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Does sustainable intensification of maize production enhance child nutrition? Evidence from rural Tanzania

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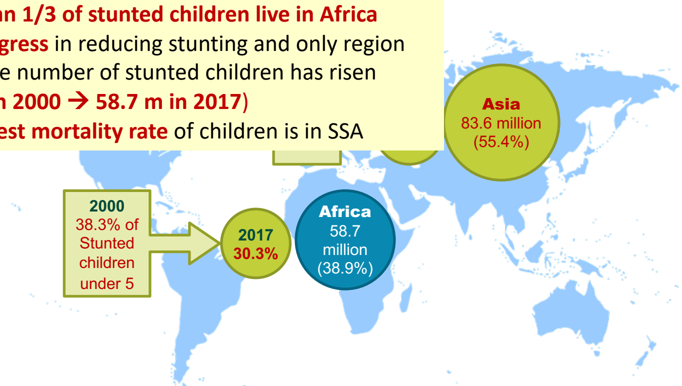
I. Motivation

- **Food insecurity, child malnutrition, and land degradation are common challenges in SSA**
  - ✓ **Hunger and child malnutrition** are especially serious in SSA
  - ✓ **45% of global deaths of children** under age 5 are linked to malnutrition (Black et al. 2013)

❖ **More than 1/3 of stunted children live in Africa**
❖ **Slow progress** in reducing stunting and only region where the number of stunted children has risen (**50.6 m in 2000 → 58.7 m in 2017**)
❖ **The highest mortality rate** of children is in SSA



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I. Motivation

- **Agriculture and nutrition are closely linked**
  - ✓ Majority of **undernourished people** still live in rural areas
  - ✓ Many of them are **smallholder farmers** (Sibhatu et al. 2015)
- **Use of improved farm inputs and management practices at the HH level → could affect nutrition outcomes of the HH members**
  - ✓ **Enhance the HH's production of food crops**: different quantities or qualities, levels of dietary diversity
  - ✓ **Increase marketable surplus & ag. income** → expenditure on food and nutrition-relevant non-food items (healthcare, sanitation, water etc.)
- **However, conventional intensification such as high-yielding crop varieties and inorganic fertilizer → may NOT be sufficient to SUSTAINABLY raise ag. productivity & may have NEGATIVE environmental consequences**
  - ✓ Over-reliance on fossil fuels, reduced biodiversity, pollution of ground and water (Matson et al. 1997; Pingali 2012)
  - ✓ W/ the use of complementary soil building practices → could **increase crop yield response to inorganic fertilizer**

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I. Motivation

- **Sustainable Intensification (SI): a possible means to address the needs for more food and for environmental sustainability**
  - ✓ "**Producing more food from the same area of land while reducing the environmental impacts**" (Godfray et al. 2010, p.813)
- **Broader definition of SI extends beyond environmental sustainability to encompass other domains**
  - ✓ e.g., productivity, economic, social, and **human well-being including nutrition and food security** (Musumba et al. 2017; Zurek et al. 2015)
- **Research question? Do ag. practices and inputs that contribute to SI from environmental standpoint indeed improve the child nutrition?**
  - ✓ Few empirical studies: Manda et al. (2016) & Zeng et al. (2017) but focus on only adoption of improved maize varieties
  - ✓ Others? → 3 soil fertility management (SFM) practices for this study
- **Additional contributions to the existing literature**
  - ✓ **The 1st empirical investigation of how combinations of ag. practices** (as opposed to single technologies) affect child nutrition
  - ✓ Leverage the **panel nature of the data**: further control for time-constant unobserved heterogeneity

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II. Background

Child malnutrition in Tanzania

- **Two indicators for measurement of child nutritional status:**
  - ✓ Weight-for-age z-score (WAZ), Height-for-z-score (HAZ)
  - ✓ **WAZ and HAZ capture long-term nutrition factors** (e.g., deficiencies in nutrition, frequent infections, inappropriate feeding practices)
- **Tanzania has the third highest rate of child malnutrition in SSA (UNICEF 2009)**
  - ✓ Child malnutrition rates (of underweight & stunting) in **rural areas are consistently higher than urban areas**

