Maize Response to Nitrogen
Role of soil quality

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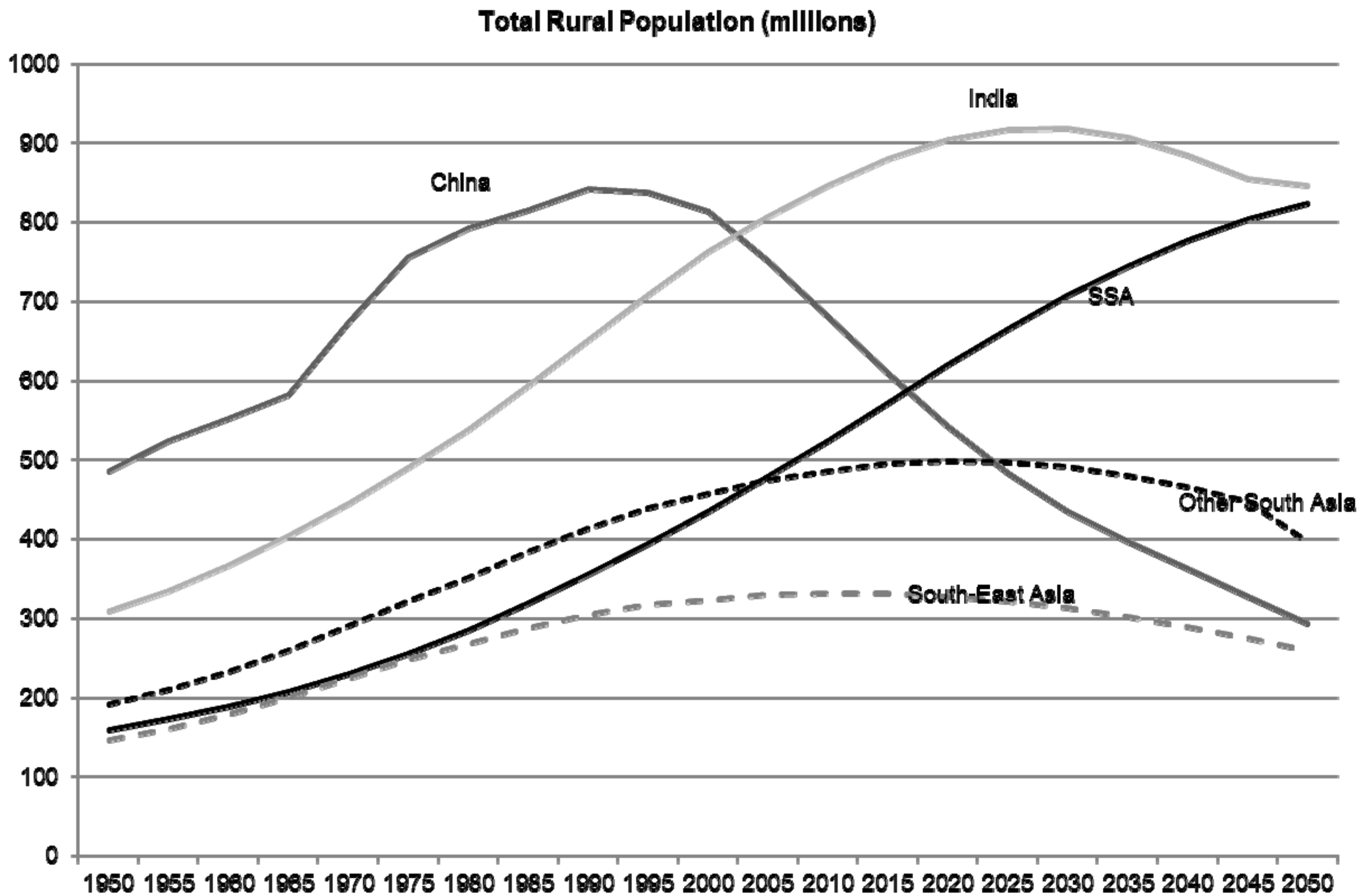
Background

- Region experiencing growing land scarcities as a result of mounting population pressure
- At high population densities, the positive relationship between population density and land intensification breaks down
- Unsustainable forms of agricultural intensification set in partly due to declining soil quality
- Region faces escalating soil fertility crisis costing the continent more than $4 billion worth of soil nutrients per year (IFDC, 2006)
- Region is experiencing degraded soil poverty traps

