Agricultural correlates of linear growth and key modifiers among children under two years in rural Uganda

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Introduction

Many sources have recently called for agricultural programs and policies to become more "nutrition-sensitive", with the aim of harnessing agriculture to improve nutrition and health. Several researchers have described potential causal pathways through which agriculture could impact the nutrition and health of vulnerable populations. Stunting, or poor linear growth, particularly in young children is a key indicator. Reflecting chronic undernutrition, stunting can begin *in utero*, and studies have shown that it can be difficult to recover from faltering in linear growth during gestation and the first two years of life, with long-term consequences through adulthood and into the next generation.

Despite the careful elaboration of potential causal pathways from agriculture to nutrition, there is little empirical evidence for these linkages in Uganda or similar settings. Furthermore, in the case of stunting, there are many potential non-agricultural determinants, such as poor diet and repeated infections. Some of these act along shorter, more immediate causal pathways than hypothesized agriculture-related determinants, and they can be important confounders in observed relationships between agriculture and nutritional outcomes. In this paper, we therefore investigate whether increased agricultural investment or productivity are associated with better linear growth in young rural Ugandan children, taking into account other key factors influencing linear growth and nutritional status.

Methods

Ethics Statement

This study was approved by the Institutional Review Boards (IRBs) at Makerere University School of Public Health, Harvard School of Public Health, and the Uganda National Council for Science and Technology. All participants provided written informed consent themselves or through a legal guardian if under 18 years of age.

Study Design

This study was a cross-sectional survey that provides a baseline to evaluate a large USAID-funded integrated nutrition and agriculture program called the Community Connector (CC). The study was conducted in three districts designated as CC Phase I and three districts designated as CC Phase II in northern and southwestern Uganda. The target sample size in each district was 600 randomly selected households, for a total target sample size of 3600 households and a final achieved sample size of 3630 households. In each sampled household, data were primarily collected using questionnaires administered to the primary caregiver of a randomly selected child aged 0-23 months. If the household had no child of that age range, a female member of the household aged 18-49 years was the primary respondent. If the household had no female member of that age range, the household head was the primary respondent. All data were collected at the household using electronic data capture methods.

Sampling (to be described in greater detail)

Districts in Uganda are administratively divided into subcounties followed by parishes and then villages. Phase I districts had Phase I, Phase II, and non-CC subcounties, while Phase II districts had Phase II and non-CC subcounties. All parishes in each selected subcounty were represented in the final sample. Within each parish, villages and then households within villages were randomly sampled.

Data Collection

Data were collected using questionnaires on household demographics, socioeconomic characteristics, livelihood activities, all sources of income, and food security. Detailed information was collected on households' agricultural activities, production, practices, and use of technologies. Information on morbidity, use of health services, diet, and feeding practices was collected on the index child and the primary caregiver. Index children and their caregivers were also assessed for height (length), weight, and mid-upper arm circumference using standard anthropometric methods; hemoglobin concentration using a HemoCue; and malaria infection using a rapid diagnostic test.

Outcome Measures

Anthropometric data on index children were used to calculate standardized scores for height (length)-for-age, weight-for-height (length), and weight-for-age based on the World Health Organization (WHO) Child Growth Standards, developed by the WHO Multicentre Growth Reference Study. Outlying values were flagged using WHO cutoffs and excluded from analysis. Children were identified as stunted, wasted, or underweight if they were more than two standard deviations below the WHO reference median for height-for-age, weight-for-height, or weight-for-age, respectively.

Data Analysis

Forcing parish into the model, stepwise selection was conducted on a regression model of household, caregiver, and child characteristics on child height-for-age Z-score (HAZ). All variables that entered and remained in the model at $P<0.20$ were retained as potential confounders in regression models of each agricultural practice or technology on HAZ [results of these pairwise relationships between agricultural practices and technologies and HAZ are given in Table 4]. In these models, all

agricultural practices and technologies with P<0.2 were retained in a multivariable model that included the confounders identified through stepwise selection [the results of this model are given in Table 5].

Results

Of the 3630 households surveyed, 1996 households had a child aged less than 24 months. Anthropometric data were collected on 1918 (96%) of these children, and height-for-age Z-scores were calculated for 1882 (94%) children. The following results are therefore based on these 1882 children, their primary caregivers, and their households.

