# Climate Smart Agriculture: Designing Effective Policies by Combining Evidence and Modelling


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FAO EPIC

ECONOMICS & POLICY INNOVATIONS FOR CLIMATE-SMART AGRICULTURE

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# The Principles of Climate Smart Agriculture (CSA)

CSA integrates the three dimensions of sustainable development (economic, social and environmental) by jointly addressing food security and climate challenges.

It is composed of three main pillars:

1. Sustainably increasing agricultural productivity and incomes [FOOD SECURITY]
2. Adapting and building resilience to climate change [ADAPTATION]
3. Reducing and/or removing greenhouse gases emissions, where possible [MITIGATION]

http://www.fao.org/climatechange/climatesmart/en/

# FAO, Rome

FAO is a technical support agency of the United Nations

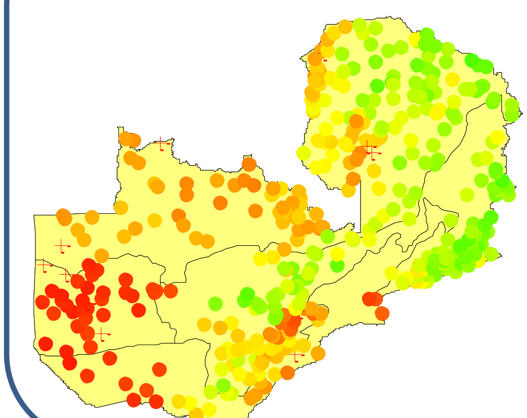
# Policy Levers and Outputs

**BUDGET**

**LEVERS**

- Extension
- Credit
- Infrastructure
- Input support
- Safety nets
- R & D
- …

**RESPONSE**



- Farmers
- Agribusiness
- Markets
- institutions

**OUTPUTS**

- Food Security
- Adaptation
- Mitigation

# Outline

## 1. Adoption analysis

Combining econometric results of adoption and disadoption with simulation models for policy analysis

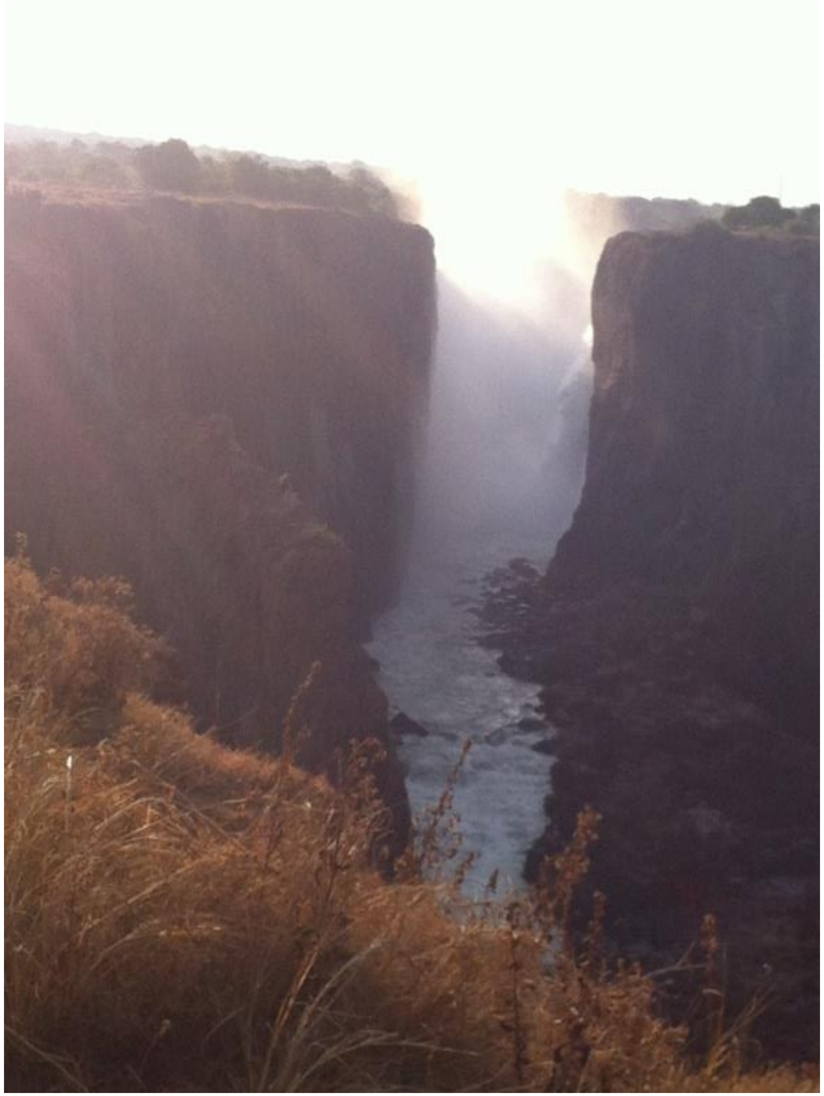
## 2. Cluster analysis

Identifying different types of farming systems to target CSA interventions

## 3. Farm Models for ex-ante analysis

Developing and using mathematical programming models based on household data

# Case Study: Zambia



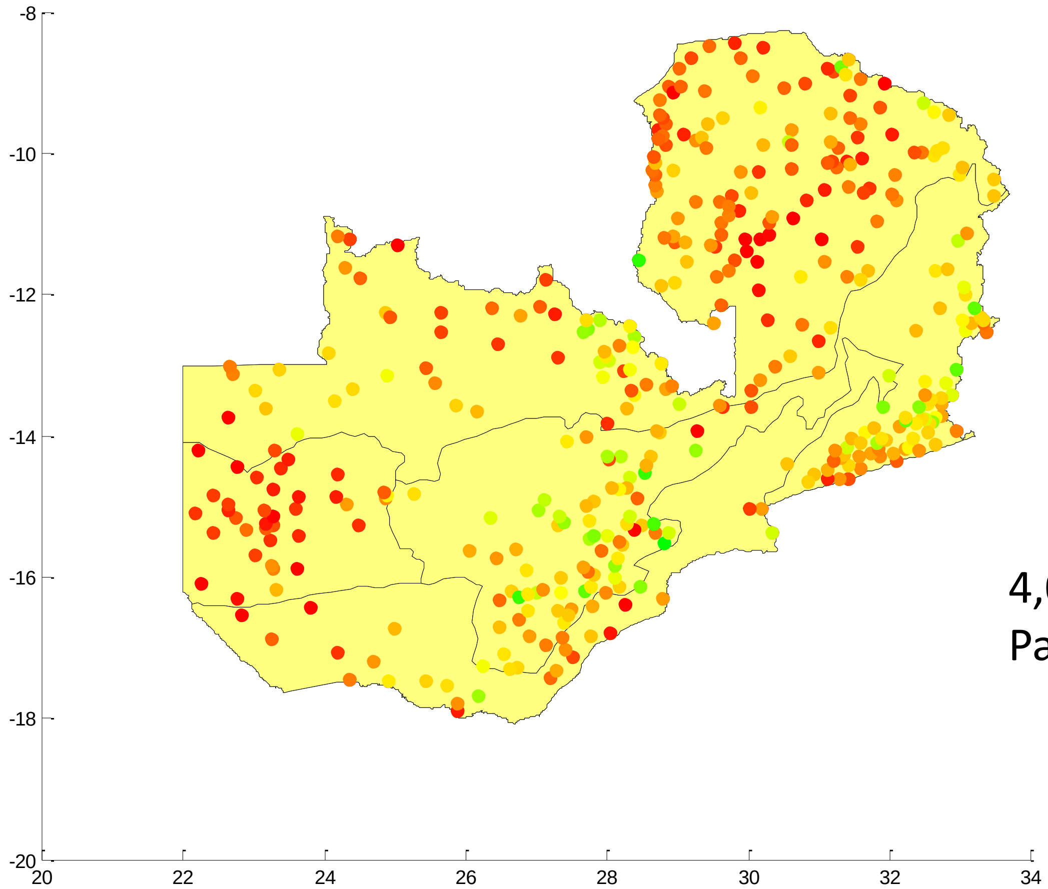

CONSERVATION AGRICULTURE
FOR SUSTAINED INCREASE IN
PRODUCTIVITY AND PROFITABILITY
This project is financed by the European

# Data

- Household (RILS*) survey for 2004 and 2008
- Maps of enumeration areas, districts, provinces and agro-ecological zones (AEZ)
- Historical weather data
- Institutional data
- Environmental data (soils, NDVI etc.)
- Infrastructure data (roads, markets etc.)
- BCA survey data