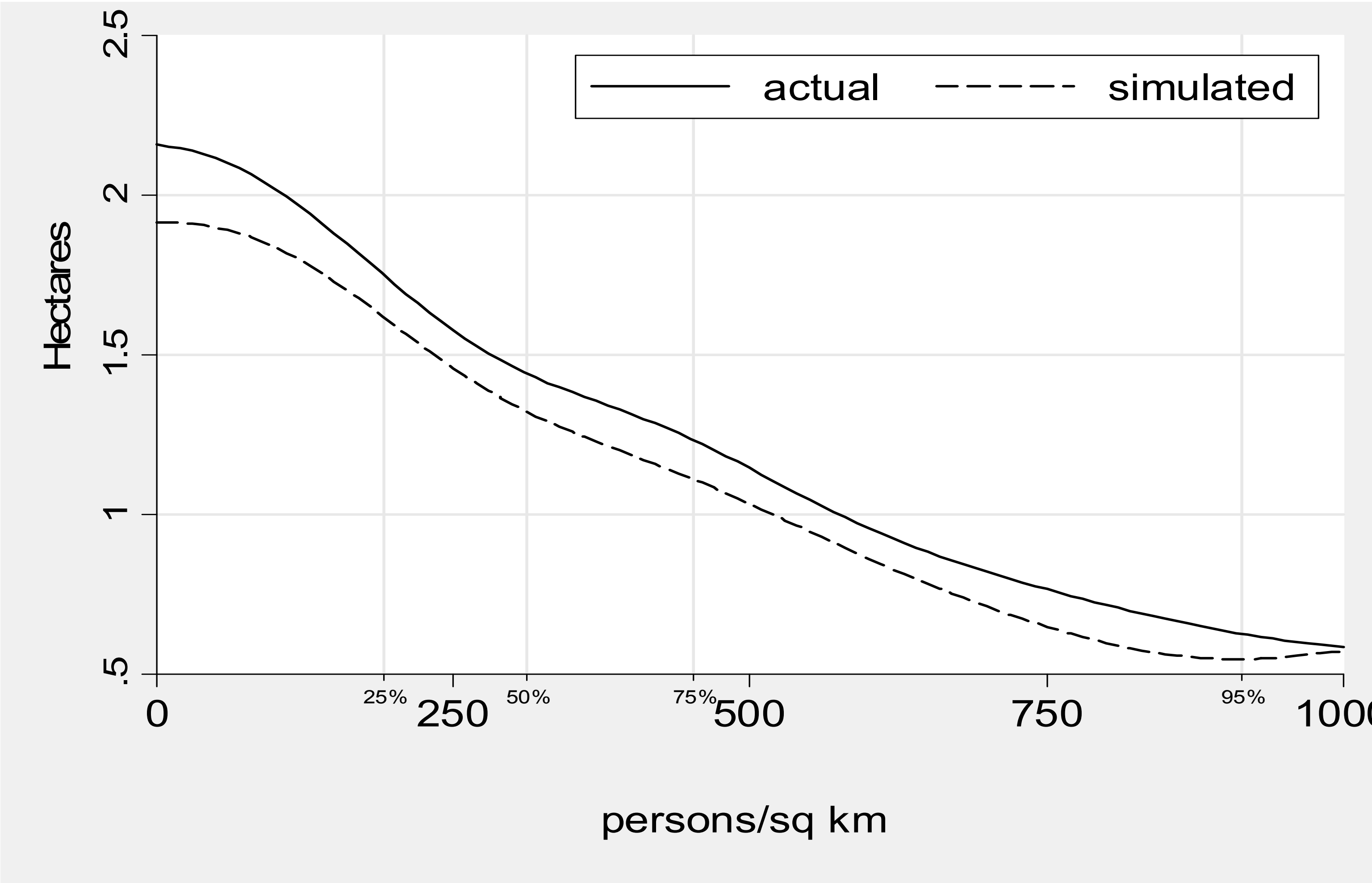
Total rural population projections



Source: UN Pop Council, 2013

Declining arable land per household in agriculture

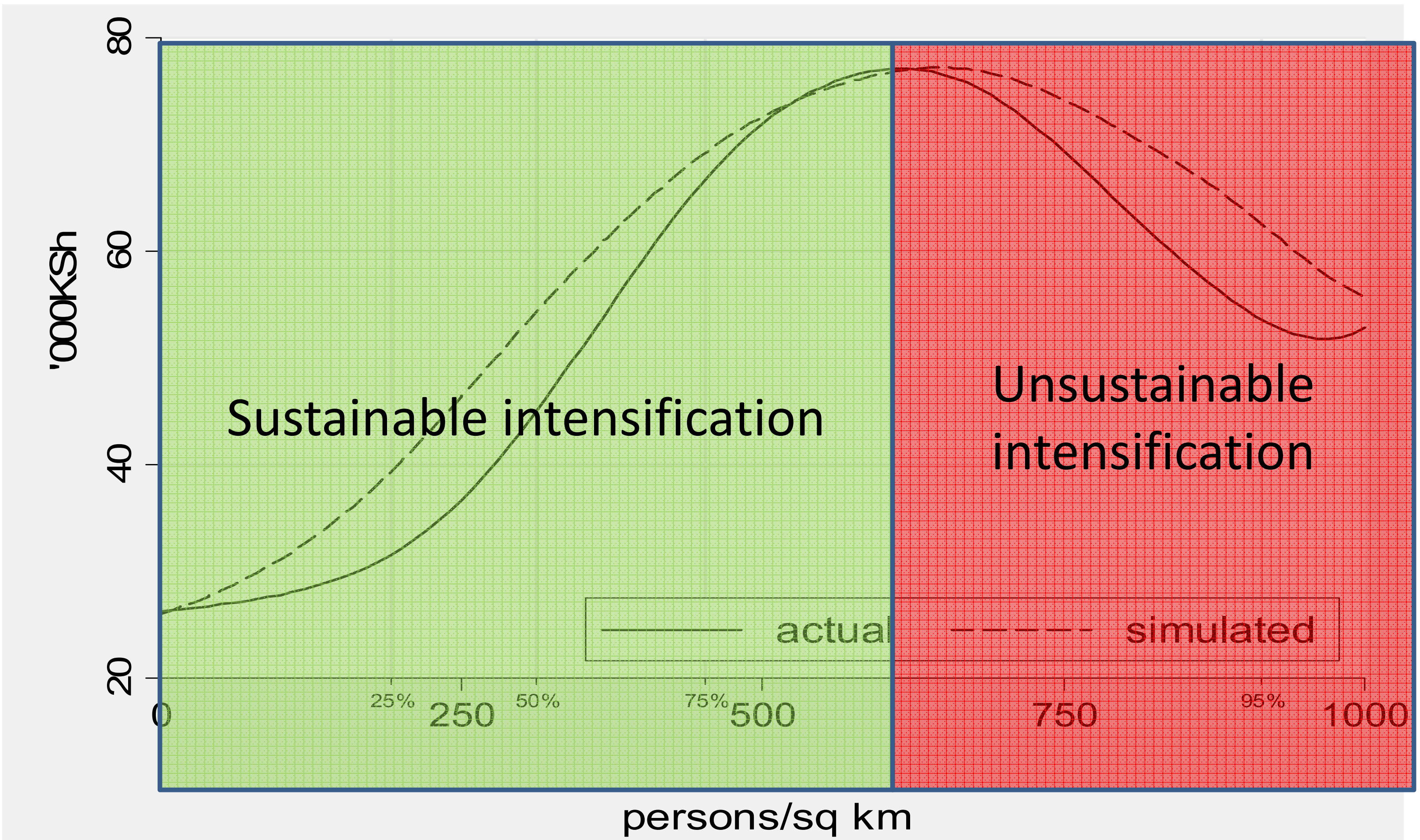
Figure 1: Area cultivated per household



Source: Tegemeo Institute Panel Data, Kenya

Unsustainable agricultural intensification

Figure 4: Net crop income per hectare cultivated



Source: Tegemeo Institute Panel Data, Kenya

Population densities in 10 topmost densely populated districts in Kenya

Province	District	Rural population	Density
Western	Emuhaya	135,723	1,011
Western	Hamisi	148,259	948
Western	Vihiga	96,535	931
Nyanza	Kisii Central	283,117	844
Nyanza	Gucha	364,460	821
Nyanza	Manga	87,859	789
Nyanza	Nyamira	263,201	779
Central	Githunguri	128,643	772
Nyanza	Gucha South	146,307	760

Source: Republic of Kenya, KNBS, 2009 Population Census Data

Low maize-fertilizer response rates on farmer-managed fields

Study	country	Agronomic response rate (kgs maize per kg N)
Morris et al (2007)	W/E/S Africa	10-14
Sheahan et al (2013)	Kenya	14-21
Marenya and Barrett (2009)	Kenya	17.6
Liverpool-Tasie (2015)	Nigeria	8.0
Burke (2012)	Zambia	9.6
Snapp et al (2013)	Malawi	7.1 to 11.0
Holden and Lunduka (2011)	Malawi	11.3
Pan and Christiaensen (2012)	Tanzania	8.5 to 25.5
Minten et al (2013)	Ethiopia	11.7

Factors behind the low maize-fertilizer response rates

1. Soil fertility depletion
2. Soil acidification

Soil fertility depletion

1. Nutrient mining and erosion
   – Micro-nutrient deficiencies
2. Low soil organic matter
   – Significant decline in SOM over past 20 years in Malawi (Mpeketula and Snapp)

