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Does Sustainable Intensification of Maize Production Enhance Child Nutrition? Evidence from Rural Tanzania

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Introduction

In many developing countries including Tanzania, food insecurity and child malnutrition remain persistent problems. In 2017, globally about 151 million children under age five are stunted, where 55% and 39% of these children live in Asia and Africa, respectively; but Africa has shown relatively slow progress in reducing stunting and it is the only region where the number of stunted children has risen since 2000 (UNICEF, WHO, and World Bank Group 2018). Malnutrition is a leading cause of child mortality, making children more vulnerable to severe diseases. Approximately 45% of global deaths of children under age five are linked to malnutrition and the mortality rate of children in sub-Saharan Africa (SSA) is the highest in the world (Black et al., 2013).

Agriculture and nutrition are closely linked because the majority of undernourished people still live in rural areas and many of them are smallholder farmers (Pinstrup-Andersen, 2007). This linkage suggests that agricultural intensification via farmers' adoption of improved inputs and management practices may improve the nutritional status of nutritionally vulnerable household members including young children by enhancing the household's agricultural production, productivity, and/or income, as well as by providing better access to more diverse or nutritious foods (Jones et al., 2014; Hawkes and Ruel, 2006). However, there is an emerging consensus that conventional agricultural intensification via high-yielding crop varieties and inorganic fertilizer may be insufficient to sustainably raise agricultural productivity and could have negative environmental consequences (Pingali, 2012).

Key Findings:

- We explore the effects of different combinations of three soil fertility management practices (inorganic fertilizer, organic fertilizer, and maize-legume intercropping) used by rural Tanzanian households on their maize plots on the nutritional outcomes of children aged 6-59 months within the household.
- The results suggest that joint use of inorganic fertilizer with maize-legume intercropping and/or organic fertilizer (which we refer to as the sustainable intensification or *SI* group of practices) is associated with increases in children's height-for-age z-score (HAZ) and weight-for-age z-score (WAZ) compared to households that adopt none of the practices.
- The positive effects of the *SI* group are mainly among children aged 25-59 months who, compared to younger children, are less likely to be breasted and may be more directly affected by household diet changes associated with changes in agricultural practices.
- Joint use of maize-legume intercropping and inorganic fertilizer is a key driver of the positive *SI* effects, and the effects appear to come through both crop income and productivity pathways.
- On the other hand, use of only inorganic fertilizer (*Intensification*) and use of only *Sustainable* practices (only organic fertilizer, only maize-legume intercropping, or both) have no statistically significant effects on the HAZ and WAZ of children age 25-59 months.

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Moreover, in many parts of SSA, rapidly growing populations and a lack of new land to farm has led to continuous cultivation of plots and reduced fallowing, thereby degrading soils and adversely affecting crop yields and yield response to inorganic fertilizer (Kassie et al., 2013; Jayne et al., 2018).

In this context, agricultural sustainable intensification (SI) has been proposed as a possible solution to simultaneously address these challenges (Petersen and Snapp, 2015). At the core of SI is the goal of "producing more food from the same area of land while reducing the environmental impacts" (Godfray et al., 2010, p. 813). Broader definitions of SI also encompass the complex social dimensions of sustainability, including nutrition and food security (Musumba et al., 2017). It is an open question, however, whether the use of agricultural inputs and management practices that contribute to SI from an environmental standpoint do indeed improve nutrition and food security. In this study, we contribute to the thin evidence base on this topic by estimating the effects of SI of maize production on the child nutrition outcomes of maize-growing households in Tanzania. We focus on maize due to its importance as a staple food in Tanzania and because it accounts for approximately 75% of total cropped area in the country (Tanzania National Bureau of Statistics (TNBS), 2014). To do this, we apply a multinomial endogenous treatment effects (METE) model combined with the correlated random effects (CRE) appraoch using three-waves of nationally representative household panel survey data (the Tanzania National Panel Surveys of 2008/09, 2010/11, and 2012/13). These surveys were conducted by the TNBS in conjunction with the World Bank.

Sustainable Intensification of Maize Production in Tanzania

SI of maize production is particularly important in Tanzania because maize is the main staple food; in addition, the most common complementary and weaning foods for children in the country are maize-based (Kimanya et al. 2010). This study focuses on three soil fertility management (SFM) practices (alone and in combination) that have the potential to contribute to SI in maize-based systems: (1) inorganic fertilizer, (2) organic fertilizer, and (3) maize-legume intercropping. We group households into four categories based on their use of these practices on their maize plots: *Non-adoption*; *Intensification* (use of only inorganic fertilizer); *Sustainable* (use of only organic fertilizer, only maize-legume intercropping, or both); and *SI* (joint use of inorganic fertilizer with organic fertilizer and/or maize-legume intercropping on the same plot) (see Table 1). We then estimate how a household's adoption of each SI category affects nutritional outcomes of children within the household. Out of 1,871 maize growing households across the three rounds of survey data used in the analysis, about 41% fall in the Sustainable category. The Intensification and SI categories are much less prevalent at 7% and 8% of maize-producing households, respectively (Table 1).

Table 1. SI of Maize Production Categories and Prevalence among Maize-Growing Households in Tanzania

Case	Inorganic fertilizer	Organic fertilizer	Maize-legume intercropping	SI category	% of maize-growing HHs in this category
1				Non-adoption	44.8
2	√			Intensification	6.7
3		√		Sustainable	40.7
4			√		
5		√	√		
6	√	√		SI	7.8
7	√		√		
8	√	√	√		

Source: Author's calculations based on Tanzania National Panel Survey (TNPS 2008/09, 2010/11, 2012/13).