*Rural Incomes and Livelihoods Survey

# RILS data points




4,000 + households
Panel: 2004, 2008

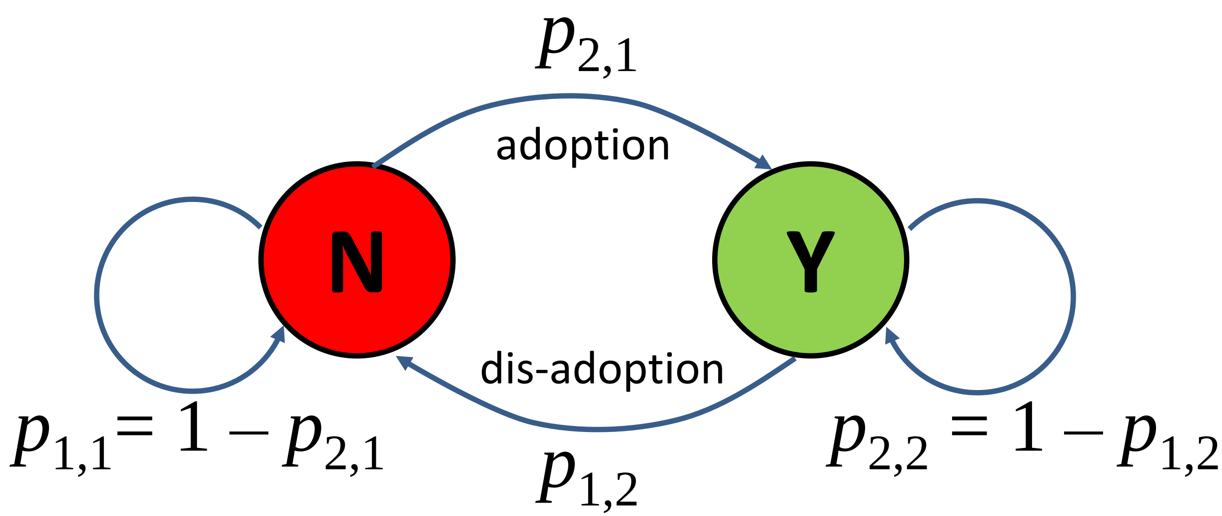
Points indicate location of enumeration areas (~20 households per EA).
This example shows intensity of extension services (green=high, red=low)



# Technologies considered

- Minimum soil disturbance (msd)
- Crop rotations (cr)
- Legume intercropping (legint)
- Inorganic fertiliser (inof)
- Improved seeds (imps)

# Adoption analysis




$$P = \overbrace{\begin{matrix} \text{N} & \text{Y} \end{matrix}}^{t} \quad \left.\begin{pmatrix} p_{1,1} & p_{1,2} \\ p_{2,1} & p_{2,2} \end{pmatrix} \begin{matrix} \text{N} \\ \text{Y} \end{matrix}\right\} t+1$$

$$Z_t = \begin{pmatrix} z_{N,t} \\ z_{Y,t} \end{pmatrix}$$

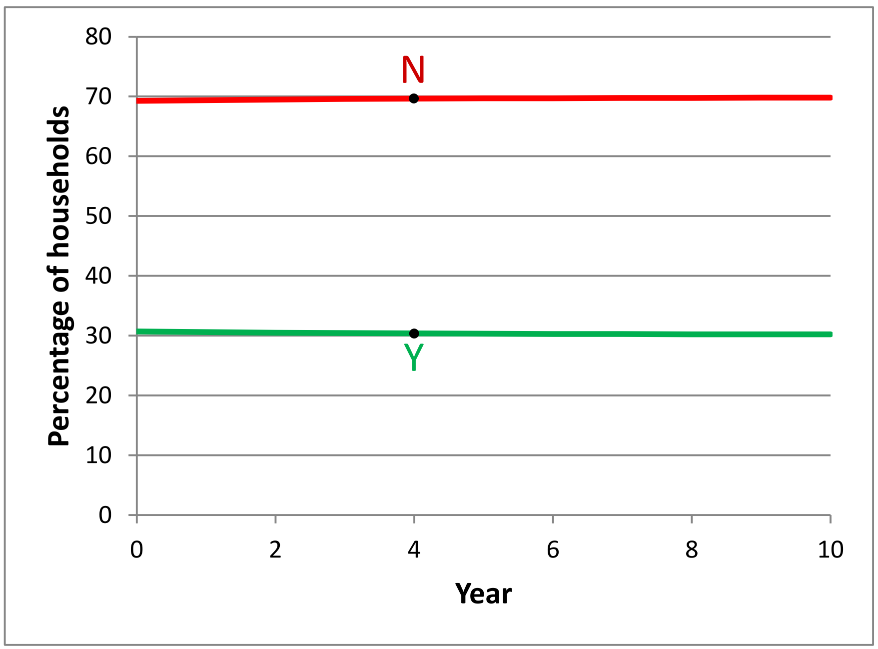
# Adoption analysis

Improved Seeds

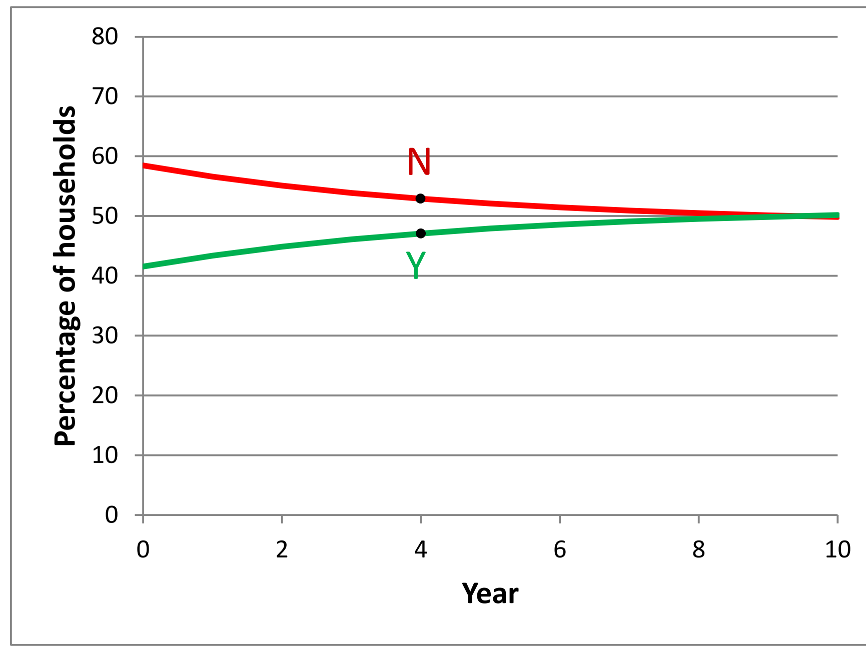
Using data for 2004-2008

$$Z_{t+1} = P\,Z_t$$

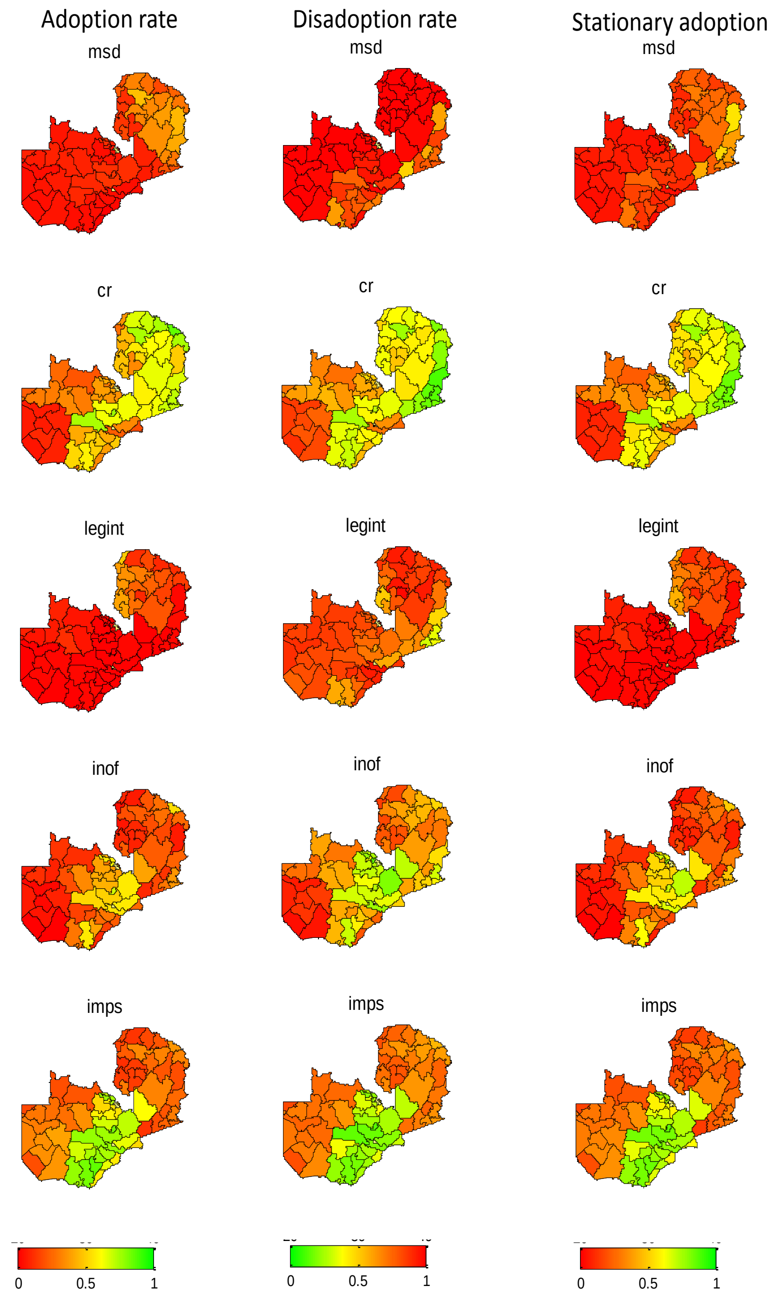
No ASP* Participation




ASP* Participation




* ASP: Agricultural Support Program


Adoption rate
Disadoption rate
Stationary adoption
msd
msd
msd
cr
cr
cr
legint
legint
legint
inof
inof
inof
imps
imps
imps
0
0.5
1
0
0.5
1
0
0.5
1