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International Year of Soils

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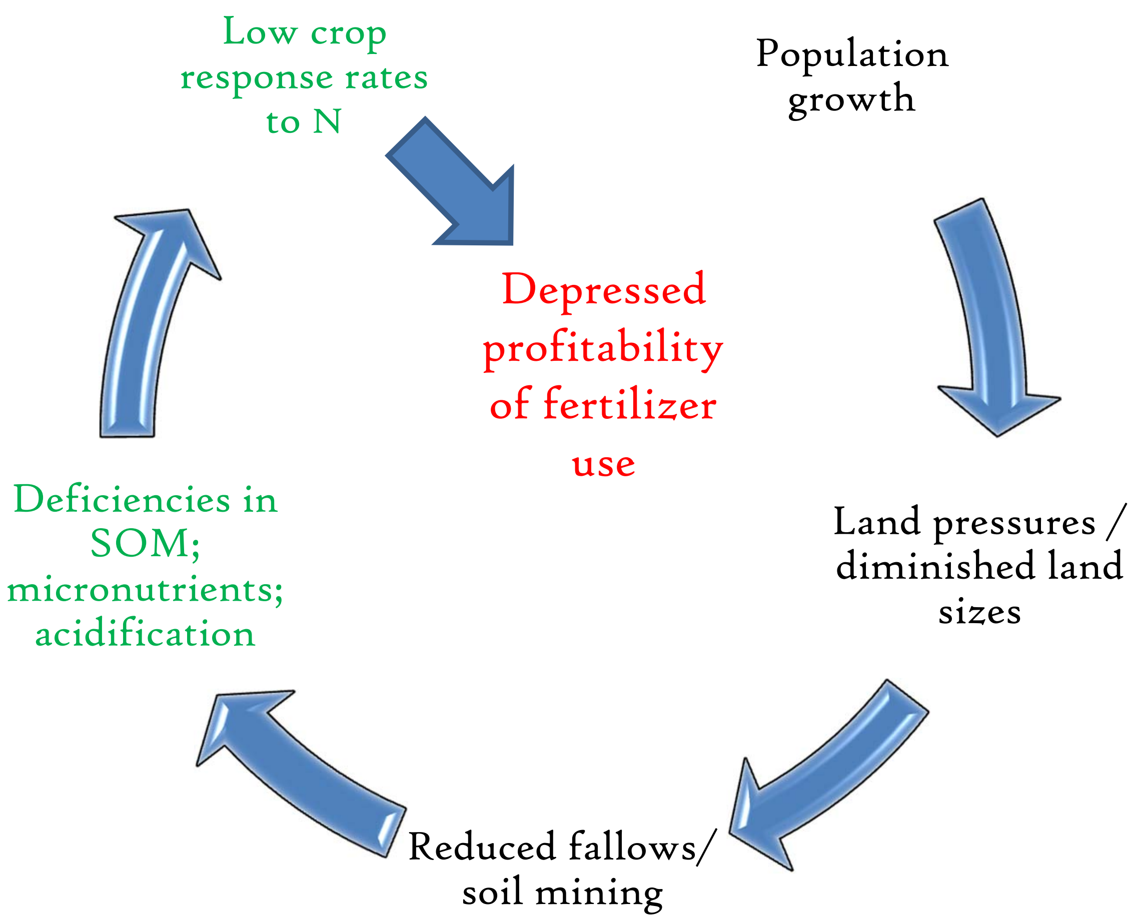
Factors behind the low maize-fertilizer response rates

1. Soil fertility depletion
2. Soil acidification

Soil acidification

- Constant mono-cropping
- Long term and repeated use of nitrogen based fertilizers
- Reduced farm yields
  - "...from now henceforth, we shall not be accepting inputs which cause more harm than good to our crops", Patrick Khaemba, Governor, Trans Nzoia County, Kenya

Conceptual framework



Study approach

- Hypotheses
  - Soil organic carbon influences maize response to fertilizer (N)
  - Active soil organic carbon (AC) is a function of plot management history
- Estimation strategy
  - Control Function approach

Data sources

- 2014 rural household survey data in Kenya
  - 650 households
  - 5 counties: Uasin Gishu, Trans-Nzoia, Kakamega, Kisii & Machakos
- Largest maize plot information
  - Characteristics (size, manager, etc.)
  - History (fallow, soil and water conservation, etc.)
  - Soil quality (AC, SOC, CEC, pH, etc.)

Econometric models [I]

- First stage:
- Dependent variable: active carbon
- Explanatory variables:
  - Plot characteristics:
    - size, manager, active disputes, etc.
  - Plot history:
    - when cleared, fertilizer application, crops grown, preparation, water and soil conservation practices, GIS characteristics, etc.

Econometric models [II]

- Second stage:
- Dependent variable: maize kg/ha
- Explanatory variables:
  - Variables of interest:
    - N kgs, active carbon, active carbon*N
  - Other variables:
    - Cropping system, maize seed, land preparation, labor, demographic variables, other soil qualities, etc.

