Profitable cropland available in sub-Saharan Africa

Jing Liu[1*] and Nelson Villoria[2]

[1] Purdue University
[2] Kansas State University
[*]Email: liu207@purdue.edu

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Profitable Cropland Supply in Africa

Jing Liu[1] and Nelson Villoria[2]
[1]Purdue University, [2]Kansas State University

Africa is in lack of profitable land despite its abundance in arable land

- 400 Million ha of arable land in Guinea Savannah
- Less than 10% is cultivated
- Much of the remaining land is not readily usable due to developmental challenges

Disagreement on how much profitable land is available in Africa

- 451 Mha (Alexandratos and Bruinsma, 2012)
- 365 Mha (Deininger and Byerlee, 2011)
- 242-384 Mha (Chamberlin et al., 2014)
- The obstacle to measuring profitability is the unknown site-specific prices and land returns

Research objectives

- Model and empirically test the effect of market access on cultivation decisions at the grid-cell level
- Estimate cropland supply elasticity
- Estimate a cropland supply schedule as a function of market access increase

Theory and method: Grid-based cultivation decisions

- Land is cultivated only if net return is not negative

$$Y_i = f(I_i, S_i)$$
$$R_i^* = P_i Y_i^* - C_i I_i^* = r(S_i, P_i, C_i)$$

- Land return is a latent variable to be inferred from the probability of observing cultivation

$$Z_i = \begin{cases} 1 & R_i \geq 0 \\ 0 & R_i < 0 \end{cases}$$
$$\mathbf{P_i}(Z_i = 1 | A_i, S_i) = \Lambda(\alpha_0 + \alpha_1 A_i + \alpha_2 \log(S_i) + \varepsilon_i)$$

- Prices follow a distance-decay function of market access (Chomitz and Gray, 1996)

$$P_i = \exp(\gamma_0 + \gamma_1 A_i), \gamma_1 > 0$$
$$C_i = \exp(\delta_0 + \delta_1 A_i), \delta_1 < 0$$

- Improved market access is equivalent to improved land profitability

$$dA_i = \frac{d\log(P_i) - d\log(C_i)}{\gamma_1 - \delta_1}, \gamma_1 - \delta_1 > 0.$$

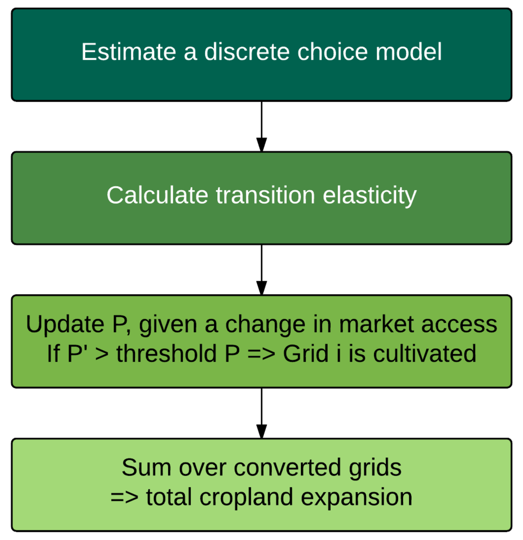
- Marginal effect determines the transition elasticity ϵ_i
  e.g. $\epsilon_i = 10$ means +1% market access $\Rightarrow$ +10% cultivation probability

$$\epsilon_i = \frac{\partial \hat{\mathbf{P}}_i(Z_i = 1)}{\partial A_i} \times \frac{A_i}{\hat{\mathbf{P}}_i(Z_i = 1)}$$

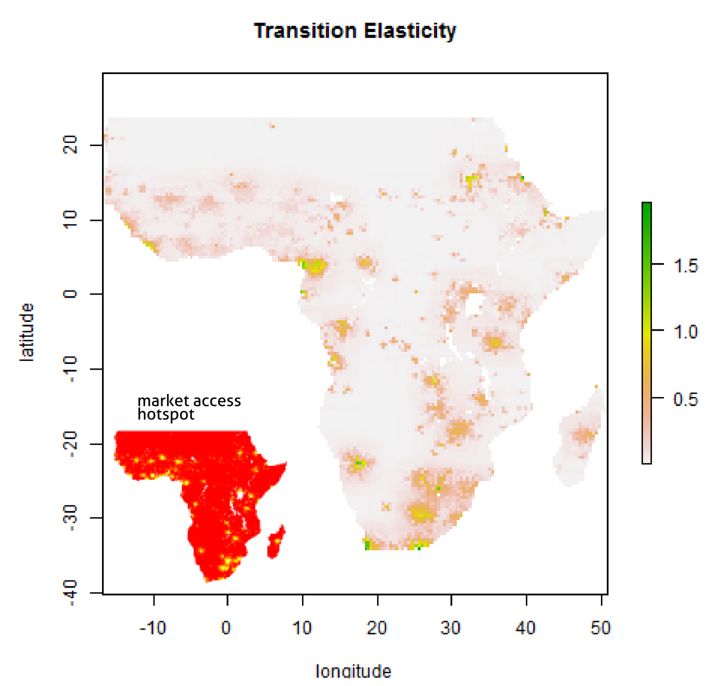
- Updated cultivation status is,

$$\hat{\mathbf{P}}_i' = \hat{\mathbf{P}}_i\left[1 + \epsilon_i \times \frac{\partial A_i}{A_i}\right])$$