The sampled households were evenly distributed across the four study districts in northern Uganda (66%) and the two study districts in southwestern Uganda (34%) (Table 1). Households were large with six members on average, and seven percent were female-headed. Only 25% of household heads attended school beyond the primary level, and 7% did not have any formal education. Half or less of houses had a metal roof or brick or concrete walls, most houses (91%) had dirt floors, and almost none were connected to the electrical grid. One out of six households did not have their own toilet, and over one-third relied on an unprotected water source. However, the majority of households had access to a radio, telephone, or bicycle. Most (98%) but not all primary caregivers were female, and caregivers typically had fewer years of formal education compared with household heads. Sampled children were distributed evenly across sexes and the target age range (0-23 months).

Key aspects of maternal and child nutritional status and health differed between the northern and southwestern regions (Table 2). Female caregivers were more likely to be overweight or obese in the southwest (16% vs. 5%) and more likely to be underweight in the north (11% vs. 3%). Only 36% of caregivers reported good food hygiene based on a list of five recommended practices. Nearly two-thirds (63%) of caregivers reported giving birth to their eldest surviving child before the end of their teenage years. Caregivers reported having had five pregnancies on average, and 45% reported having made

fewer than four antenatal care visits during their most recent pregnancy. While households were reported as more food insecure in the southwest based on the Household Food Insecurity Access Scale (HFIAS), the two regions did not differ in the prevalence of moderate or severe household hunger based on the Household Hunger Scale (HHS).

Children in the southwest were 2.1 times as likely to be stunted than children in the north, while children in the north were 2.6 times as likely to be acutely malnourished than children in the southwest. As an interesting consequence, the prevalence of underweight was therefore not different between these two regions. The prevalence of anemia among young children was high in both regions (60%), and consumption of animal source foods was low, with only 10% of children having consumed at least one such food in the preceding 24 hours. The prevalence of diarrhea was comparable between the two regions (17% in a two-week period), while the prevalence of respiratory infections was higher in the north. The prevalence of malaria (and fevers generally) was markedly lower in the southwest, likely a consequence of the higher elevations.

Households' adoption of agricultural practices and technologies also differed significantly between the north and southwest (Table 3). Households in the north owned more land, and households in both regions used most of the available land for cultivation. Cereals were important crops in both regions (cultivated by 91% of households), and southwestern households grew roots and tubers, legumes, and especially bananas (*matooke*) more often. Northern households meanwhile grew fruits and vegetables, including crops rich in vitamin A, and cash crops more often.

Northern households were more likely to plant crops in rows but also to use burning to clear land. Crop rotation was more common in the north and intercropping was more common in the southwest. These regional differences in agricultural practices were likely due at least in part to the greater frequency of banana cultivation in the southwest. A quarter of households in both regions had allowed some land to go fallow in a 12-month period. While northern households were more likely to

use improved seed or seedlings, southwestern households were more likely to use fertilizers, including inorganic fertilizers, herbicides, pesticides, and other agrochemicals (largely in the field rather than for post-harvest uses), as well as other local and integrated practices to manage pests or soil fertility. Irrigation was rare in both regions.

Livestock ownership was high, particularly in the north (90% vs. 64%). Ownership of improved livestock, however, was low, though slightly more common in the southwest (4% vs. 1%). Northern households were more likely to vaccinate their livestock (12% vs. 4%), but overall most households did not vaccinate and use of improved feed was rare in both regions. More than half (57%) of northern households used animal traction, which was not practiced in the hillier southwest. Mechanization was rare in the north and again not practiced in the southwest.

The majority (60%) of northern households employed farm labor, compared with a third (36%) of southwestern households. Overall, use of improved post-harvest practices and technologies, post-harvest processing, and value addition was low. Southwestern households were more likely to use improved drying methods, while northern households were more likely to use improved storage methods and transportation.

Most households (84%) sold some, but not the majority, of their crop production. Sale of livestock products was less common overall, though more practiced in the north (44% vs. 32%). Northern households were more likely to use improved marketing methods including travel to markets for sale of agricultural products. Use of farmers' groups for sale of agricultural products was not common (3%). Households cultivated six crops species on average, and northern households were more likely to have multiple livestock species. On-farm and off-farm income was highly variable in the study population. The majority of households had some off-farm income, and northern households were more likely to have off-farm income than southwestern households (79% vs. 66%). However, in both regions, off-farm income accounted for a quarter or less of total household income.

Stepwise selection of household, caregiver, and child characteristics that could be confounders in associations between agriculture and HAZ identified the following, which were controlled when examining pairwise relationships between agricultural practices and technologies and HAZ: parish, child sex, child age, child multiple birth, child's consumption of animal source foods in the preceding 24 hours, child anemia status, child's difficult or fast breathing in the preceding two weeks, caregiver's current age, caregiver's age at the birth of her eldest surviving child, caregiver's attendance at four or more antenatal care visits during her latest pregnancy, caregiver's overweight or obese status, household having a metal roof, household having brick or concrete walls, household having grid electricity, household having its own toilet, and household having access to a bicycle. Households that used fertilizer (specifically inorganic fertilizer) had children with higher HAZ. Households with higher per capita total income also had children with higher HAZ, but having a greater proportion of household income coming from off-farm rather than on-farm sources was negatively associated with HAZ. All other pairwise relationships between agricultural practices and technologies and HAZ were not significant at a 0.05 level.

