Maize Yield Response to Fertilizer under Differing Agro-Ecological Conditions in Burkina Faso

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Motivation

- **Achieving food security depends on smallholder productivity**

- **Intensification the only option:**
  - **High population density**
  - **Aged, degraded soils need mineral fertilizer**

- **Fertilizer policy: "blanket recommendations"**

- **Diverse agro-ecologies → variable economic incentives**

Research hypothesis

- *Response* of maize yields to fertilizer and *profitability* of fertilizer use on maize varies by agro-ecological factors

- Contribution to a sparse regional literature

Context

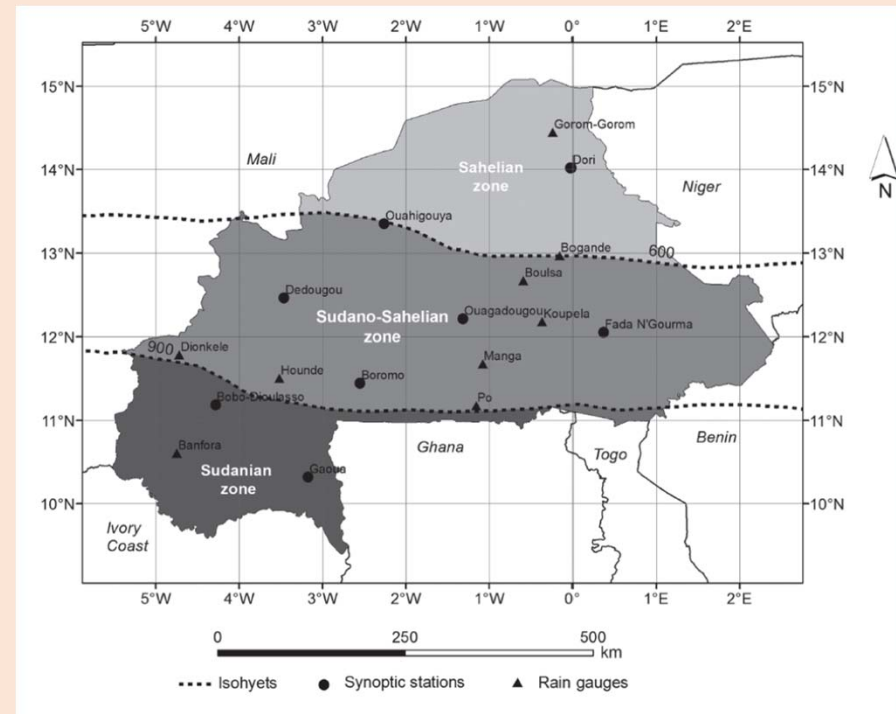**3 agro-ecological zones**

- Sahelian (< 600 mm)
- Sudano-sahelian (600-900)
- Sudanian (900-1200)

10 soil types

- 2/3 of the country is covered by soils that are iron-rich and low in organic matter

Maize area ↑ by 700% in 40 years

Data

- **Continuous farm household survey from the General Research and Sectoral Statistics Department (DGESS), 2009/10-2011/12**

  - 2,321 households (out of 2,700) and 9,526 maize plots

- **National Oceanic and Atmospheric Administration's Climate Prediction Center**

- **European Union's Soil Atlas of Africa**

Methods

Yield response function

- Control function approach with correlated random effects
- Quadratic term for N
- Interaction of N with agro-ecological factors
- Agro-ecological factors measured at several scales

Profitability

- Marginal product of N
- Marginal value-cost ratio (MVCR)
- Average value-cost ratio (AVCR)
- Low, average, and high farm gate prices
- Market, official subsidized, and transacted-subsidized fertilizer prices

Yield Response

Yieldijt = αNijt + βXijt + Uijt

Nijt	application rate
Xijt	vector of other covariates
Uijg	is composed of
V'ijt	unobserved plot characteristics correlated with N application
Eijt	random errors
Cj	unobserved household time-invariant characteristics

$$c_j = \overline{X'}_j \delta + \alpha_j + \omega, \qquad \alpha_j \mid X_j \sim N(0, \sigma_\alpha^2)$$

Nijt = πZijt + Vijt+ Cj   (Z_{ijt} is a set of covariates & instrumental variable)

Profitability

Parameters

1. Agronomic optimum

$\partial E(Y|X)/\partial N = 0$

2. $E(MVCR_{ijt}) = E(MP_{ijt})*P_{maize}/P_N$

3. $E(AVCR_{ijt}) = E(AP_{ijt}) * (P_{maize}/P_N)$

Sensitivity

- Average low, mean, and high farmgate price for maize
- Fertilizer prices
  - Market
  - Official, subsidized (50% of P_f)
  - Transacted, subsidized
    - 23% of urea price
    - 28% of NPK price