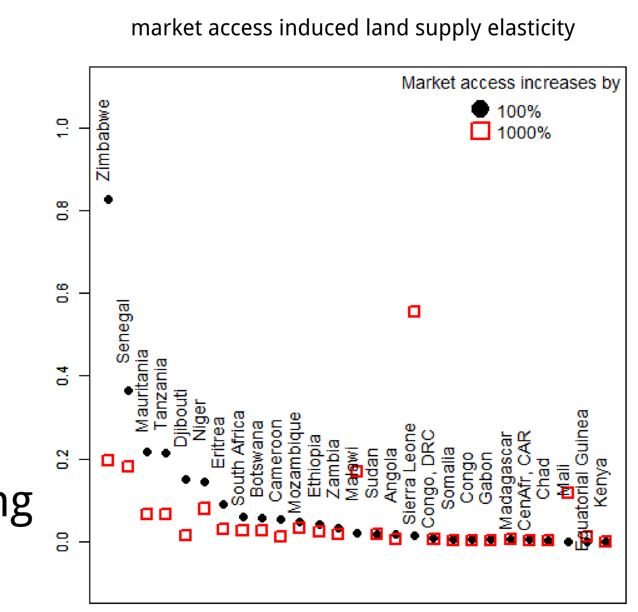
workflow



Finding 1: Remarkable variation in cropland supply elasticity within sub-Saharan Africa

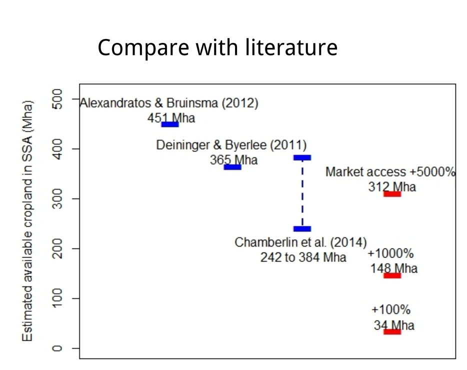


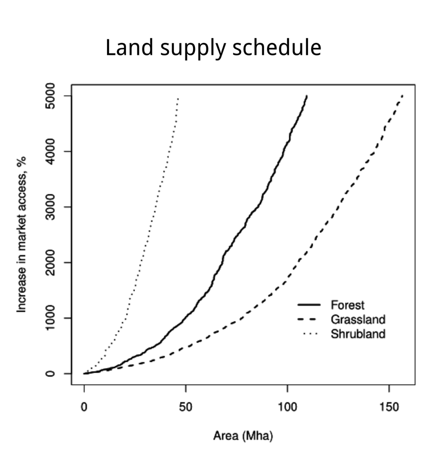
- Transition elasticity =1 indicates +1% in market access increases the probability of observing cultivation by 1%
- Market access is an index [0,100] of traveling time to the nearest central market (sourced from Verburg et al., 2011)



- Market access increases by 100% indicates transportation time is cut by half
- Very inelastic cropland supply in SSA
- In the least developed countries, market access needs substantial improvement to bring new land into cultivation.

Finding 2: Market access needs to increase by more than ten folds to reach the lower bound of previous estimation





- Current Africa has much less profitable land than arable land
- Observed cropland expansion according to FAOSTAT:
  - 20 Mha (2011 vs. 2005)
  - 56 Mha (2010 vs. 1990)

Finding 3: A two-decade TFP growth in Africa can improve food security

- Improved food security in Africa

	E-Afr	S-Afr	C-Afr	W-Afr	RoW
Change in crop price (%)	-55	-44	-67	-71	-11
Change in crop consumption (%)	5.5	5.0	8.0	8.1	1.1
Change in cropland use (Mha)	-1.66	-0.13	-0.44	-0.60	-5.73

- Less cropland conversion and CO_2 emissions

Cropland saving, **SSA** (Mha)	2.84
Cropland saving, **world** (Mha)	8.57
Emission reduction, **world** ($GtCO_2e$)	2.52

- Borlaug hypothesis vs. Jevons' paradox
- TFP growth is land-sparing conditional on the inelastic food demand.
- If food demand is price elastic, the inelastic cropland supply means a smaller cropland expansion.

Data and empirical strategies

- Estimate a spatial Durbin (logit) model to correct for autoregressive errors and alleviate omitted variable bias

$$\mathbf{P}(Z = 1|\mathbf{X}) = \Lambda(\rho \mathbf{WP} + \mathbf{X}\beta_1 + \mathbf{WX}\beta_2 + \mu)$$

- Y: a binary based on the fraction of harvested area
- X: market access, land features (precip, irrigation, etc), region dummies, agro-ecological zone dummies

Application: Economic and environmental impacts of TFP growth

- Experiment: Faster crop TFP growth in SSA, 2004-2025
  - Exp1: TFP +18.3% everywhere
  - Exp2: TFP +38.4% in SSA, +18.3% everywhere else
- Impacts of Africa TFP growth = Exp2 - Exp1
- Model: Multi-region, multi-sector CGE model GTAP-AEZ, baseline 2004 world economy
- Use our estimated land supply elasticity to calibrate region-specific land transformation elasticity for SSA: -.077, -.117, -.084, -.062 for South, East, Central and West Africa respectively

Conclusions

- The evolving market access bridges two contradictory views on Africa's cropland expansion: land abundance (Deininger and Byerlee, 2011) and scarcity (Chamberlin et al., 2014).
- Given the current low land supply elasticity in SSA, barring major investments in market access, the broad-based ag-technological progress is unlikely to incentivize major land expansion.

Corresponding author: Jing Liu
liu207@purdue.edu