Does participation in climate-smart agriculture programs enhance environmental sustainability and food security? Evidence from southern Malawi

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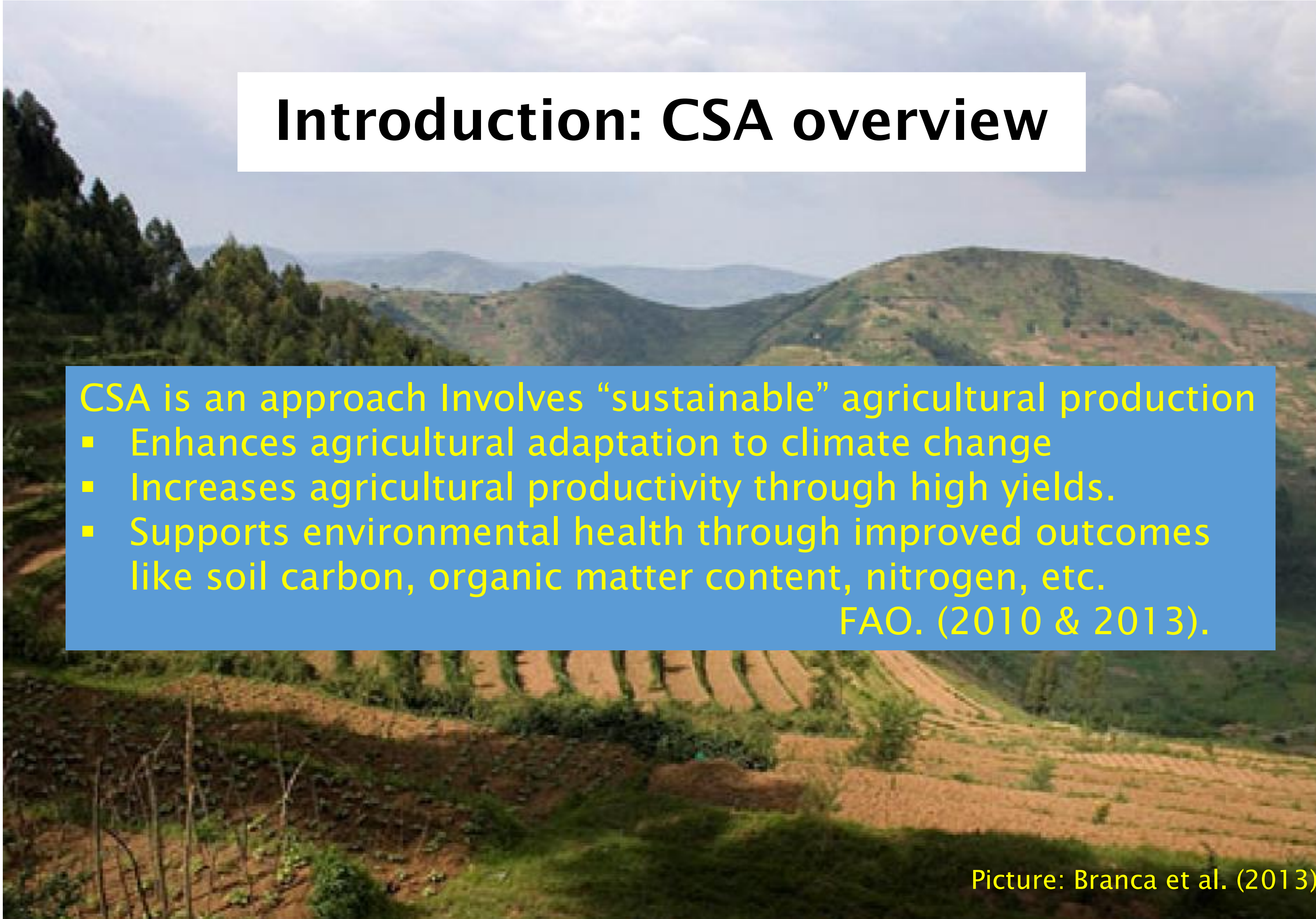
Outline

- ❖ Study motivation & research questions.
- ❖ Sample selection & data
- ❖ Analytical technique – Endogenous switching regression (ESR) and control function (CF) for endogeneity & selection bias.

Introduction: CSA overview



CSA is an approach Involves “sustainable” agricultural production

- Enhances agricultural adaptation to climate change
- Increases agricultural productivity through high yields.
- Supports environmental health through improved outcomes like soil carbon, organic matter content, nitrogen, etc.

FAO. (2010 & 2013).