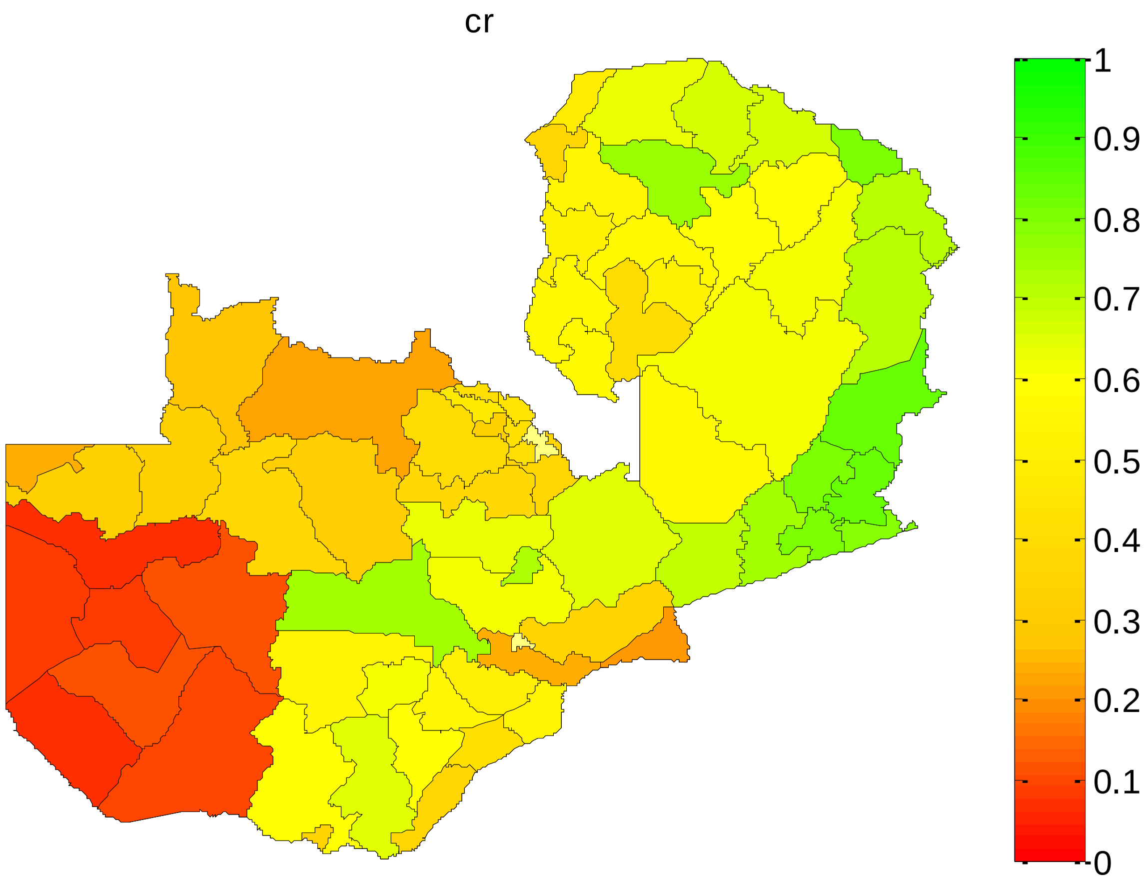
# Probit models

Crop rotation

| | $\beta_A$ Adopt | $\beta_D$ Disadopt |
|---|---|---|
| Female HH head (tavg) | -0.148 | 0.180** |
| Widow HH head (tavg) | -0.590** | 0.231 |
| Polygamous HH head | 0.308*** | |
| Polygamous HH head (tavg) | -0.274** | -0.068 |
| Age of HH head (tavg) | -0.006 | 0.004* |
| Education of HH head | 0.034** | |
| Education of HH head (tavg) | -0.011 | -0.048*** |
| Agric.Wealth | 0.086** | |
| Agric.Wealth (tavg) | 0.015 | -0.082** |
| Wealth (tavg) | -0.081*** | 0.052** |
| Oxen owned | 0.052*** | |
| Moderate nutrient constraint | 0.221*** | |
| Severe nutrient constraint | 0.249*** | |
| Severe nutrient constraint (tavg) | | -0.250** |
| CoV of Oct-Apr rainfall | -3.366** | |
| Fertilizer support prog. (tavg) | 0.273*** | -0.178 |
| Extension (share of HHs exposed) | 0.415*** | |
| Extension (tavg) | 0.507*** | -1.221*** |
| … | | |