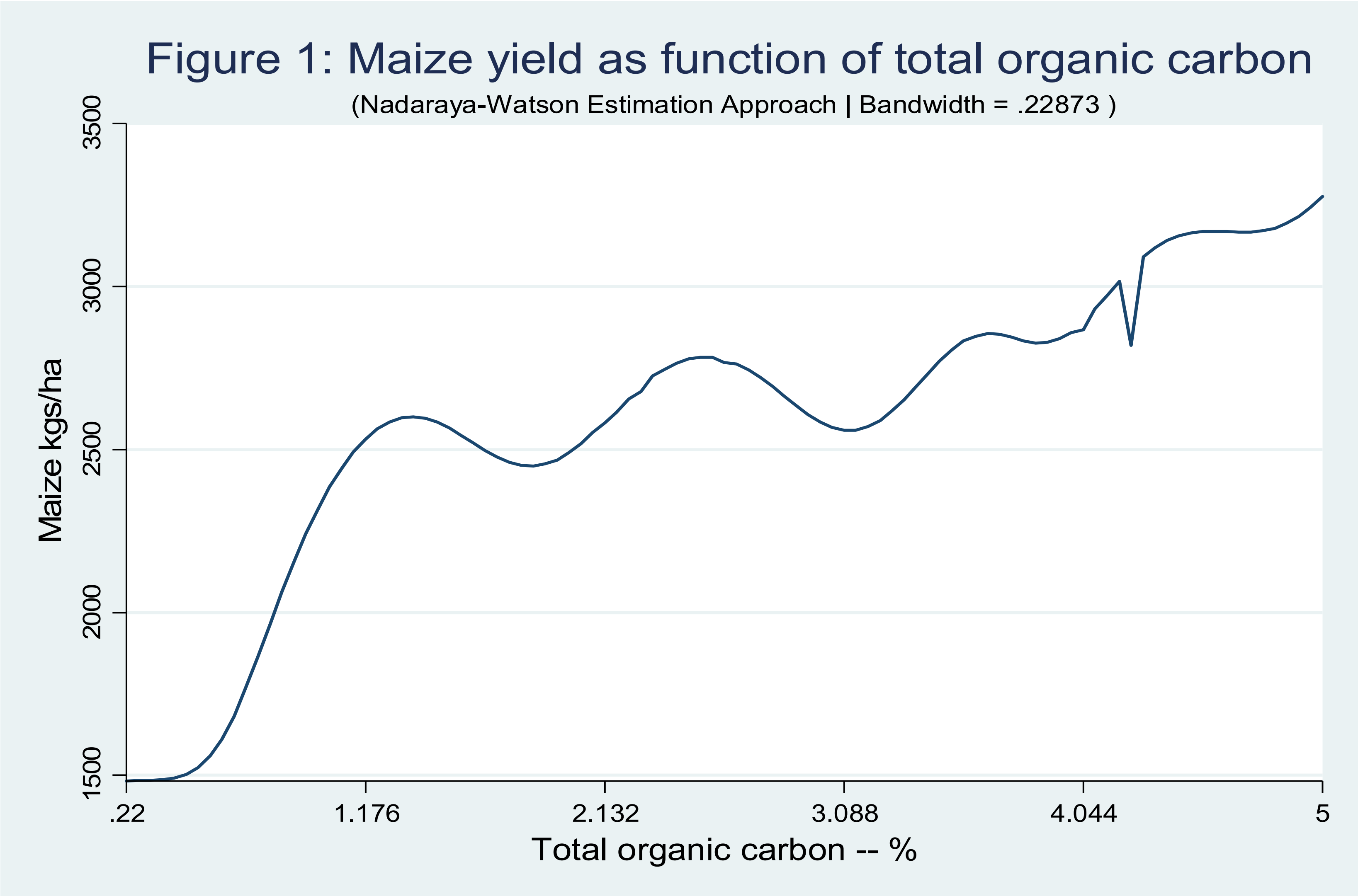


Figure 1: Maize yield as function of total organic carbon
(Nadaraya-Watson Estimation Approach | Bandwidth = .22873)
Maize kgs/ha
3500
3000
2500
2000
1500
.22
1.176
2.132
3.088
4.044
5
Total organic carbon -- %