Table 1. Trends in the malnutrition status of children under age 5 in Tanzania

	Underweight (%) (WAZ < -2)			Stunting (%) (HAZ < -2)		
	2008/09	2010/11	2012/13	2008/09	2010/11	2012/13
Tanzania	15.9	13.6	12.5	43.0	34.8	37.4
Urban	9.8	9.2	9.3	30.2	24.1	29.5
Rural	17.1	14.6	13.3	45.6	37.2	39.3

Source: Tanzania National Bureau of Statistics 2014

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II. Background

Child malnutrition in Tanzania

- ❖ Rapid growth faltering from **0-24 months,** then remain stable (Victora et al. 2010)
- ❖ "**Critical window of opportunity**" for preventing child malnutrition
  - → **Need to explore the effects on nutrition status of children in different age groups**

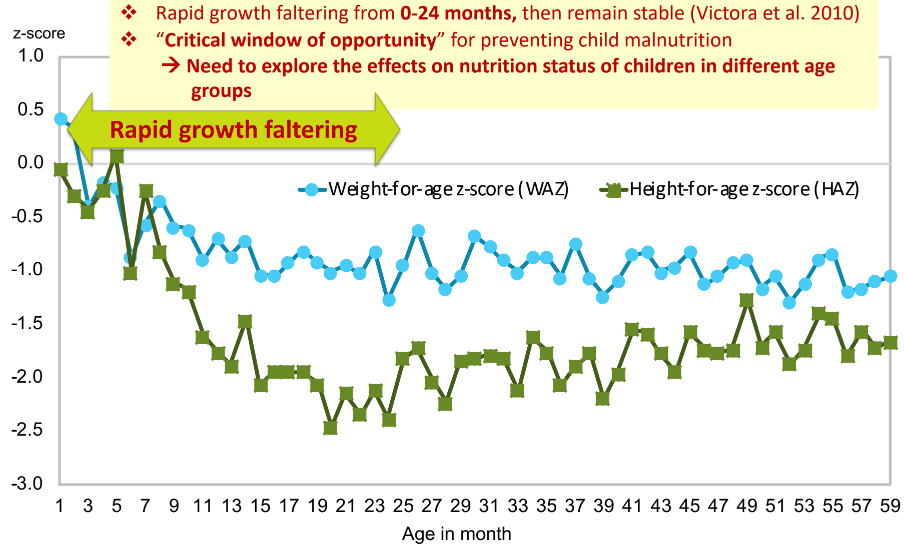

Figure 1. Mean WAZ and HAZ by age in months, relative to the WHO standard

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II. Background

SFM practices & SI category

- **Three SFM practices for SI: inorganic fertilizer, organic fertilizer, and maize-legume intercropping (IC)**

1. Inorganic fertilizer: "Intensification" but not SI
- ✓ not sufficient to **sustainably** increase agricultural productivity without the use of complementary soil building practices
- ✓ could result in **negative environmental consequences**

2. Organic fertilizer: "Sustainable" but not SI
- ✓ various benefits: increasing SOM, reducing soil acidity etc.
- ✓ but **relatively low nutrient content, large quantities needed, a long time-horizon for observed benefits**

3. Maize-legume IC: "Sustainable" but not SI
- ✓ **a local and renewable source** of soil fertility: can improve properties for nutrient and moisture holding capacity
- ✓ but generally require complementary investments in order to support high crop yields

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II. Background

SFM practices & SI category

- **In this study, "SI" is defined as joint use of inorganic fertilizer with organic fertilizer and/or maize-legume intercropping**
  - ✓ Higher maize yields and gross margins **when they are jointly used** (Waddington et al. 2017; Mekuria and Waddington et al. 2002)

Table 2. SI of maize production categories and prevalence on maize plots

Case	Inorganic fertilizer	Organic fertilizer	Maize-legume intercropping	% of maize plots	SI category	% Plot level
1				46.5	Non-adoption	46.5
2	√			7.3	Intensification	7.3
3		√		6.3	Sustainable	38.1
4			√	26.8		
5		√	√	5.0		
6	√	√		1.7	SI	8.1
7	√		√	5.2		
8	√	√	√	1.2		
Use of inorganic fertilizer					Intensification	15.4
Use of organic fertilizer					Sustainable	14.2
Use of maize-legume intercropping					Sustainable	38.2