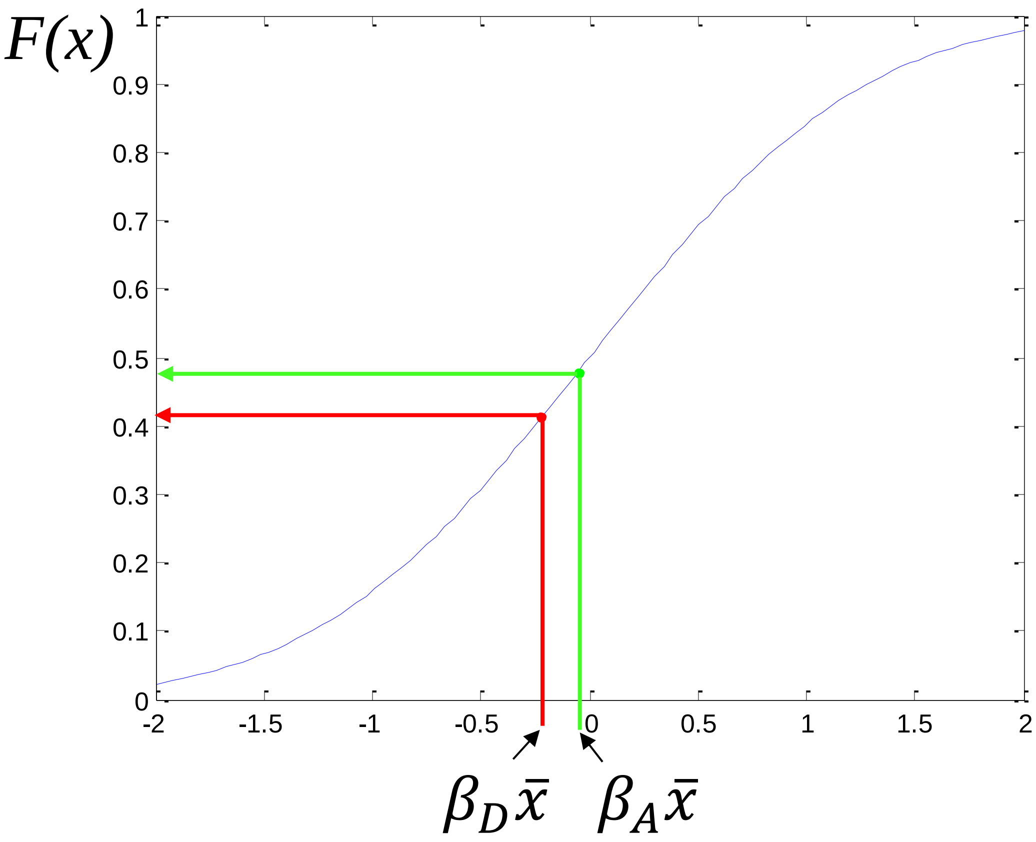
# Mapping adoption

Crop Rotation

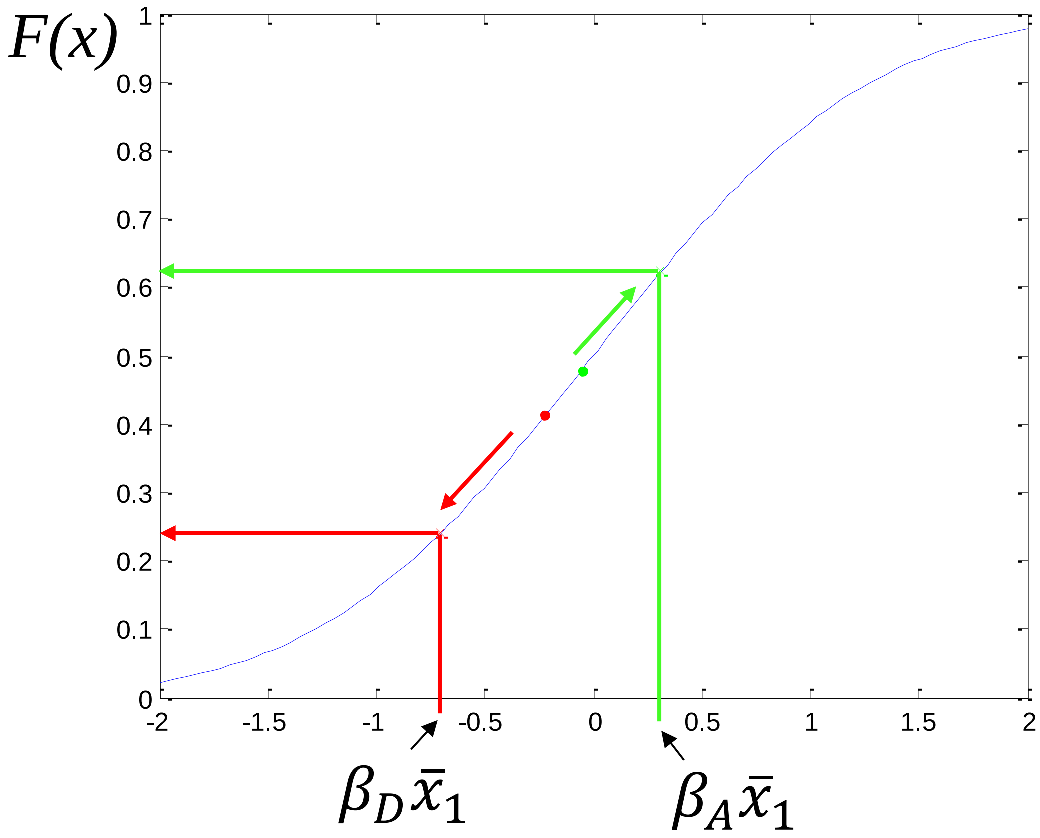



Using data for 2004-2008

# Predicted adoption/disadoption



# Doubling extension exposure




Stationary adoption level: before: 0.54

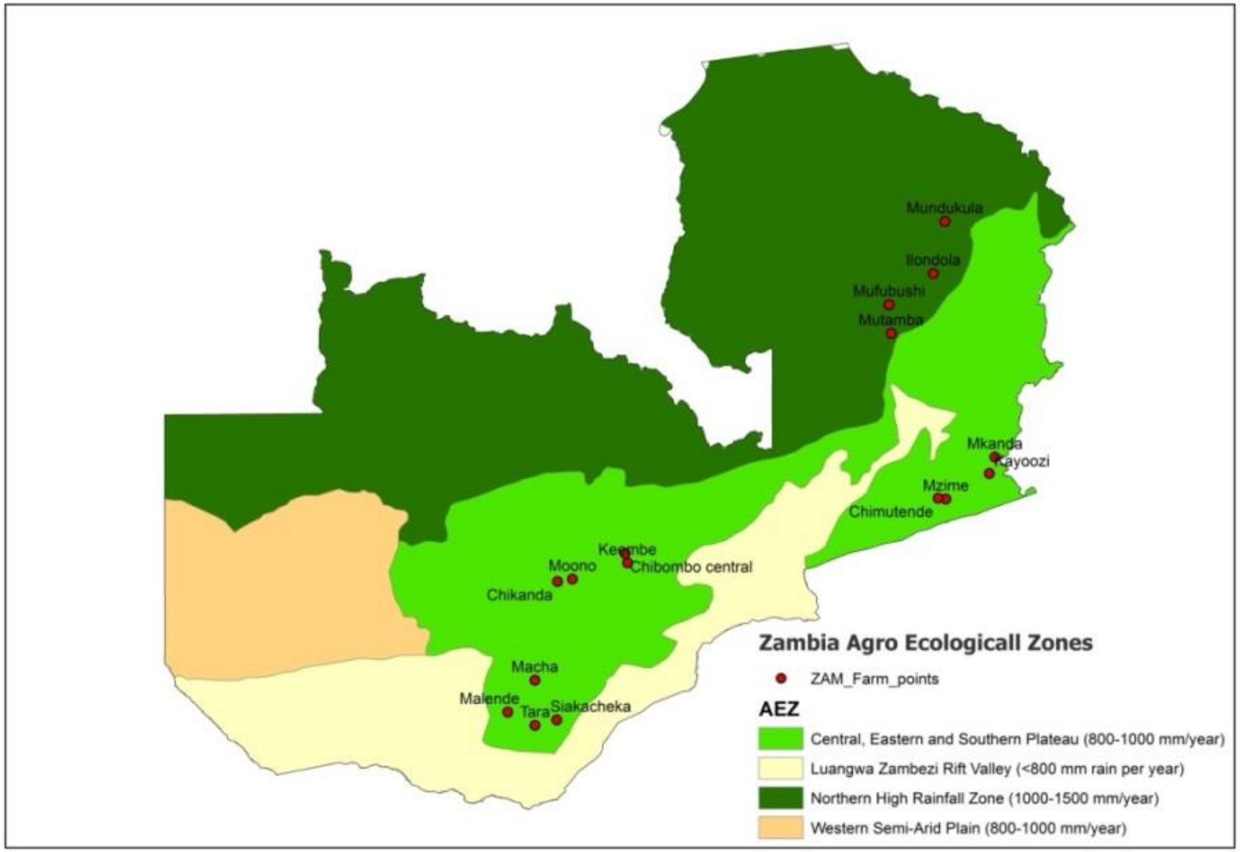
after: 0.72

# Extension

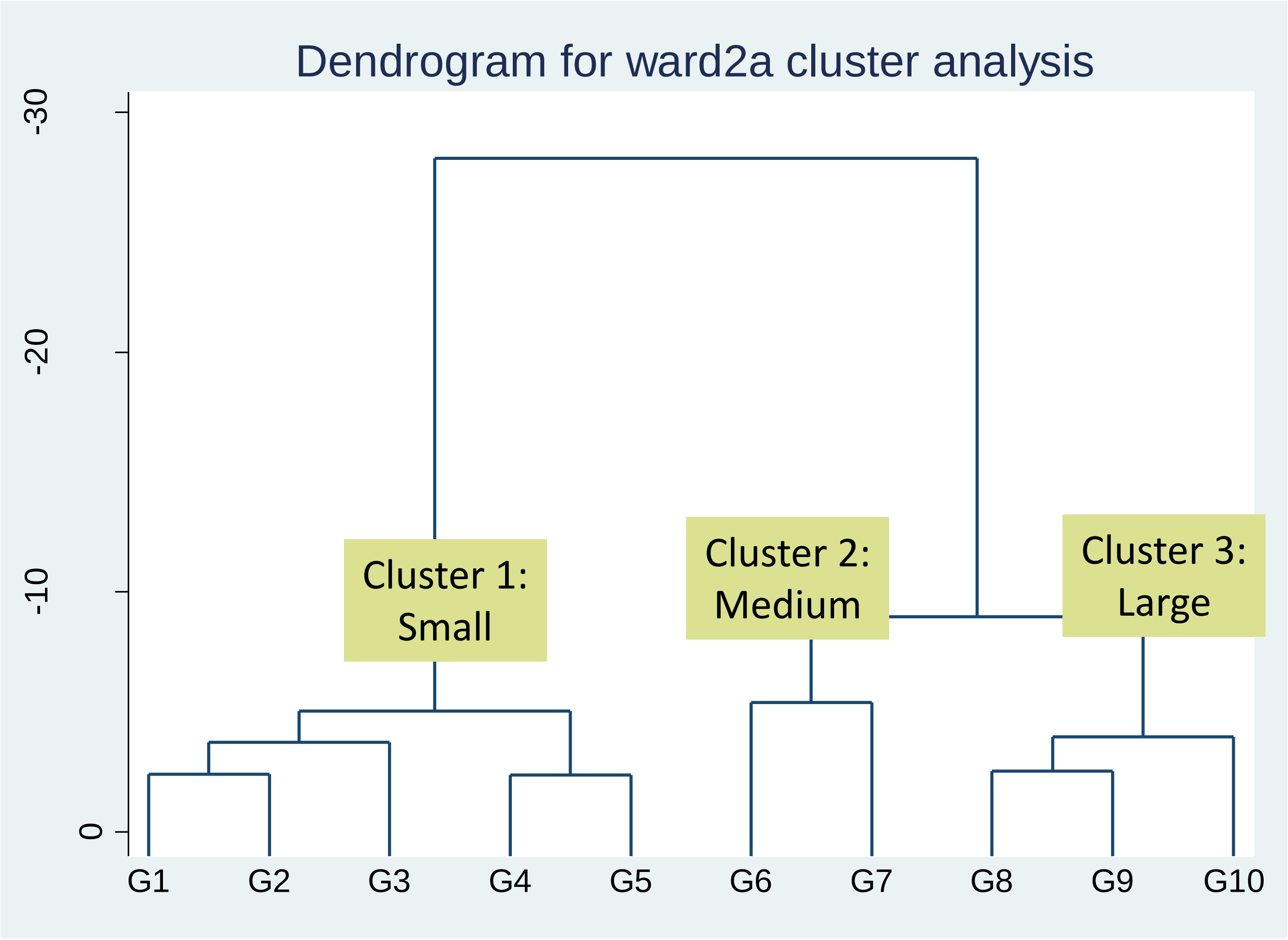
- This example is based on expected parameter values and does not account for confidence intervals
- Applying Monte Carlo methods to econometric results we can derive confidence intervals numerically
- We can then compare the likely effects of alternative policy packages and their distribution