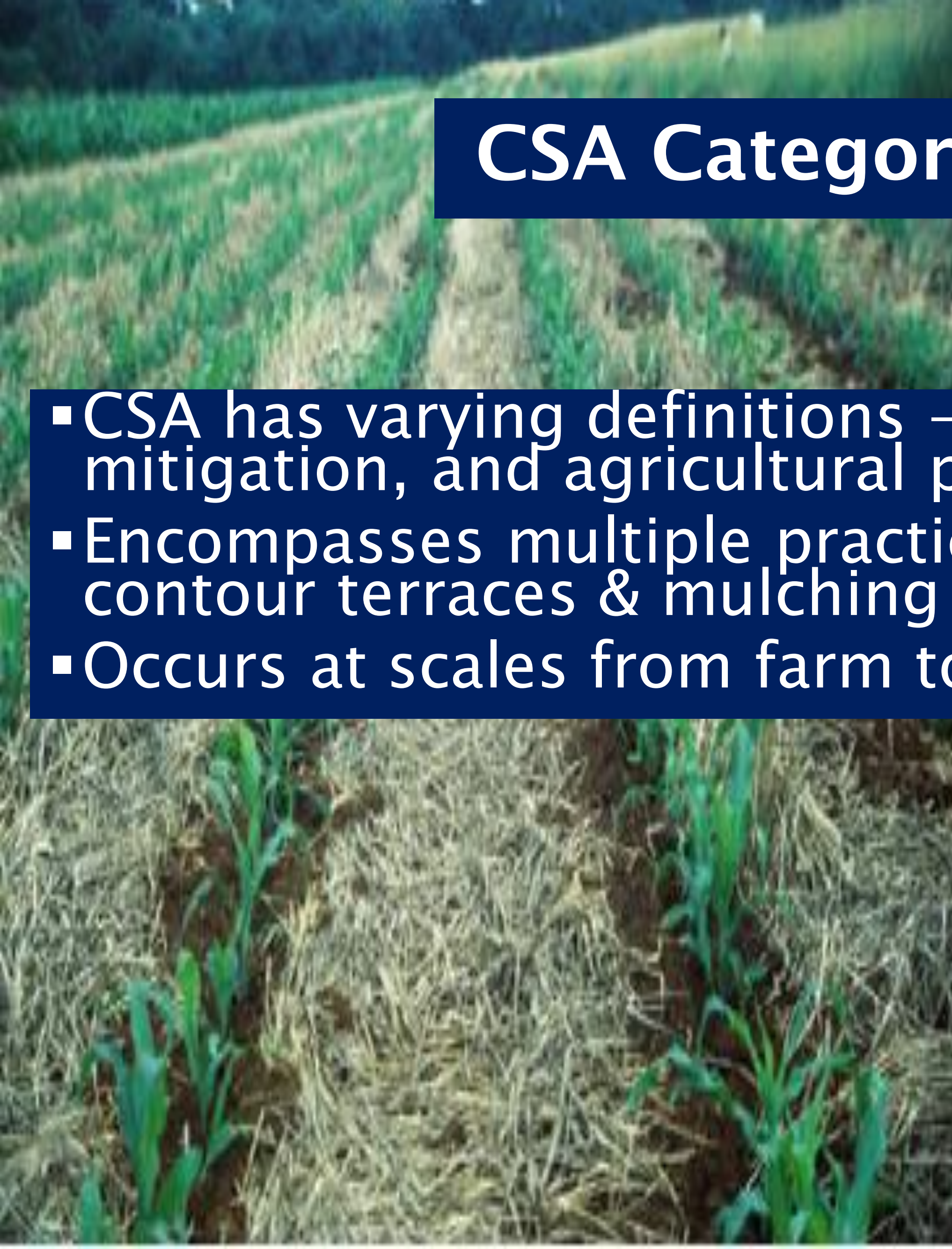
Picture: Branca et al. (2013)

