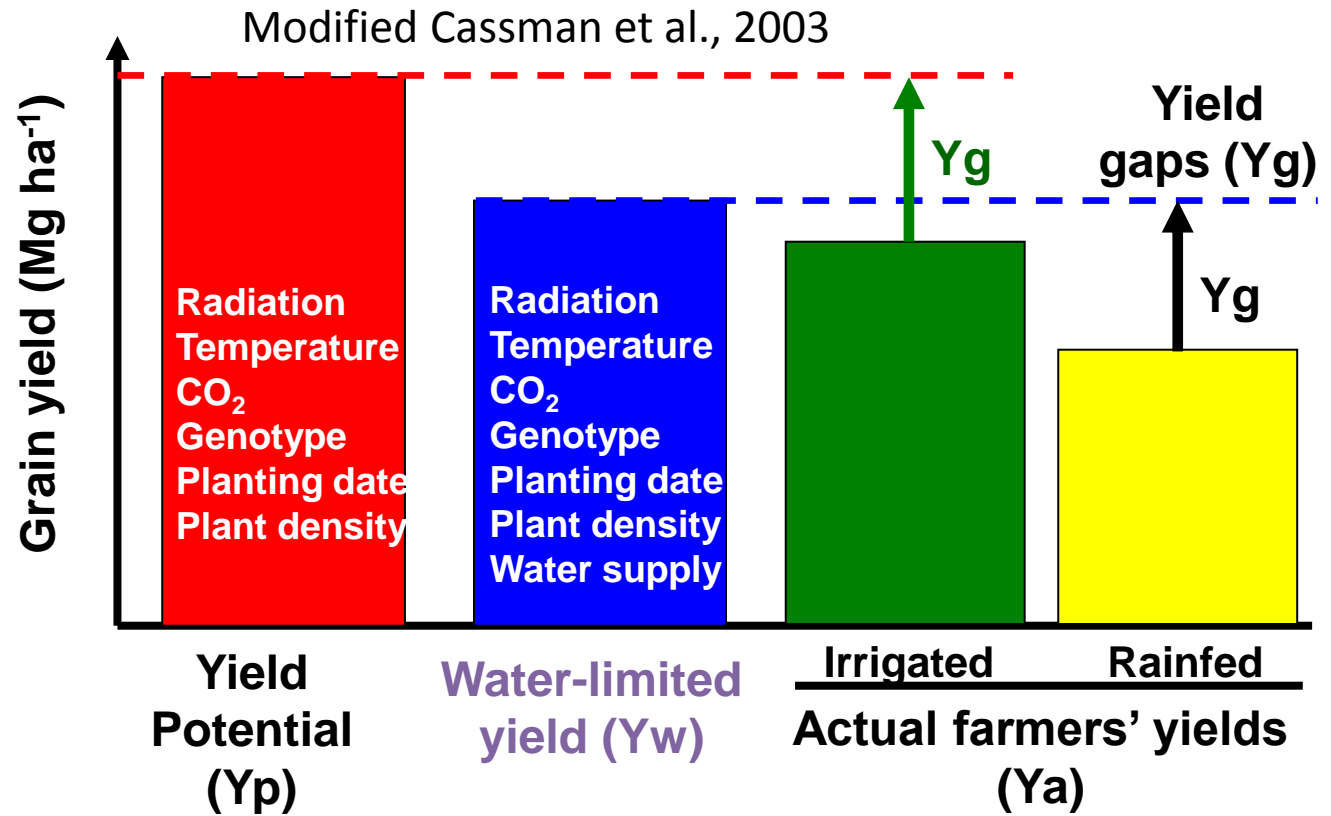
Vote counting / averages of averages

Study Quality Very Low...

Addressing knowledge gaps in SI (EI) Research

CA / Yield Impacts Research: Recs for Future Work (Brouder & Macpherson, in review)

- Minimum datasets:
  - Caveats: Geo-referencing; useful vs. onerous; HD & quality guidelines for surveys; evolution science process
- Infrastructure for data stewardship & sharing
- Need for / importance of systematic (meta-analysis) reviews in "evidence-based" practice (supplement biophysical process modeling)
- New opportunities for Journals & Sponsoring Organizations to foster high quality science in empirical studies and systematic reviews

Addressing knowledge gaps in SI (EI) Research

Modified Cassman et al., 2003

Grain yield (Mg ha^{-1})

Yield gaps (Yg)

Yg

Yg

Red bar (Yield Potential):
Radiation
Temperature
CO$_2$
Genotype
Planting date
Plant density

Blue bar (Water-limited yield):
Radiation
Temperature
CO$_2$
Genotype
Planting date
Plant density
Water supply

Yield Potential (Yp)

Water-limited yield (Yw)

Irrigated **Rainfed**
Actual farmers' yields (Ya)

- Yield Gap Research (ground up) ~ crops $\rightarrow$ cropping sys. $\rightarrow$ farming systems

- Understanding the coupled natural resource / farm $\leftrightarrow$ landscape scale management opportunities
  – Ecosystem service research for CA in SSA & SA less conclusive than yield research (min. data & SOPs)

- Other issues: Agro-ecozones $\rightarrow$ mgmt. package categories, inference space boundaries & land use change, etc.