# CBA Survey

- 1,264 fields cultivated by 695 HHs over 17 camps located in 8 districts



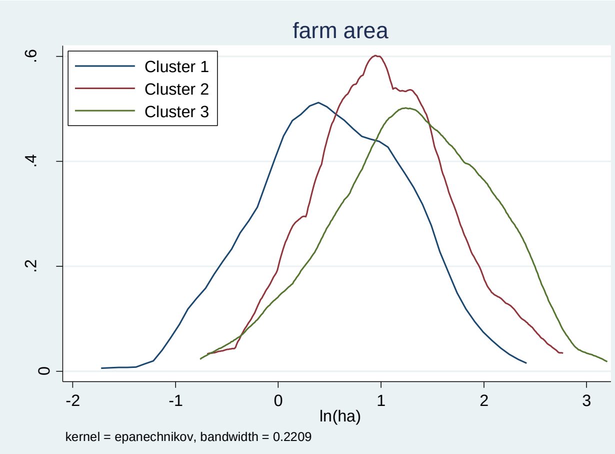
# Cluster analysis



# Household / farm characteristics

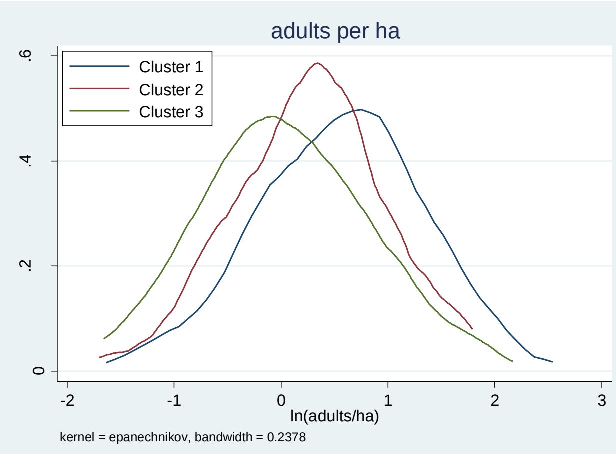
CBA 2014 AEZ IIa

## Farm area



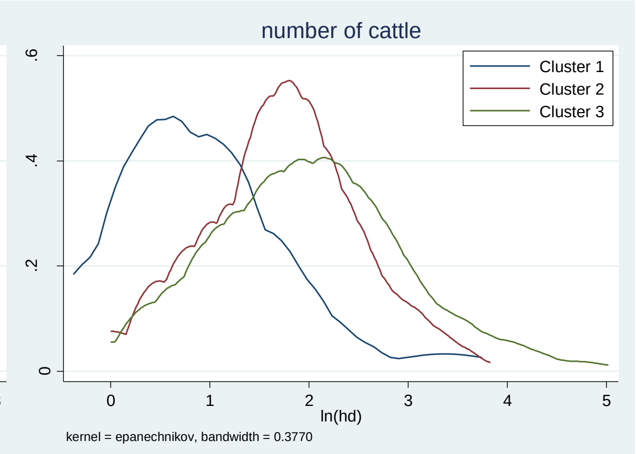

| Cluster | Mean | Group |
| --- | --- | --- |
| 1 | 2.16 | A |
| 2 | 3.48 | B |
| 3 | 4.80 | C |

## Adults / ha




| Cluster | Mean | Group |
| --- | --- | --- |
| 1 | 2.2 | B |
| 2 | 1.6 | A |
| 3 | 1.4 | A |

## Cattle owned



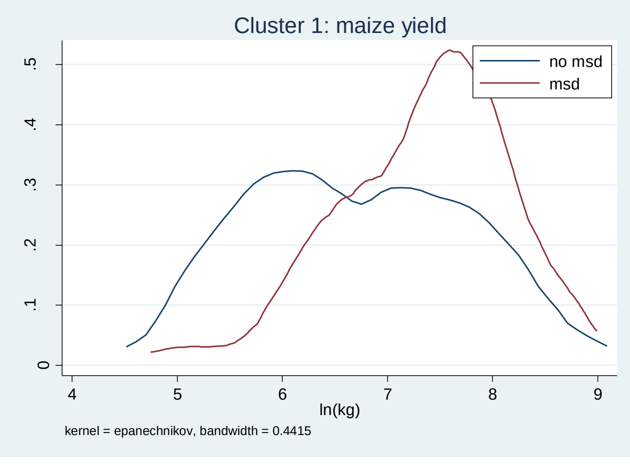

| Cluster | Mean | Group |
| --- | --- | --- |
| 1 | 0.50 | A |
| 2 | 6.90 | B |
| 3 | 12.05 | C |

* Groups sharing same letter are not significantly different ($p<0.05$)

# Maize yields

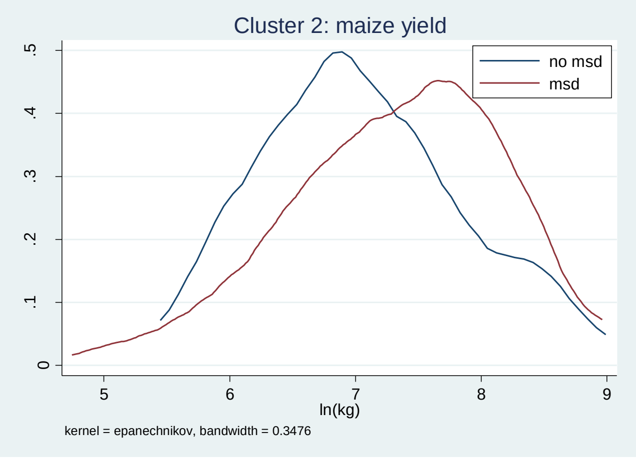
## MSD vs conventional

### Small farms



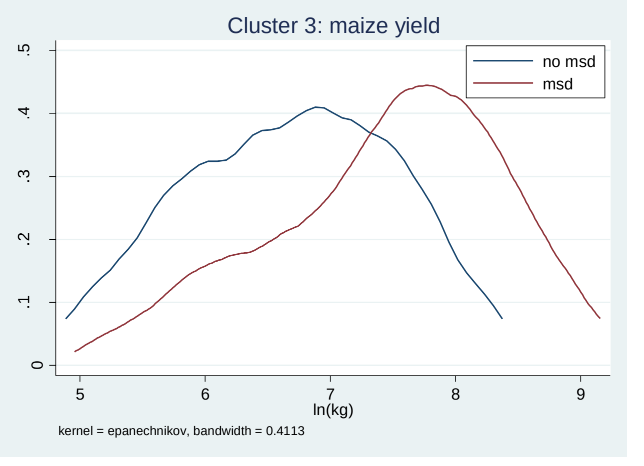

| MSD: | NO | YES |
|---|---|---|
| Obs | 34 | 163 |
| Mean | 1,314 | 2,048 |
| Std. | 225 | 119 |
| Pr(T < t) = 0.0048 | | |

### Medium farms




| MSD: | NO | YES |
|---|---|---|
| Obs | 20 | 108 |
| Mean | 1,553 | 2,068 |
| Std. | 310 | 156 |
| Pr(T < t) = 0.0922 | | |

### Large farms

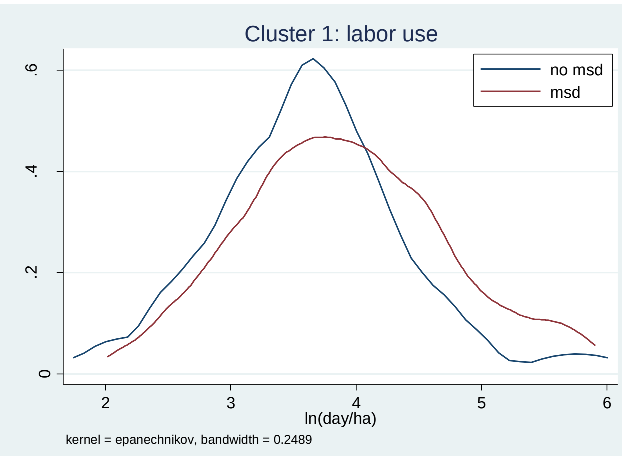



| MSD: | NO | YES |
|---|---|---|
| Obs | 13 | 127 |
| Mean | 1,053 | 2,429 |
| Std. | 219 | 170 |
| Pr(T < t) = 0.0057 | | |