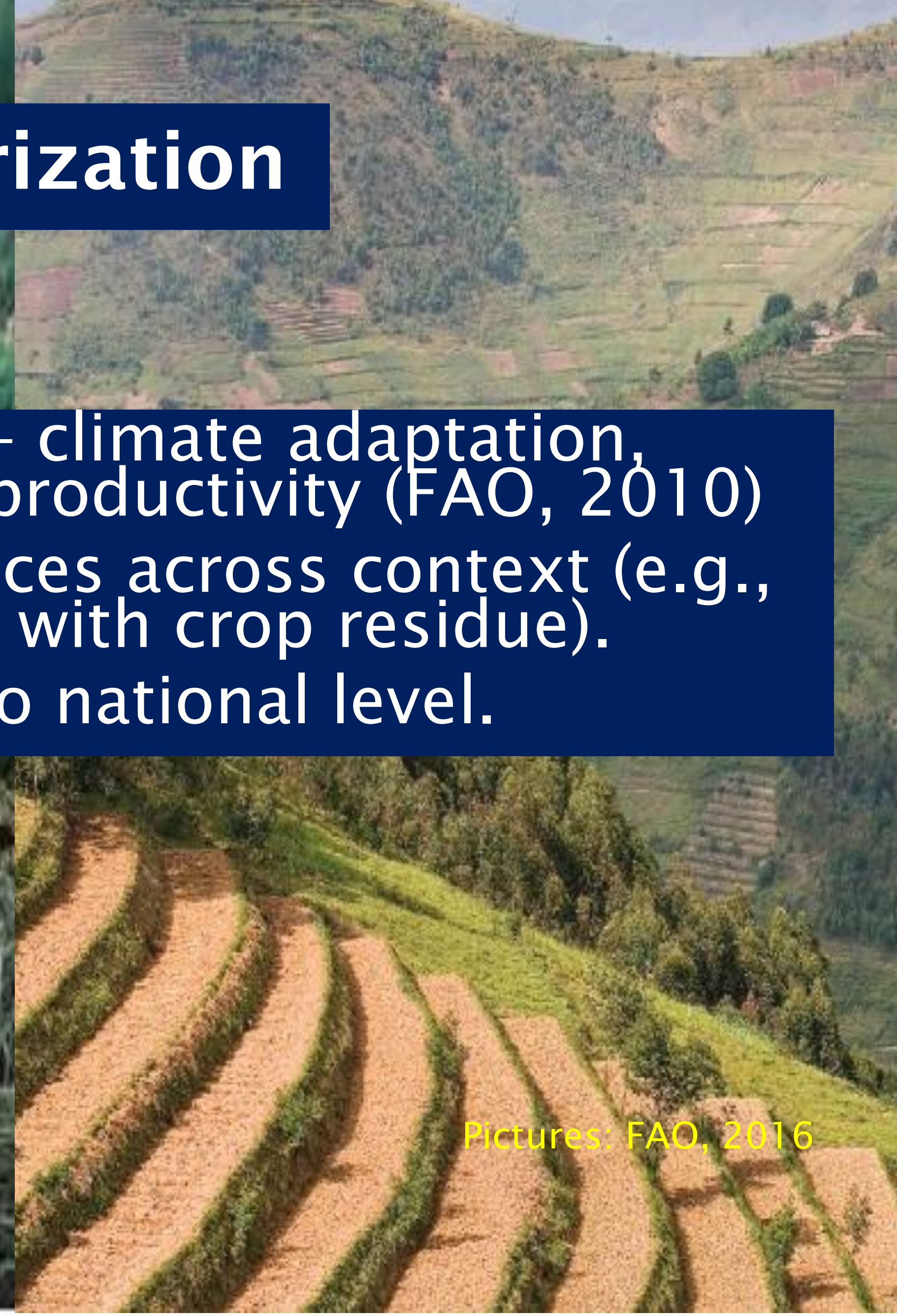
Highlights of the main results

Results show that CSA program participation significantly increased crop yields & environmental factors as follows:

- Maize yields by 87%.
- Soil organic matter content by 56%.
- Soil organic carbon by 41%.
- Soil Nitrogen content by 39%.
- Soil Potassium content by 29%.