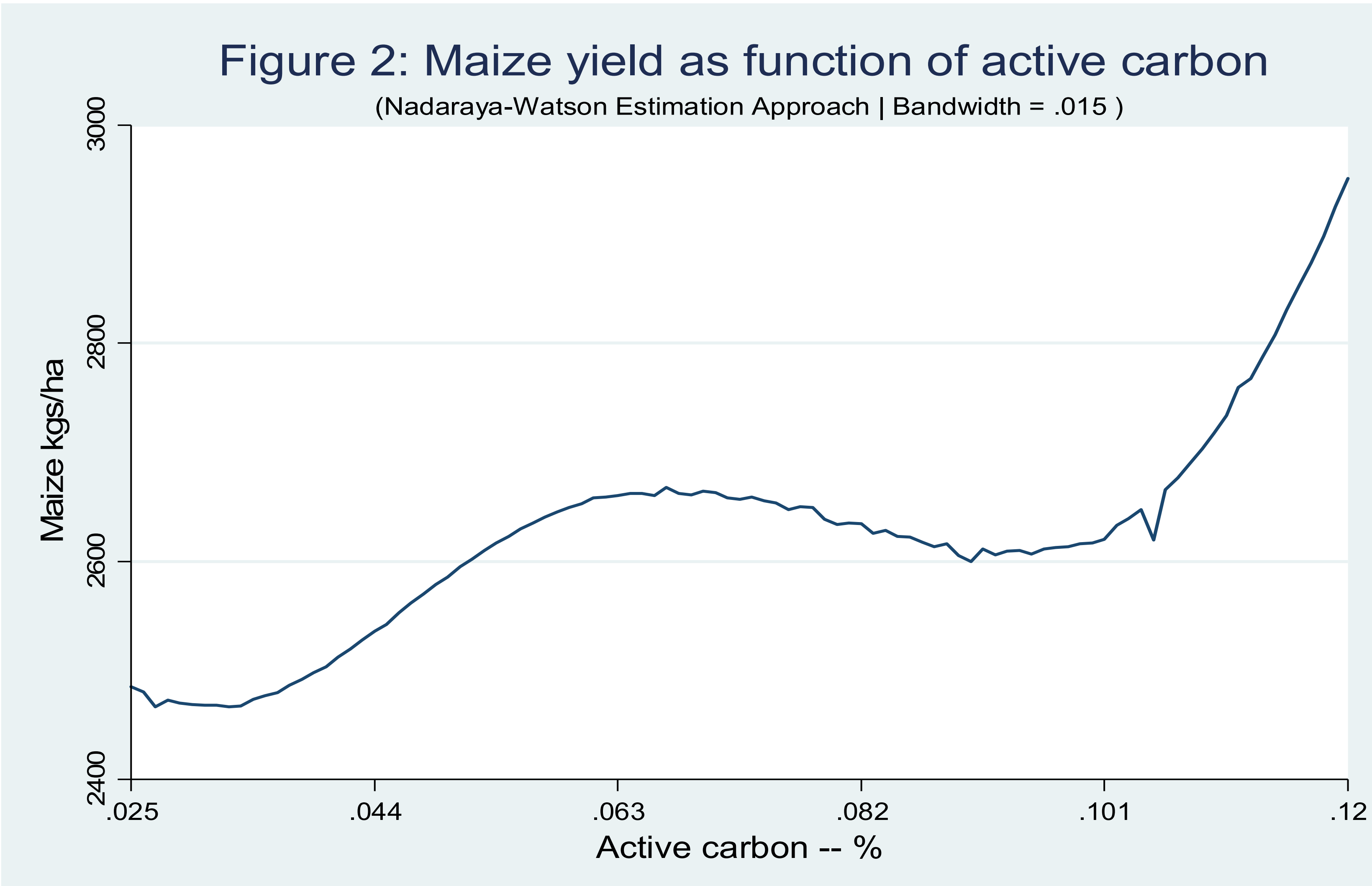


Figure 2: Maize yield as function of active carbon
(Nadaraya-Watson Estimation Approach | Bandwidth = .015)
Maize kgs/ha
3000
2800
2600
2400
.025
.044
.063
.082
.101
.12
Active carbon -- %

Econometric results
First Stage: Soil organ carbon

Dep var: SOC	Coef.	P>t
Maize field size (ha)	-0.0388	0.16
Number of years field has been in cultivation	-0.0326	0.14
Field has active dispute concerns (years)	-0.0118	0.05
Field land preparation (base: manual/no preparation)		
_oxen	0.1944	0.10
_tractor	-0.3008	0.01
Livestock graze in the field after harvest (# of years)	-1.3130	0.00
Soil and water conservation practices (# of years)		
_crop rotation	0.2723	0.08
_crop basins	0.6472	0.09
_minimum tillage	0.1519	0.14
_drain water logged field	0.1565	0.09
_planted trees	0.4312	0.00
Elevation	0.0030	0.00
_cons	-2.6618	0.00
Obs	590	
R square	0.46	

Econometric results
Second Stage: Maize response to N

Dep. var: Maize yield (kgs/ha)	Coef.	P>t
Maize field size (ha)	-337.30	0.03
N/ha (kgs)	5.63	0.00
TOC- Total oganic carbon (%)	133.54	0.25
TOC*N/ha	3.54	0.00
Hybrid maize seed (1=yes; 0=no)	477.43	0.01
Seed rate (kgs/ha)	172.18	0.05
Sq seed rate (kgs/ha)	-1.31	0.78
Land preparation (base=manual)		
_oxen	552.49	0.00
_tractor	287.67	0.18
Labor intensity (days/ha harvested)	3.11	0.01
Soil pH	151.09	0.11
Soil texture (base=clay)		
_sandy	-6.22	0.22
_silt	-26.61	0.03
First stage regression residuals	-197.72	0.17
_cons	-232.01	0.79
Obs	590	
R square	0.37	

Econometric results
First Stage: Active Carbon

Dep var.: Active carbon %	Coef.	P>t
Total organic carbon	0.0088	0.00
Number of years field has been in cultivation	-0.0008	0.07
Inorganic fertilizer application (base: no application)		
_planting	-0.0013	0.60
_top dress	-0.0028	0.08
Field land preparation (base: manual/no preparation)		
_oxen	0.0067	0.00
_tractor	-0.0070	0.01
Livestock graze in the field after harvest (1=yes; 0=no)	-0.0178	0.00
Soil and water conservation practices (1=yes; 0=no)		
_terracing	0.0032	0.06
_grass strip	-0.0032	0.06
_planted trees	-0.0060	0.00
Elevation	0.0000	0.04
_cons	0.0949	0.00
Obs	590	
R square	0.35	