# Labour use

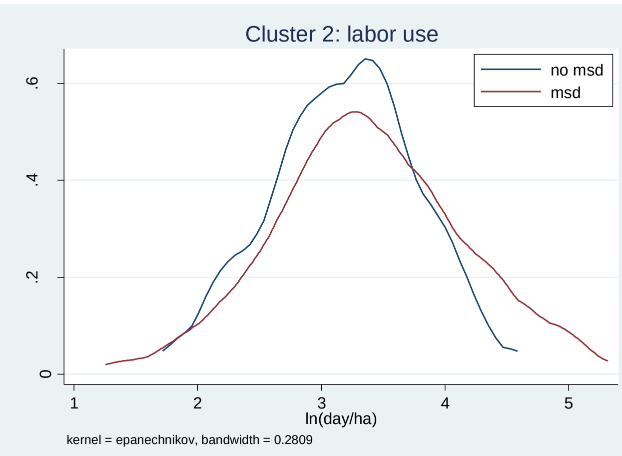
## MSD vs conventional

### Small farms



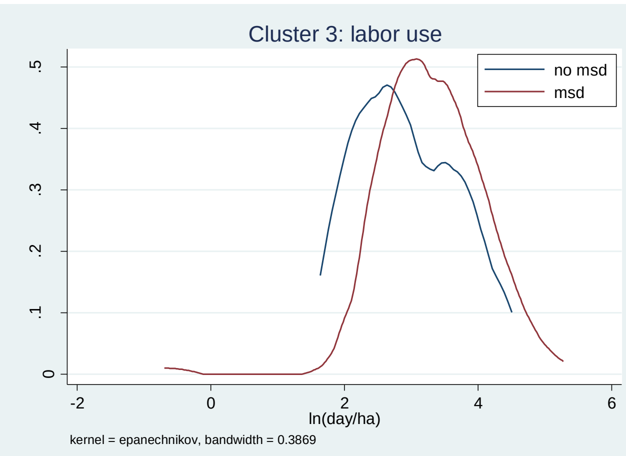

| MSD: | NO | YES |
|---|---|---|
| Obs | 34 | 164 |
| Mean | 50.85 | 70.36 |
| Std. | 9.30 | 5.26 |
| Pr(T < t) = 0.0572 | | |

### Medium farms




| MSD: | NO | YES |
|---|---|---|
| Obs | 20 | 113 |
| Mean | 27.98 | 39.20 |
| Std. Err. | 3.56 | 3.18 |
| Pr(T < t) = 0.0742 | | |

### Large farms

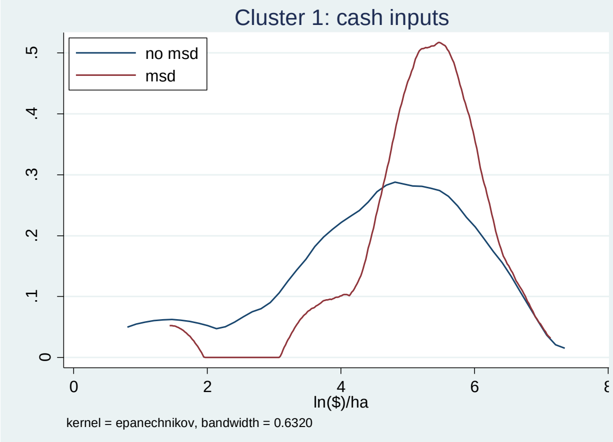



| MSD: | NO | YES |
|---|---|---|
| Obs | 13 | 129 |
| Mean | 24.12 | 35.57 |
| Std. Err. | 5.04 | 2.56 |
| Pr(T < t) = 0.0838 | | |

# Cash inputs

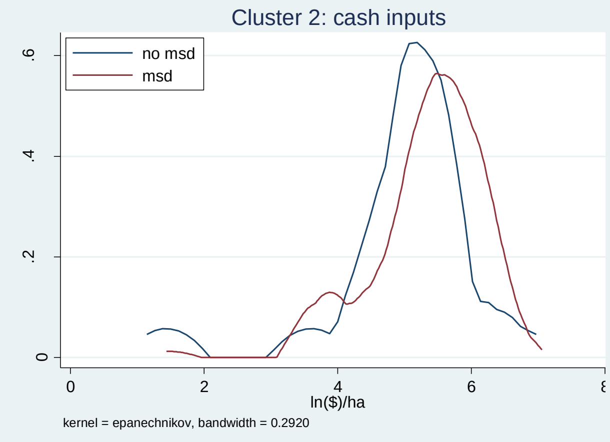
## MSD vs conventional

### Small farms



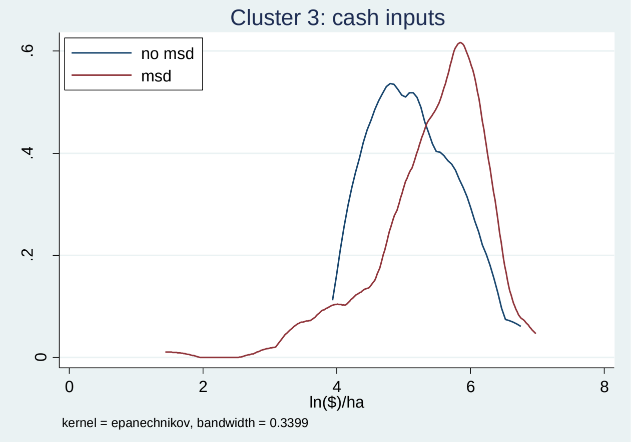

| MSD: | NO | YES |
|---|---|---|
| Obs | 34 | 164 |
| Mean | 171.49 | 260.62 |
| Std. Err. | 29.43 | 16.53 |
| Pr(T < t) = 0.0112 | | |

### Medium farms




| MSD: | NO | YES |
|---|---|---|
| Obs | 20 | 115 |
| Mean | 209.97 | 278.23 |
| Std. Err. | 37.98 | 17.40 |
| Pr(T < t) = 0.0643 | | |

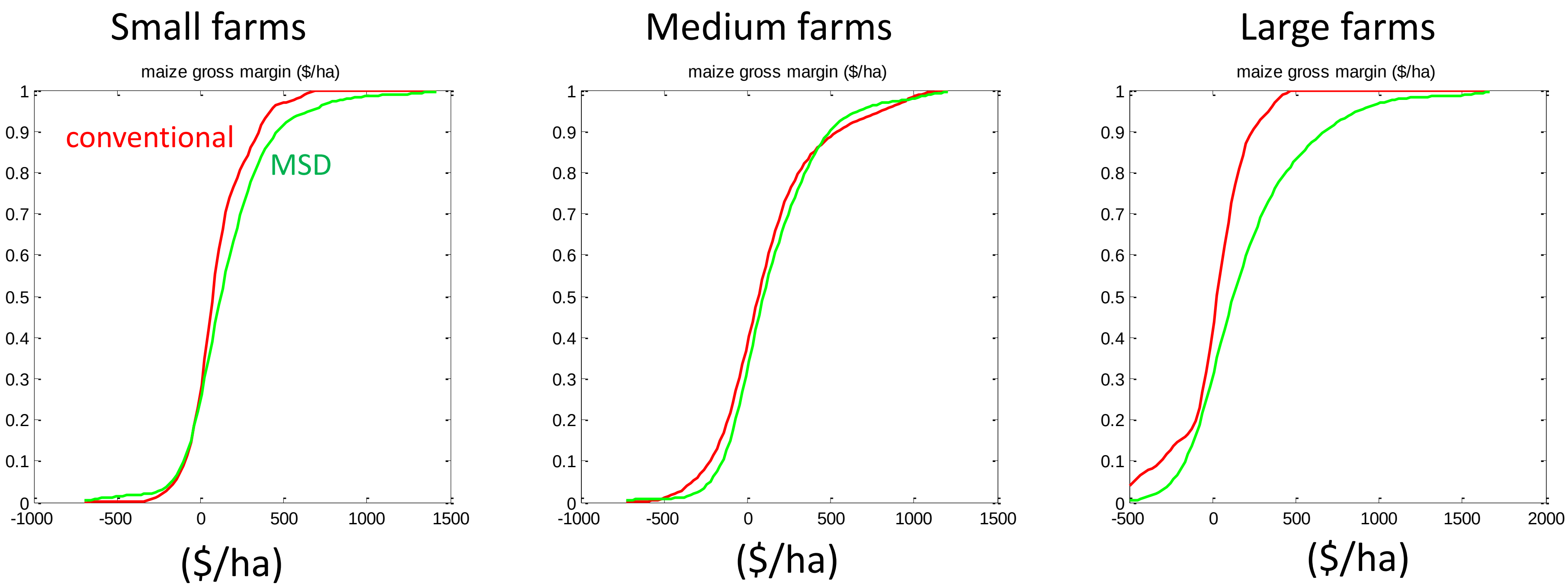
### Large farms




| MSD: | NO | YES |
|---|---|---|
| Obs | 13 | 132 |
| Mean | 209.68 | 293.82 |
| Std. Err. | 41.48 | 16.69 |
| Pr(T < t) = 0.0636 | | |