CSA Categorization



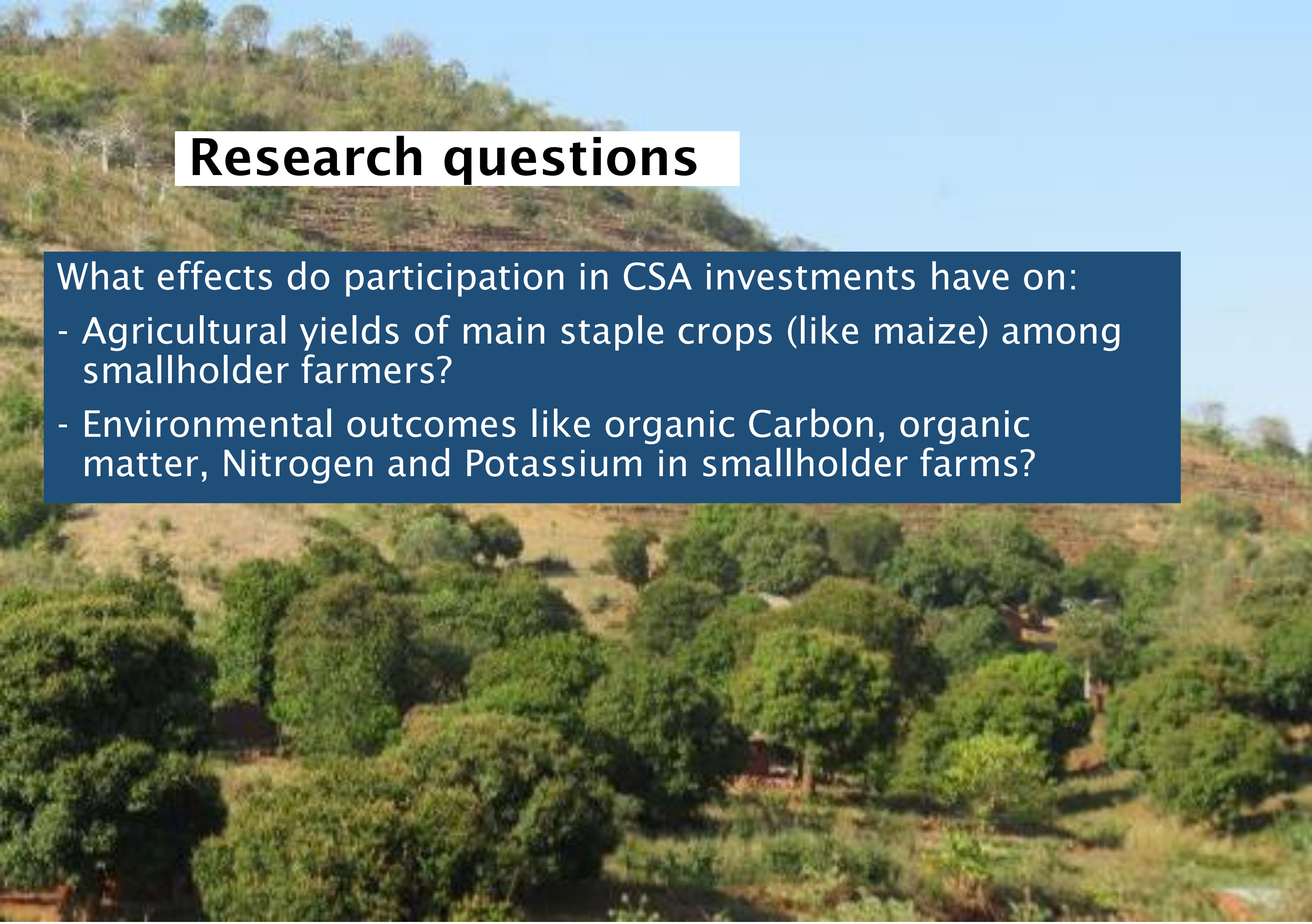


- CSA has varying definitions – climate adaptation, mitigation, and agricultural productivity (FAO, 2010)
- Encompasses multiple practices across context (e.g., contour terraces & mulching with crop residue).
- Occurs at scales from farm to national level.

Pictures: FAO, 2016

Motivation

- CSA financing a major global objective in the past decade:
  - $100bn projected in 2020 (Dinesh, 2017; World Bank, 2017).
- Limited impact assessment of CSA program participation on socioeconomic outcomes (like crop yields) and environmental outcomes (like soil organic matter and carbon, and nitrogen).
- Conclusion of a major aid funded CSA project in southern Malawi presents an opportunity to address this gap.