Econometric results
Second Stage: Maize response to N

Dep. var.: Maize yield (kgs/ha)	Coef.	P>t
Maize field size (ha)	-225.36	0.08
N/ha (kgs)	4.42	0.01
AC- Active carbon (%)	9,709.83	0.21
AC*N/ha	139.02	0.00
Hybrid maize seed (1=yes; 0=no)	444.93	0.01
Seed rate (kgs/ha)	190.24	0.03
Sq seed rate (kgs/ha)	-2.32	0.61
Land preparation (base=manual)		
_oxen	448.58	0.03
_tractor	400.91	0.05
Labor intensity (days/ha harvested)	2.94	0.01
Field decision maker months at home in a year	-46.92	0.18
Soil pH	165.90	0.08
Soil texture (base=clay)		
_sandy	-8.51	0.10
_silt	-18.94	0.10
First stage regression residuals	-16,023.66	0.05
_cons	-788.08	0.44
Obs	590	
R square	0.31	

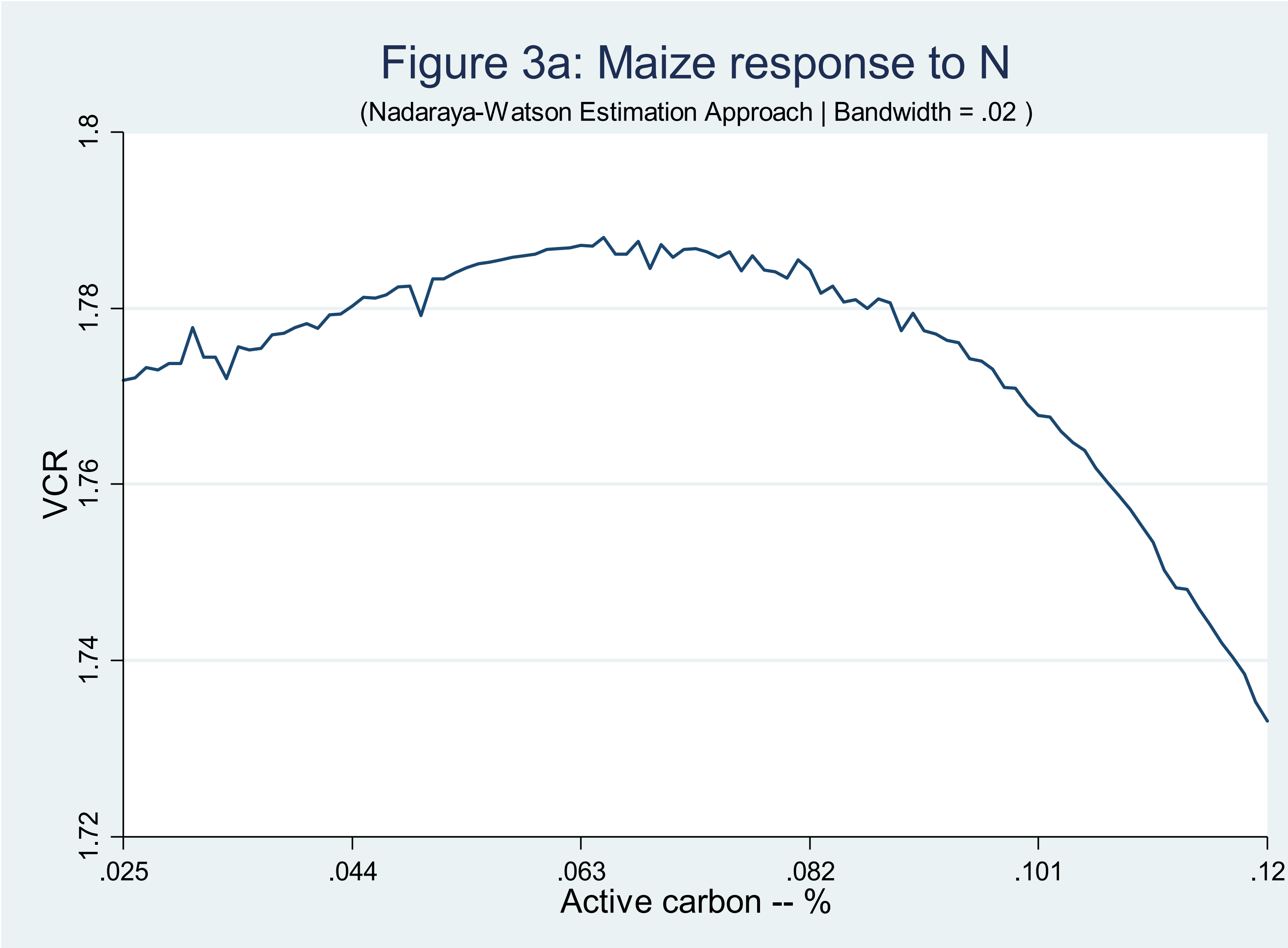


Figure 3a: Maize response to N
(Nadaraya-Watson Estimation Approach | Bandwidth = .02)
VCR
1.8
1.78
1.76
1.74
1.72
.025
.044
.063
.082
.101
.12
Active carbon -- %