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III. Conceptual framework

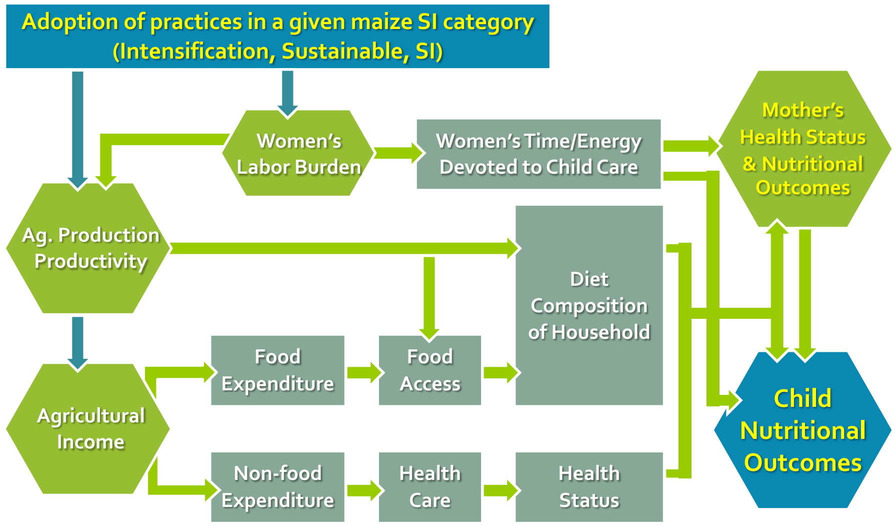

Figure 2. Conceptual pathways between SI of maize production and child nutrition (adapted from Herforth and Harris (2014))

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IV. Econometric approach & Data

- **Multinomial Endogenous Treatment Effects (METE) model**
  - ✓ allow to **control for selection bias stemming from both observed and unobserved heterogeneity** (Deb and Trivedi 2006)
  - ✓ allow to **evaluate alternative combinations** of practices
  - ✓ **1st stage**: a mixed multinomial logit (MMNL) selection model, where dep. var. is the HH-level SI category (Non-adoption, Intensification, Sustainable, and SI)
    - *For more robust identification (Deb and Trivedi 2006), utilize traditional exclusion restrictions by including IVs in the 1st stage*
    - *IVs: existence of a farmer's cooperatives, access to agricultural advice, input subsidy voucher*
  - ✓ **2nd stage:** estimate the impact of the adoption of the various SI categories on two indicators (HAZ and WAZ) of child nutritional status
- **Combined with correlated random effects (CRE)/Mundlak-Chamberlain (MC) device**
  - ✓ address the issue of time-invariant unobserved household-level heterogeneity that may be correlated with observed covariates
  - ✓ include the mean value of time-varying household level explanatory var.

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IV. Econometric approach & Data

- **Tanzania National Panel Survey (TNPS)**
  - ✓ 3 waves of nationally-representative HH panel survey data (TNPS 2008/09, 2010/11, and 2012/13)
  - ✓ Socioeconomic characteristics, consumption, ag. production, and non-farm income activities
  - ✓ **Analytical sample**: rural maize-growing HHs with children under age 5 at the time the HH started their maize harvesting
  - ✓ 2,055 total HH observation and 2,898 of children
- **HH-level SI category**
  - ✓ need to assign each HH to a single SI category in METE model
  - ✓ by calculating the HH's maize area cultivated under each SI category and then **choose the category with the largest area**
  - ✓ Only **one maize plot** (**64% of the total HHs**), **same category** in both plot and HH **(87% of maize plots)**

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V. Results

Full sample Analysis: children aged 0-59 months

- **Effects of the "SI" category:**
  ⬆ children's HAZ and WAZ by 0.60 units and 0.43 units, respectively
- **But, effects of the "Intensification" category:**
  ⬇ children's HAZ by 0.54 units
  ⇒ counter-intuitive and not robust

Table 3. CRE METE model estimates: impacts of the adoption of each SI category on child nutritional outcomes

Variables	HAZ	WAZ
Full sample (n=2,898): children aged 0-59 months		
Intensification	**-0.535***** **(0.155)**	-0.038 (0.309)
Sustainable	0.130 (0.150)	0.128 (0.370)
SI	**0.598***** **(0.135)**	**0.426**** **(0.175)**