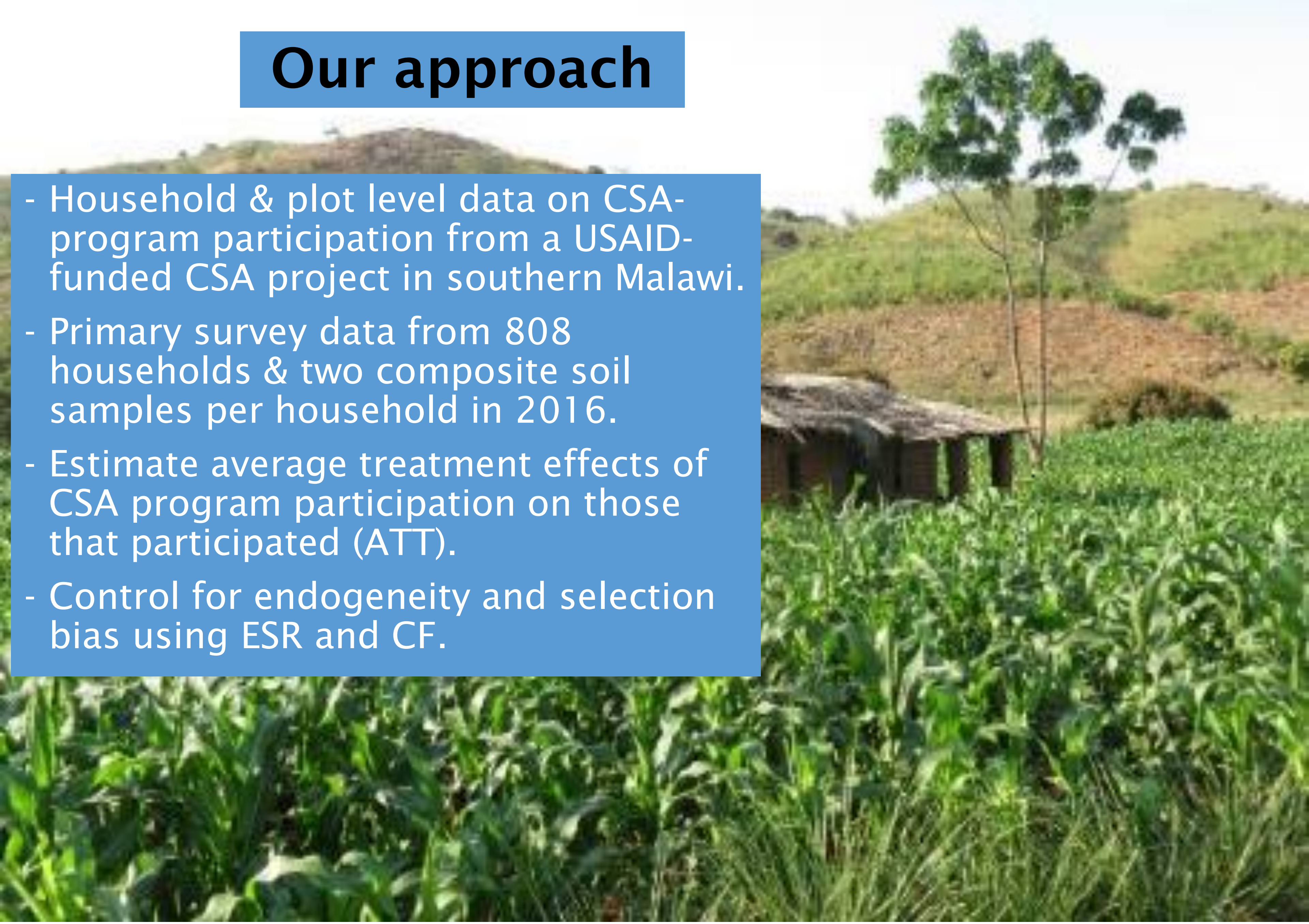
Research questions

What effects do participation in CSA investments have on:

- Agricultural yields of main staple crops (like maize) among smallholder farmers?
- Environmental outcomes like organic Carbon, organic matter, Nitrogen and Potassium in smallholder farms?

Study context: Wellness & Agriculture for Life Advancement (WALA) project

- A $86 million USAID-funded food security & community development project in southern Malawi.
- Promoted CSA through watershed development in eight districts in southern Malawi, 2009-2014.
- Ended in 2014. But no quantitative impact assessment occurred.