# Gross margin CDFs

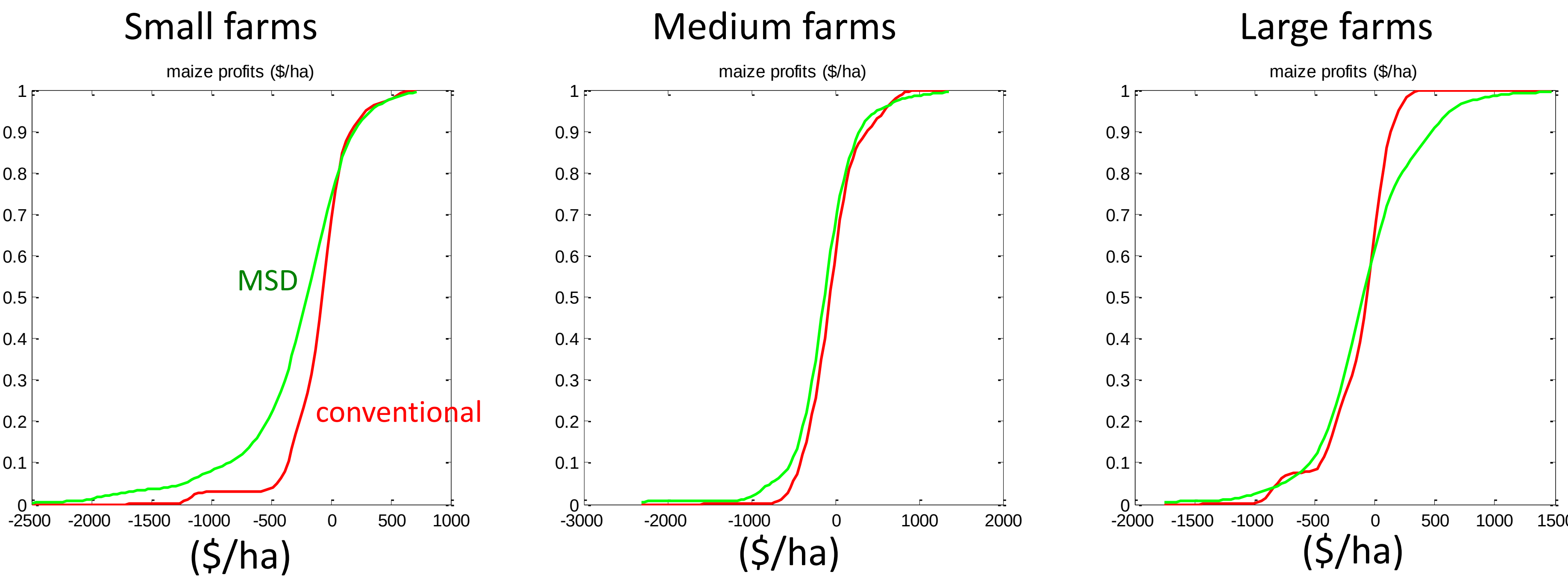
MSD vs conventional




First-degree stochastic dominance is evident only on large farms

# Maize profit CDFs

MSD vs conventional




Once the value of family labor is considered the dominance of MSD disappears

… but we have only accounted for spatial variability, the effect of a climate fluctuations through time is not captured here

Is the left tail of the yield distribution smaller under MSD?

We need panel data or other sources of information on the possible advantages of MSD in dry years

# Farm household models

Different policies, locations and technologies can be represented by changing particular components of the matrix.

Objective function

Activities

Constraints

| | Crops | | | Livestock | | | Off-farm Labor… | … | |
|---|---|---|---|---|---|---|---|---|---|
| max/min | $C_1$ | … | $C_n$ | $L_1$ | … | $L_n$ | $X_1$ | | |
| **Land** | $ac_{11}$ | … | $ac_{1n}$ | $al_{11}$ | … | $al_{1n}$ | … | $\leq$ | $b_1$ |
| **Labor** | $ac_{21}$ | … | $ac2_n$ | $al_{21}$ | … | $al_{2n}$ | … | $\leq$ | $b_2$ |
| **Capital** | … | … | … | … | … | … | … | $\leq$ | $b_3$ |
| **Fertilizer** | … | … | … | … | … | … | … | $\leq$ | $b_4$ |
| **Water** | … | … | … | … | … | … | … | $\leq$ | $b_5$ |
| **…** | $ac_{m1}$ | … | $ac_{mn}$ | $al_{m1}$ | … | $al_{mn}$ | … | $\leq$ | $b_6$ |

Technical coefficients

MP models of typical farms can be calibrated based on cluster analysis (i.e. PMP)

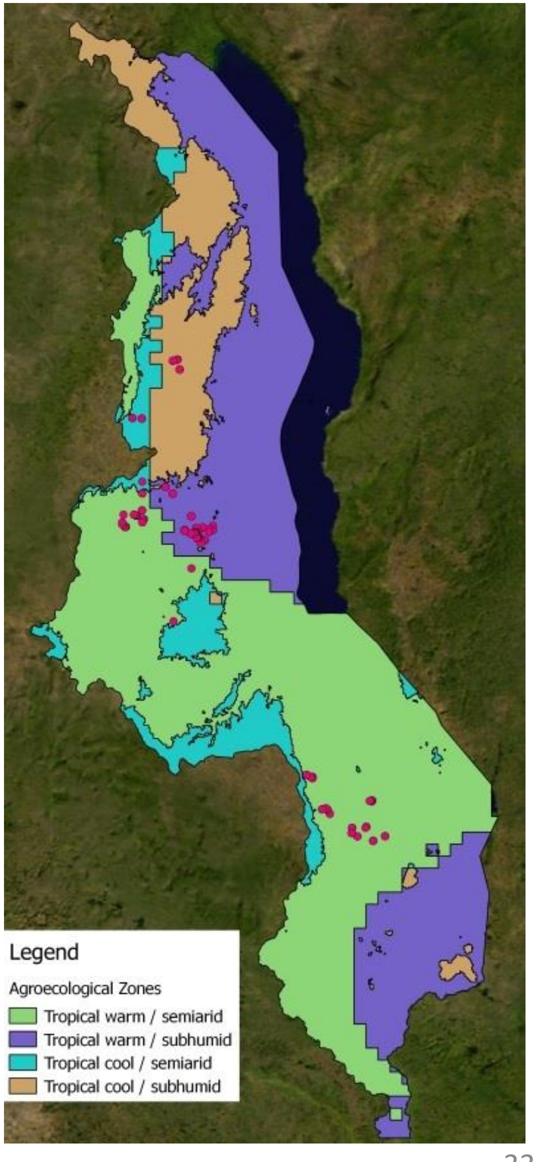
The models can then be extended to include yield variability in the activities and risk aversion in the objective function

Optimal enterprise mixes that account for uncertainty can then be determined

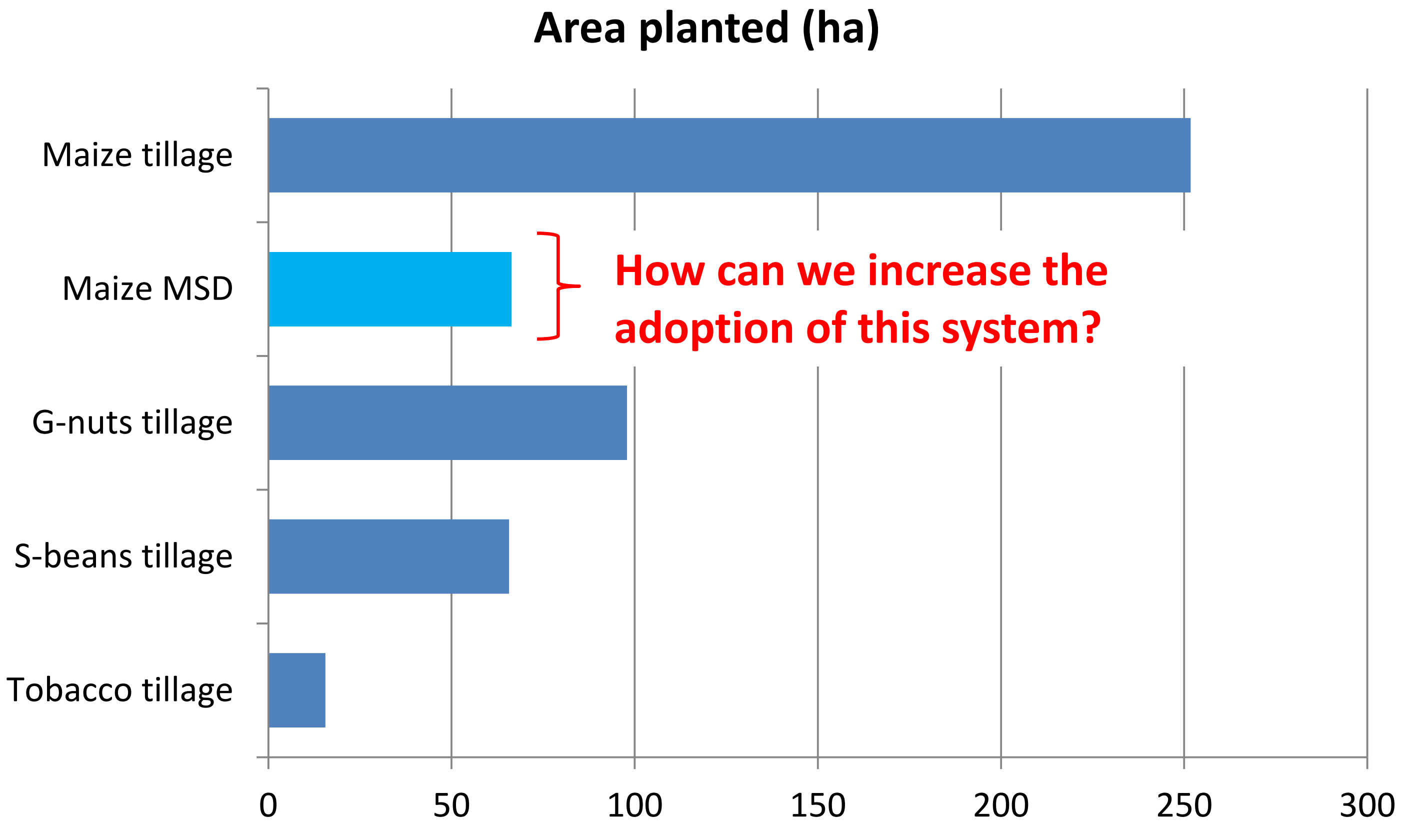
# BCA Data for Malawi

Survey carried out by FAO-EPIC in collaboration with country FAO office for reference cropping season 2012-13