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V. Results

Sub-sample analyses

- **Sub-sample 1**
  - ✓ **Drop children age 0-5 months:** since they are exclusively breastfed and less likely to be affected by diet changes
  - ✓ **Add interaction terms** to examine differential effects on the nutritional outcomes of **the children in the "critical window"** (up through 24 months)
- **Effects of the "SI" category:** ⬆ **children's HAZ and WAZ by 0.33 units and 0.61 units, respectively**
- **No statistically significant effects for children age 6-24 months**
  - ✓ Why? still breastfed & largely dependent on complementary foods instead of consuming adult foods

Table 4. CRE METE model estimates: impacts of the adoption of each SI category on child nutritional outcomes

Variables	HAZ	WAZ
Sub-sample 1 (n=2,560): children aged 6-59 months		
Intensification	-0.103	-0.110
	(0.192)	(0.223)
Sustainable	**0.599*****	0.148
	(0.203)	(0.304)
SI	**0.332****	**0.607*****
	(0.152)	**(0.122)**
Intensification×6-24 months of age	-0.139	-0.075
	(0.228)	(0.173)
Sustainable×6-24 months of age	0.188	0.030
	(0.117)	(0.088)
SI×6-24 months of age	0.112	0.073
	(0.172)	(0.146)

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V. Results

Sub-sample analyses

- **Sub-sample 2**
  - ✓ **Focus on children beyond breast-feeding age** (i.e., children age 25-59 months)
- **Effects of the "SI" category:** ⬆ **children's HAZ and WAZ by 0.36 units and 0.58 units, respectively**
  - ✓ consistent with the Sub-sample 1 results in terms of the level of impacts of the "SI"
  - ✓ but, the coefficients on the **"Sustainable" is no longer statistically significant**

Table 4. CRE METE model estimates: impacts of the adoption of each SI category on child nutritional outcomes

Variables	HAZ	WAZ
Sub-sample 1 (n=2,560): children aged 6-59 months		
Intensification	-0.103	-0.110
	(0.192)	(0.223)
Sustainable	**0.599*****	0.148
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Sustainable×6-24 months of age	0.188	0.030
	(0.117)	(0.088)
SI×6-24 months of age	0.112	0.073
	(0.172)	(0.146)
Sub-sample 2 (n=1,453): children aged 25-59 months		
Intensification	-0.210	-0.207
	(0.199)	(0.198)
Sustainable	-0.139	0.031
	(0.140)	(0.125)
SI	**0.360***	**0.576*****
	(0.186)	**(0.113)**

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V. Results

- **Overall, the adoption of the "SI" treatment group substantially improves both HAZ and WAZ of the children age 25-59 months**
  - ✓ They are **less likely to be breastfed** and
  - ✓ **more likely to be directly affected by household diet changes** associated with changes in ag. practices

- **Three factors to potentially explain the effects of the "SI":**
  1. **Legume crops produced** through maize-legume IC ⇒ **Change the diet composition** of HHs (needed protein, iron, and zinc), **increase ag. income** b/c higher sale prices/kg for legumes
  2. Adoption of the "SI" (**e.g., mz-leg. IC + Inorg. Fert.**)⇒ **higher maize yields, crop output, and/or HH income** b/c synergistic effects b/w practices (Waddington et al. 2007, Manda et al. 2016, Teklewold et al. 2013)
  3. **Increased maize yield response to inorganic fertilizer** through synergistic effects when organic manure is jointly used (Place et al. 2003, Schoebitz and Vidal 2016, Mahmood et al. 2017)

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VI. Implications

- **Two main implications for agricultural policy and future research**

  1. Find effective ways to increase joint use of SFM practices (i.e., inorganic fert. + organic fert. or maize-legume IC) by Tanzanian maize farmers
  - ✓ much lower adoption rates of the SFM practices than other countries such as Kenya, Malawi, and Ethiopia (Kassie et al. 2015)
  - ✓ Agricultural extension and subsidies for inorganic fertilizer (from 1st stage regression)

  2. Future research could
  - ✓ examine if SI of maize production also enhance HH food security
  - ✓ identify the pathways through which SI of maize production affects child nutrition (and potentially HH food security)

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Thank you! Questions/comments?

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