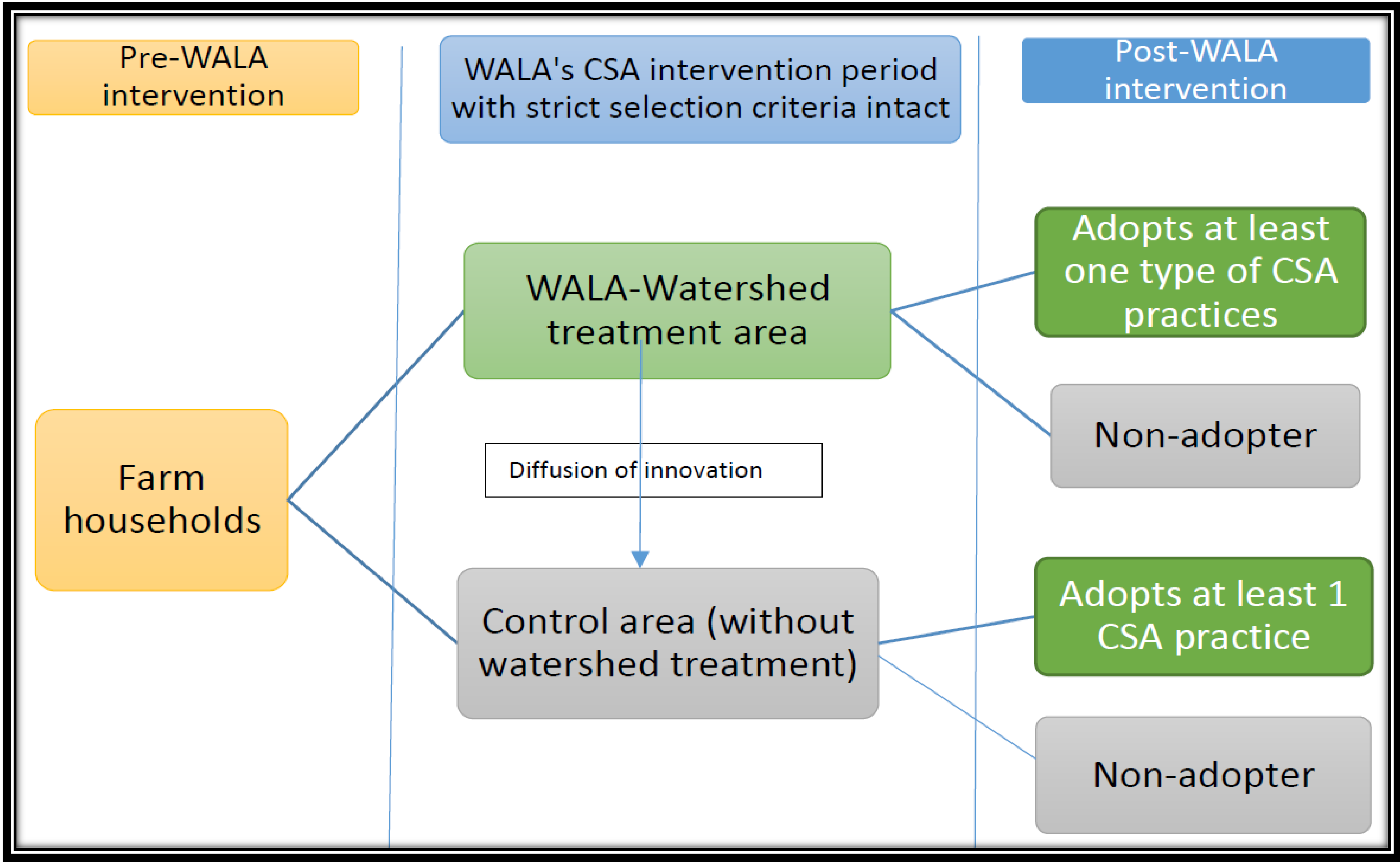


Our approach

- Household & plot level data on CSA-program participation from a USAID-funded CSA project in southern Malawi.
- Primary survey data from 808 households & two composite soil samples per household in 2016.
- Estimate average treatment effects of CSA program participation on those that participated (ATT).
- Control for endogeneity and selection bias using ESR and CF.

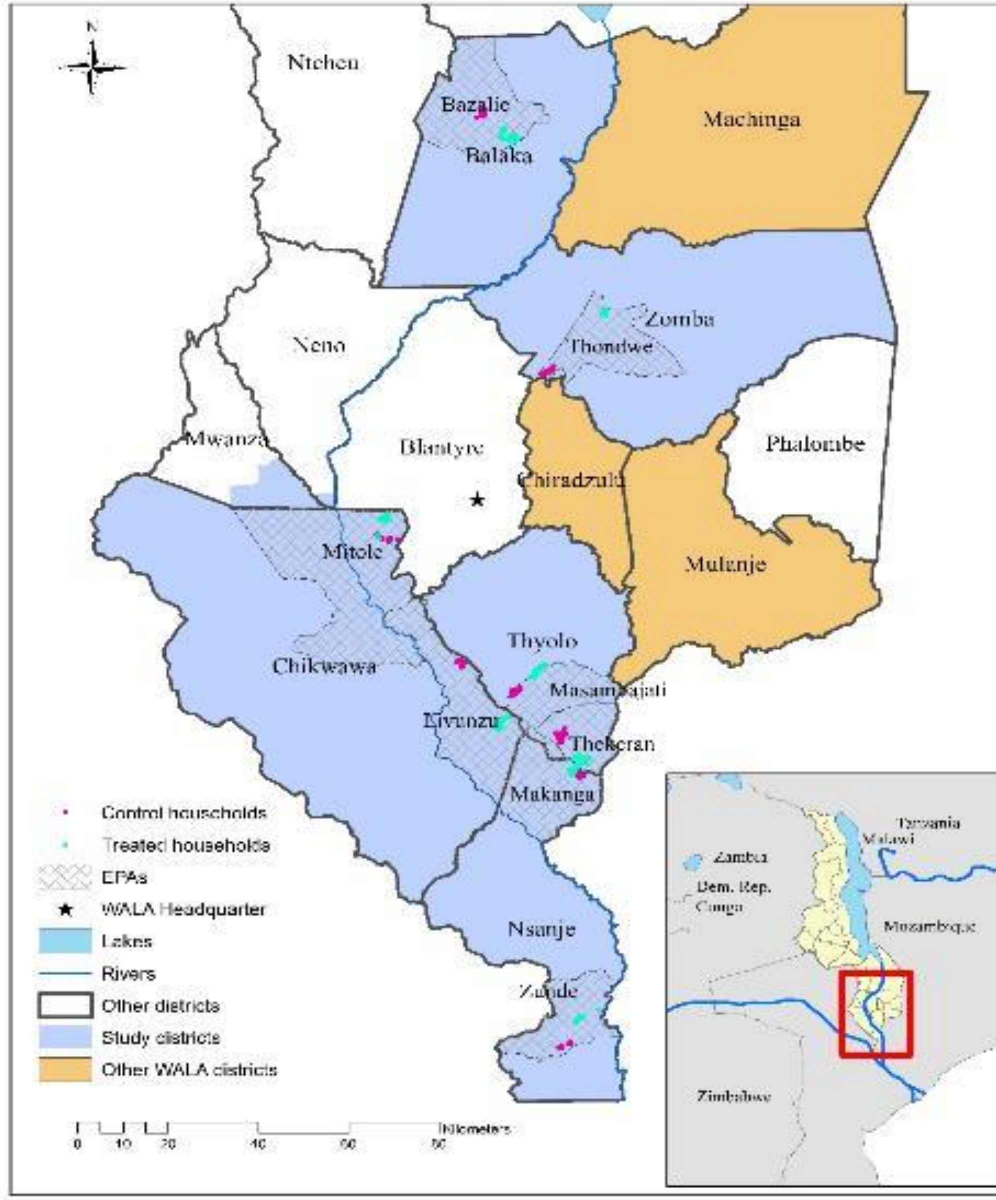
Examples of CSA practices under WALA

Stylized theory of change



Data

- Treatment & control Grouped Village Headman (GVH) communities in 5 districts.
- Randomly sampled 15% of households per GVH.
- A total of 808 households surveyed on maize yield in 2016.
- Two composite soil samples per household's main plot.
- Obtain soil properties through analyses at Chitedze lab in Lilongwe