Variables

Agroecological factors at three scales of analysis:
- **Plot**
  - size (ha), location (in/outside of compound), and toposequence (lowland, plain, slope)
  - Presence of soil or water conservation structures, agroforestry, intercropping, and fallow
- **Village**
  - Total rainfall, coefficient of variation of rainfall (village)
  - Excellent, good, or poor/marginal soils (village)
- **Zone**
  - Sudano-sahelian or Sudanian zone

- **Other productive inputs, plot manager, plot management type and tenure, household characteristics**

Estimated maize yield response functions

Variables	CRE	CFA-CRE
N	2.91***	22.46***
N*N	-0.014***	-0.016***
Intercropping	-235.24***	-155.90***
SWC	70.28**	78.85**
Excellent soils	16.26	52.52*
Good soils	178.75***	239.20***
Sudanian zone	-198.46	-65.62
N*excellent soils	-1.82**	-1.68**
N*good soils	-3.12***	-2.09***
N*sudano-sahelien zone	1.22***	1.44***
Controlling for other productive inputs, plot manager and household characteristics, household time-averages and crop years.		

Average partial effect of N and optimum

	Average partial effect of N-hat	Average partial effect of N-95% CI	Unconditional N (kg/ha)	Conditional N (kg/ha)	Agronomic optimum N
Average	22	13-31	16	38	722

Net loss of ~700 kg/ha of N over a 30 year period (World Bank, 1996)
Nutrient depletion can even reach 100 kg NPK/ha/year (Henao 1992)

Our results suggest a continuous soil fertility depletion in maize farming

Value-cost ratios

Price Scenario	Fertilizer at market price		Subsidized fertilizer price		Subsidized + TC price	
	MVCR	AVCR	MVCR	AVCR	MVCR	AVCR
Low	1.6	1.6	3.2	3.2	2.1	2.2
Average	1.7	1.8	3.5	3.5	2.3	2.4
High	1.9	2.0	3.9	3.9	2.6	2.6

Profit maximization at MVCR=1

Incentive if AVCR >2 (Morris et al. 2007); AVCR >3-4 (Kelly 2006)

Conclusions

- Maize yield response to N is ~ 22 kg/ha

- Agro-ecological factors, at the scale of plot, village soil type and climatic zone, do affect maize yield response to fertilizer and productivity

- Optimal N rates > maximum N application rates
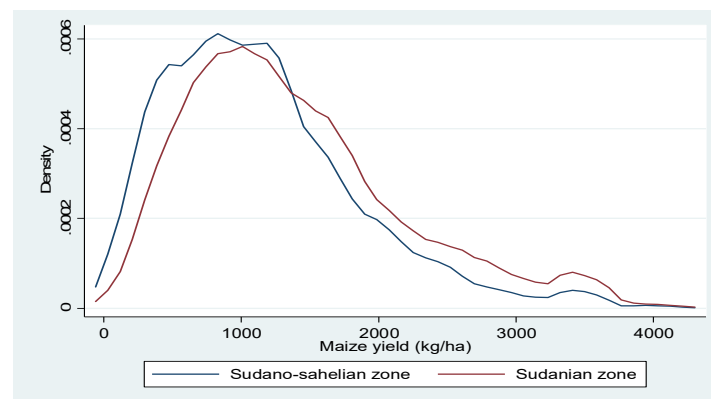
- Not always profitable to use fertilizer

Policy implications

- Caution when generalizing across agroecologies
- Does a crop targeted fertilizer subsidy program make sense?
- Importance of reducing transaction costs
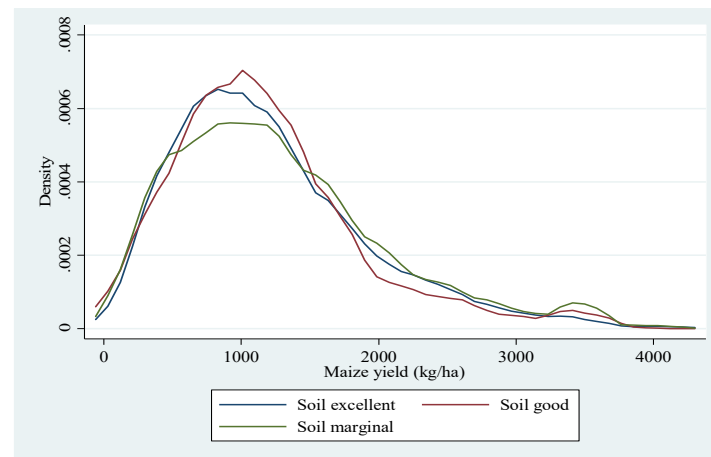- Location-specificity vs. scale

Descriptives

- **40% of maize plots fertilized (all years)**
- **Unconditional mean of N kg/ha=16**
- **Conditional mean of N kg/ha=38**
- **Mean yield w/out fert=970 kg/ha**
- **Mean yield w/fert=1314 kg/ha**
- **Recommended rate = 45.5-53 N/ha**

zones

soils