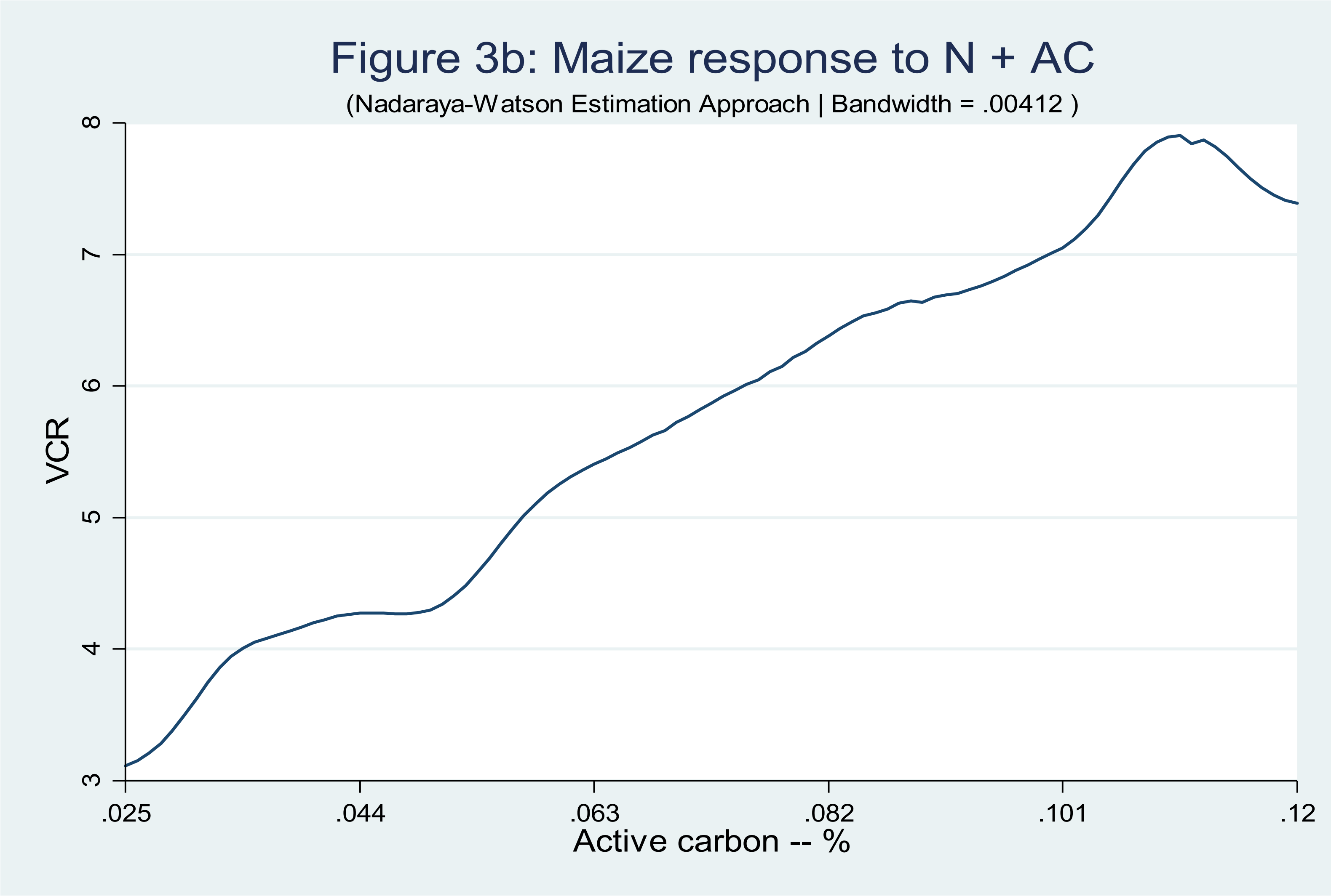


Figure 3b: Maize response to N + AC
(Nadaraya-Watson Estimation Approach | Bandwidth = .00412)
VCR
3
4
5
6
7
8
.025
.044
.063
.082
.101
.12
Active carbon -- %

Conclusions

- Active carbon influences maize crop response to nitrogen
- Active carbon is indeed endogenous
  - Function farm management practices

Policy question

How to move from a situation where ISPs are the cornerstone of agricultural development to a holistic program of sustainable productivity growth?

Policy recommendations

1. R&D (national ag research)
2. Extension programs / soil testing
3. Programs to help farmers restore soil quality
4. More appropriate fertilizer use recommendations