Map of the distribution of households in the study

Sample selection in the study area

District	Extension planning area	Participation status of Households selected		Total households selected
		Treated (1)	Control (0)	
Balaka	Bazalie	61	29	90
Chikwawa	Livunzu	60	58	118
	Mitole	72	37	109
Nsanje	Makhanga	45	34	79
	Zunde	41	41	82
Thyolo	Masambajati	65	51	116
	Thekeran	63	74	137
Zomba	Thondwe	43	34	77
N = 5	Total = 8	450	358	808

Summary statistics for outcome variables

Variable	Full sample		Mean by treatment status				
			Participants		Control		Mean
	Mean	SD	Mean	SD	Mean	SD	diff
CSA program participation	0.56	0.50	–	–	–	–	–
Maize yield/acre	6.54	5.85	8.08	6.40	4.60	4.37	3.48***
Organic carbon	1.29	0.89	1.50	0.96	1.03	0.73	0.47***
Organic matter	2.26	1.48	2.60	1.48	1.70	1.28	0.90***
Soil Nitrogen	0.12	0.09	0.14	0.10	0.09	0.08	0.04***
Soil Potassium	0.18	1.32	0.15	0.15	0.21	1.98	-0.06

Threshold Values

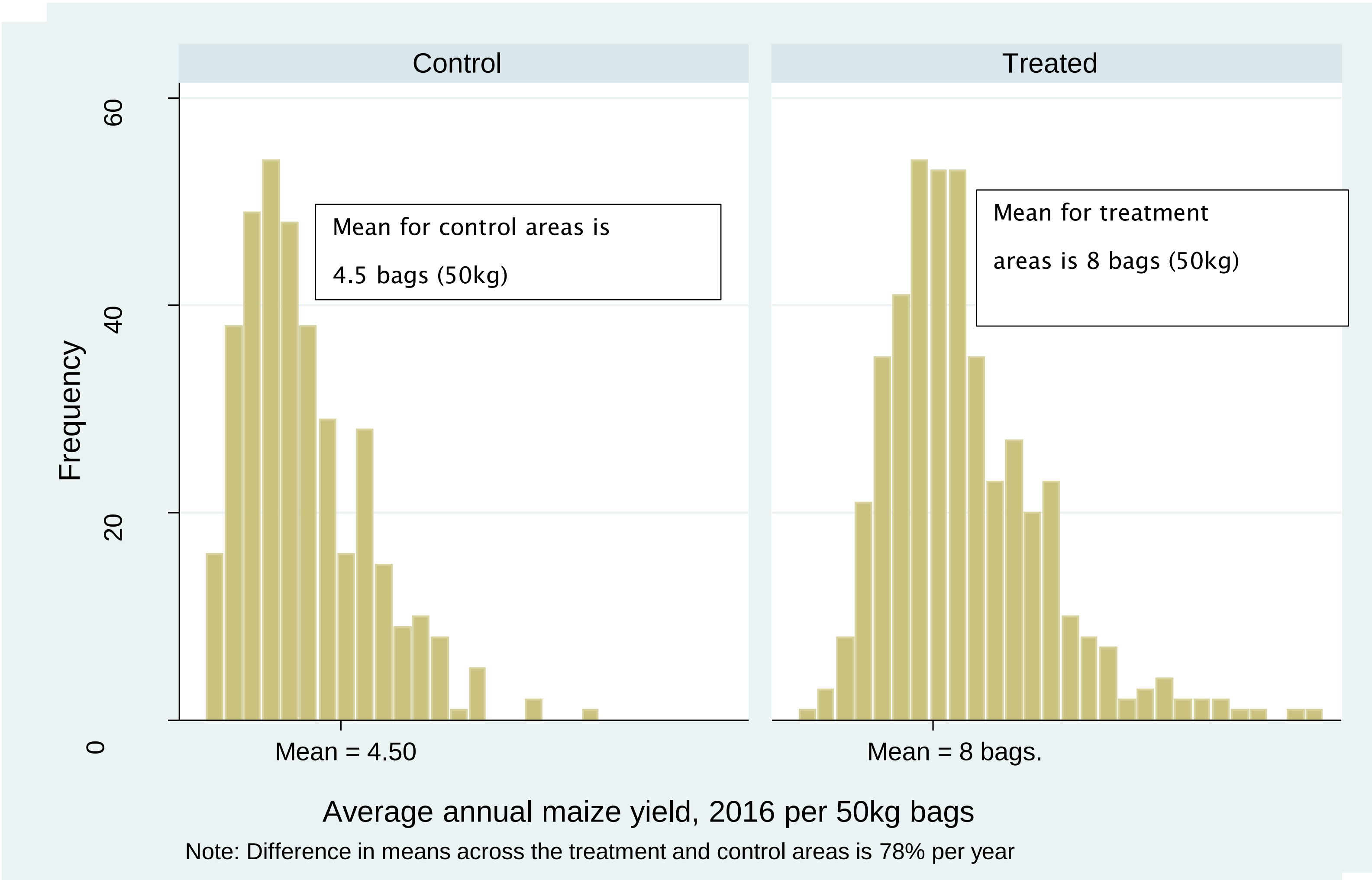
% Carbon		Organic matter%	Rating
< 0.88	low	1.5	low
0.88 - 2.35	medium	1.5 - 4.0	medium
> 2.35	medium	> 4.0	High