Sample of 524 HHs cultivating 1,433 plots



# Optimal regional crop mix calibrated on data



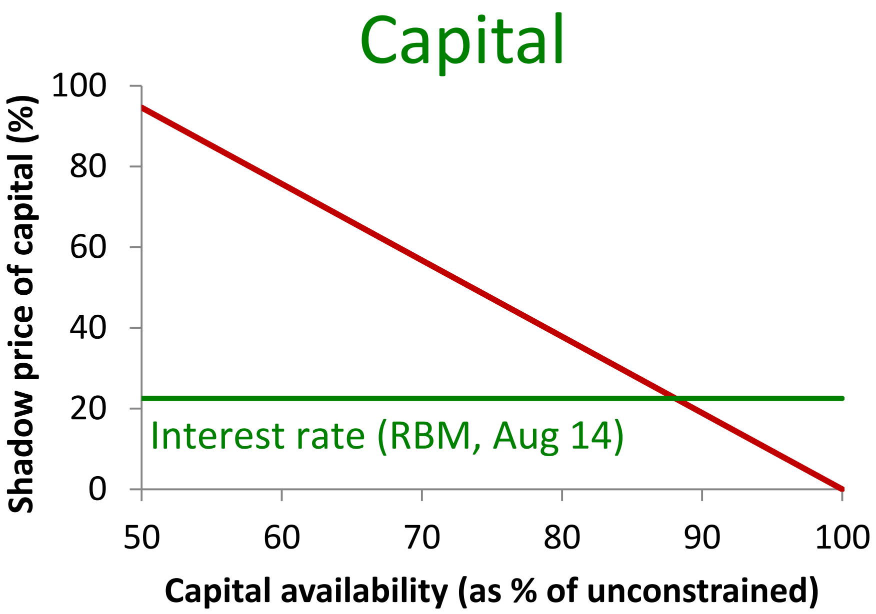
# Optimal input mix with and without constraints

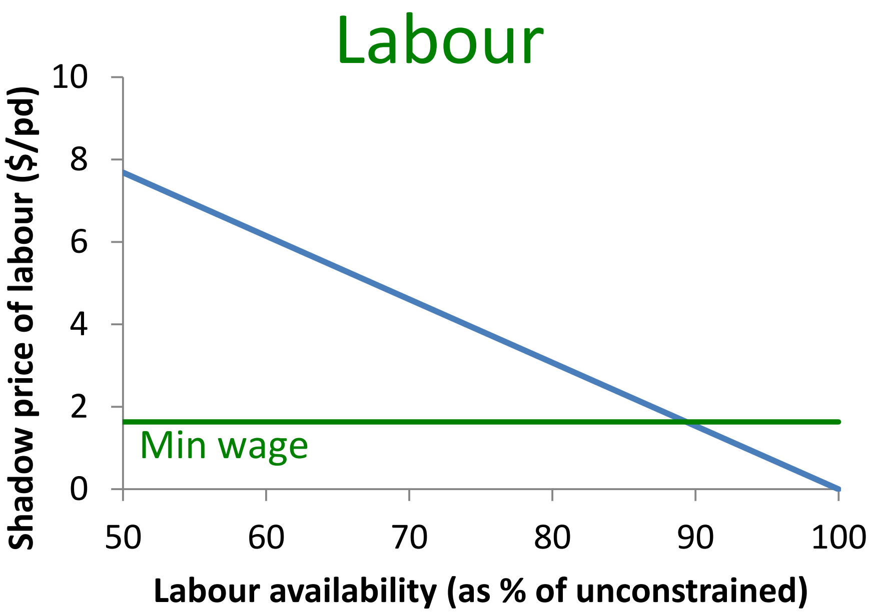
| | Base (unconstrained) | Capital constraint (0.8) | Labour constraint (0.8) |
|---|---|---|---|
| **Profit ($)** | 148,897 | 143,426 | 143,338 |
| **Land (ha)** | 497 | 405 | 402 |
| **Capital ($)** | 144,581 | **115,665** | 116,445 |
| **Seeds (kg)** | 7,955 | 6,577 | 6,406 |
| **Manure and lime (kg)** | 1,010,887 | 807,864 | 797,251 |
| **Fertilizers (kg)** | 99,759 | 80,069 | 80,837 |
| **Chemicals (lt)** | 2,030 | 1,657 | 1,640 |
| **Total labour (pd)** | 77,900 | 1,155,662 | **63,061** |
| **SHADOW PRICE ($)** | | 0.38 | 3.07 |

Value of an additional $ of credit

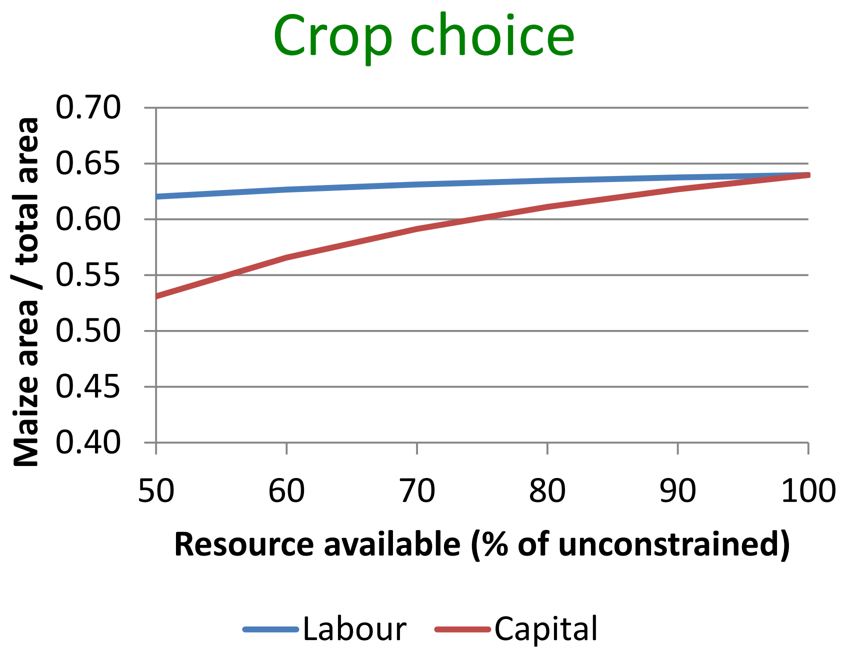
Value of an additional pd of labour

# Sensitivity analysis: shadow prices

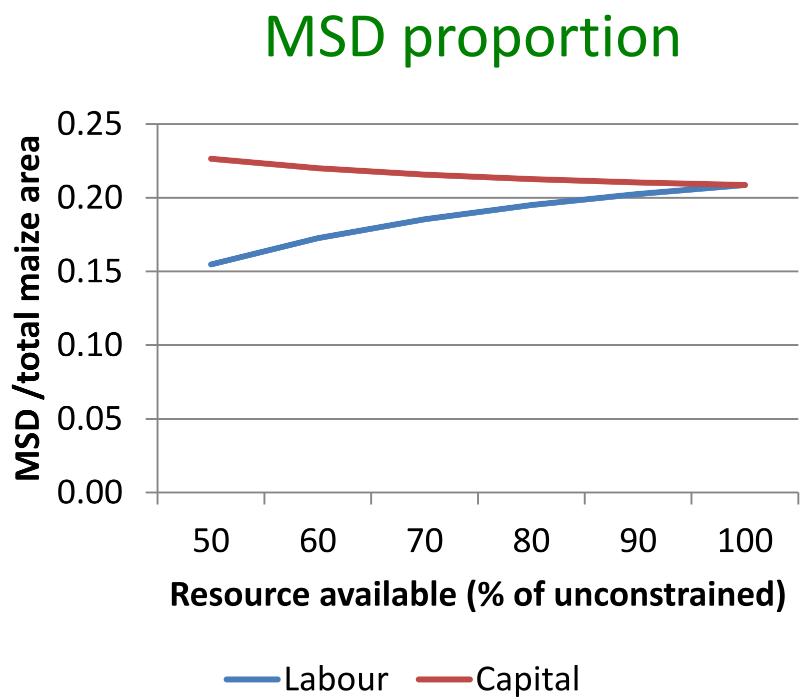


# Sensitivity analysis




Labour constraint has almost no effect on crop choice but it affects the decision to adopt MSD *vs* tillage




Capital constraint has strong effect on crop choice and a small negative effect on MSD area

# Conclusion

Combining econometric results with simulation and optimisation models can greatly enhance our capacity for policy analysis