Child Malnutrition in Tanzania

We analyze two indicators of child nutritional status: weight-for-age z-score (WAZ) and height-for-age z-score (HAZ). These measures reflect long-term factors such as deficiencies in nutrition, frequent infections, and inappropriate feeding practices. WAZ and HAZ measure nutritional status in the form of z-scores derived by comparing children's weight-for-age or height-for-age with these outcomes for children in a well-nourished reference group. For example, WAZ is the difference in standard deviations of a child's weight-for-age from the median weight of children of the same age and gender in the reference group. A child is considered underweight if his/her WAZ is below -2, and stunted if his/her HAZ is below -2. The national prevalence of underweight children under age five in Tanzania steadily decreased from 16% in 2008/09 to 13% in 2012/13 (Table 2); stunting also declined from 43% in 2008/09 to 37% in 2012/13. However, child malnutrition rates in rural areas continue to be substantially higher than in urban areas (Table 2).

Findings and Policy Implications

The full regression results from the CRE-METE model are reported and discussed in Kim et al. (in press). For simplicity, this policy brief focuses on the effects of adoption of the various categories on child nutritional outcomes, exploring if the effects come through the crop income and/or productivity pathways. Table 3 summarizes the local average treatment effects of adoption of the various SI categories on child nutritional outcomes among maize-growing households in Tanzania. The upper panel in Table 3 shows the results for the full sample of children age 6-59 months. These findings suggest that, on average, use of practices in the SI group is associated with increases in children's HAZ and WAZ of 0.36 units and 0.45 units, respectively, compared to those in non-adopting households. These are sizeable increases relative to the sample mean HAZ and WAZ of -1.82 and -0.98, respectively. However, the negative impacts of the Intensification category on HAZ is counter-intuitive because the use of inorganic fertilizer is expected to raise maize yields relative to the Non-adoption group, which we expect to either positively affect child nutrition outcomes or have no statistically significant effect. We therefore treat this result with caution and as shown below, this finding does not hold in the sub-sample analysis. Because children aged 6-24 months who are largely breastfed may not be as responsive to food intake, we re-estimate the models using the sub-sample of children aged 25-59 months. The sub-sample results (shown in the middle panel of Table 3) suggest that adopting practices in the SI group increases HAZ and WAZ by 0.37 and 0.44 units, respectively, on average.

Overall, the robust finding in this study is that adoption of the SI treatment group substantially improves both HAZ and WAZ. These effects are mainly among children age 25-59 months who, compared to younger children, are less likely to be breastfed and may be more directly affected by household diet changes associated with changes in agricultural practices. [1] This could be for the following reasons. First, we find that the combined use of maize-legume intercropping and inorganic fertilizer is a key driver of the positive SI effects on child nutrition. The legume crops produced as a result may directly affect the diet composition of adopting households by providing needed protein and micronutrients (Messina, 1999); this, in turn, may positively affect child nutrition. Furthermore, these legume crops could help farmers to increase their crop income since per-kilogram prices for legumes are higher than maize prices.

Table 2. 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.

Table 3. Estimated Effects of the Adoption of Each SI Category on Child Nutritional Outcomes and Crop Income and Productivity (Changes relative to Non-Adopters)

Child nutritional outcomes

Full sample: 6-59 months (n=2,486 children)

	HAZ	WAZ
Intensification	-0.46	No effect
Sustainable	No effect	No effect
SI	+0.36	+0.45

Sub-sample: 25-59 months (n=1,411 children)

	HAZ	WAZ
Intensification	No effect	No effect
Sustainable	No effect	No effect
SI	+0.37	+0.44

Crop income and productivity

Full sample (n=1,871 households)

	Crop income (Tanzanian Shillings)	Output index per acre
Intensification	+350,835	+488
Sustainable	-114,242	No effect
SI	+720,637	+531

Notes: Base category is Non-adoption. No effect indicates that the result is not statistically different from zero. All other results reported in the table are statistically significant at the 10% level or lower.

Second, relative to farmers in the other treatment groups, households in the SI group may have higher crop income or productivity due to synergistic effects when Sustainable practices are used jointly with inorganic fertilizer. As shown in the lower panel of Table 3, SI is indeed associated with increases in crop income and productivity on households' maize plots.[2] Intensification is as well but the crop income effects are considerably and statistically larger for SI. In contrast, Sustainable is associated with negative effects on crop income and no significant effects on productivity, which supports the findings above of no evidence that Sustainable agricultural practices alone improve child nutrition outcomes.

Our results have significant implications for agricultural policy and future research. It is important for policy makers to find effective ways to increase joint use of inorganic fertilizer with maize-legume intercropping and/or organic fertilizer by Tanzanian maize farmers. At present, Tanzania has much lower adoption rates of inorganic fertilizer, maize-legume intercropping, and organic fertilizer than other countries in eastern and southern Africa such as Kenya, Malawi, and Ethiopia (Kassie et al., 2015). Therefore, further research is needed to explore how best to incentivize SI of maize production, and to investigate how SI of agricultural systems more broadly (beyond SI of maize production) contributes to food security and child nutrition outcomes.

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[1] In the paper associated with this policy brief (Kim et al., in press), we examine differential effects of various SI categories on the nutritional outcomes of younger children (i.e., children aged 6-24 months) but we do not find evidence of statistically significant child nutrition effects.

[2] Following Liu and Myers (2009), this study used gross value of crop production from the household's maize plots as a proxy for crop income and an index of crop output per acre on those plots as a proxy for productivity.

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