% Nitrogen	Rating
< 0.08	Very low
0.08 - 0.12	Low
0.12 - 0.20	Medium
0.20 - 0.30	High
> 0.30	Very high

Potassium cmol/kg (Mehlich 3)	Rating
< 0.05	very low
0.06 - 0.10	low
0.11 - 0.40	medium (adequate range)
0.50 - 0.80	high
> 1.00	very high

Note: Critical levels determined using Mehlich 3 standard (Mehlich, 1984);
Other relevant literature (Cai et al., 2016; Moebius-Clune et al., 2011; Wu et al. 2018; Xu et al., 2018)

Descriptives (e.g., average annual maize yields by treatment and control areas)



Conceptual framework

Standard Cobb-Douglas production specification as:

$$Y_i = L^{\alpha_{1i}} K^{\alpha_{2i}} B^{\alpha_{3i}}, \quad (1)$$

where Y_i are outputs – maize yield, soil Organic Matter, Carbon, Nitrogen, & Potassium., *L, K, B* are labor, capital & biophysical factors,

$\alpha_{1i}, \alpha_{2i}, \alpha_{3i}$ are vectors of parameters to be estimated.

From (1), we have:

$$ln\Upsilon_i = \alpha_0 + \alpha_{ni} \ln \langle \left[\sum_{n=1}^{N} \mathrm{X}_i \right] \rangle + \omega_i \quad (2)$$

where $ln\Upsilon_i$ = natural log of outputs above,

α_0 and α_{ni} are parameters, X_i are vectors of household and plot-level characterisitics, and ω_i is an error term.

Identification strategy

ESR to estimates of CSA program participation follows thus:

- CSA program participation probability (CWt_i^*)

$CWt_i^* = \tau Z_i + \upsilon_i$, with

$$CWt_i = \begin{cases} 1, & if \ \tau Z_i + \upsilon_i > 0, \\ 0, & if \ \tau Z_i + \upsilon_i = 0 \end{cases} \tag{3}$$

Outcome equations

$$\ln Y_{1i} = \theta_1 X_{1i} + \psi_{1i} , \quad \text{for} \quad CWt = 1 \tag{4}$$

$$\ln Y_{0i} = \theta_0 X_{0i} + \psi_{0i} , \quad \text{for} \quad CWt = 0 \tag{5}$$

Where $\ln Y_{1i}$ and $\ln Y_{0i}$ = yield and environmental outcomes of participants & non-participants respectively, X_i & Z_i are vectors of determinants of and program participation respectively,

$\tau, \& \ \theta$ are parameters to be estimated, ψ_{0i}, ψ_{1i}, & υ_i are error terms.

Results

Endogenous switching regression estimates for yield and environmental outcomes

	Participants' mean		Non-adopters' mean		ATT		
Natural logs (ln) of outcome variables	Coeff.	Std. error	Coeff.	Std. error	Coeff.	Std. error	%ATT
Maize yields per acre	6.75	0.11	3.61	0.07	3.14***	0.29	87.21***
Soil Nitrogen	0.12	0.00	0.09	0.00	0.03***	0.01	38.82***
Soil Organic Carbon	1.27	0.01	0.91	0.01	0.37***	0.05	40.66***
Soil Organic matter	2.34	0.02	1.51	0.01	0.84***	0.08	56.19***
Soil Potassium	0.11	0.00	0.08	0.00	0.02*	0.01	28.92*

Note: ATT, Average treatment effects of participation; Significance levels: * < 10%; *** < 1%;

Robustness check- Other considerations

- Performed same rigorous econometrics at the EPA level
- Performed propensity score as a basic non-parametric analyses

- Nearest neighbor matching
- Kernel-based matching
- Radius matching

Results are consistent across specifications

Conclusion & Policy implication

In the medium to long-term, CSA could significantly:

- ✓Improve crop yields and livelihoods of smallholder farmers.
- ✓Enhance soil improvements in smallholder agricultural contexts.
- ✓Address food insecurity & environmental degradation.
- ✓Enhance sustainable development goals on food security & climate change.

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