Multivariable modeling indicated that caregiver and child characteristics had more significant and greater effects on child HAZ than agricultural or household characteristics (Table 5). Children from a multiple birth had a HAZ that was 1.5 standard deviations lower than singleton children, after controlling for other factors in the model. HAZ decreased with age, particularly in the second year of life, though interestingly girls in this population had higher HAZ than boys. Children who had consumed an animal source food in the previous day, likely indicating a greater likelihood or frequency of consumption of such foods, had higher HAZ. HAZ was also higher among children whose caregivers were overweight or obese or who had met the recommended minimum of four antenatal care visits during their most recent pregnancy. Households with a toilet, thereby providing access to better sanitation, had children with higher HAZ. Among household agricultural characteristics, households using inorganic fertilizer had

children with higher HAZ, while those using long-handled hoes had children with lower HAZ [possible reasons for these relationships are being investigated].

Next Steps in Analysis

- We will finalize review of the models and results presented in Tables 4 and 5.
- We will examine effect modification by income quintile. (While it is possible that the correlates of linear growth may vary by income quintile, we note that the prevalence of child undernutrition [stunting, acute malnutrition, and underweight] do not.)
- We will examine effect modification by region (north vs. southwest). As the two regions have very different agriculture and nutrition situations, it is possible that the relationships between agriculture and nutrition differ between the two regions.

Some Points for Discussion

- This paper aims to address the lack of empirical evidence for agriculture-nutrition linkages in Uganda and similar settings and to estimate the independent effects of agricultural practices and technologies on linear growth in young children while controlling for key confounders.
- Long impact pathways may result in weak associations between agriculture and nutrition, particularly when there are more immediate causes of poor nutritional status. This motivates integrated interventions.
- Northern and southwestern Uganda have very different nutritional and agricultural situations, and we study the consequences for associations between agriculture and nutritional status. We also study effect modification by income.
- This cross-sectional study provides limited evidence for causality. Longitudinal data (from upcoming studies and data collection planned by the Nutrition Innovation Lab) will provide stronger evidence on causal mechanisms, and deeper investigation of mechanisms is needed.

Table 1. Demographic and other household characteristics.

Category	Characteristic	Mean (SD)[1] (n=1882)
Household	Northern region	66
	Household size	6.0 (2.5)
	Household has metal roof	43
	Household has brick or concrete walls	50
	Household has improved floor	9
	Household has grid electricity	0
	Household has own toilet	83
	Household uses protected water source	63
	Radio available	65
	Telephone available	51
	Bicycle available	54
Household head	Female household head	7
	Household head's education (years)	6.5 (3.3)
Caregiver	Male caregiver	2
	Caregiver's age (years)	28.4 (7.2)
	Caregiver's education (years)	4.3 (3.1)
Child	Child is female	50
	Child was multiple birth	2
	Child age	
	- 0-5 months	24
	- 06-11 months	25
	- 12-17 months	28
	- 18-23 months	22

[1] Values are means (SD) or percentages.

Table 2. Household food security and caregiver and child nutritional status and health by region.

Category	Characteristic	Region	
		North (n=1234)	**Southwest (n=648)**
Household food security	HFIAS score	6.7 (5.7)	8.6 (5.4)
	HFIA category		
	- Food Secure	23	11
	- Mildly Food Insecure	22	28
	- Moderately Food Insecure	32	35
	- Severely Food Insecure	23	27
	Moderate or severe household hunger	11	11
Caregiver	Caregiver BMI		
	- Underweight	11	3
	- Normal	80	74
	- Overweight or obese	5	16
	- Pregnant	5	7
	Caregiver has good food hygiene	39	30
	Female caregiver parity	5.0 (2.9)	4.5 (2.9)
	Caregiver's age at first live birth	18.8 (3.7)	19.9 (3.6)
	4+ ANC visits during last pregnancy	56	54
Child	Child length-for-age Z-score	-0.8 (1.5)	-1.6 (1.5)
	Child is stunted (HAZ<-2)	18	39
	Child weight-for-length Z-score	-0.3 (1.3)	0.3 (1.3)
	Child has acute malnutrition (WHZ<-2)	9	3
	Child weight-for-age Z-score	-0.7 (1.2)	-0.7 (1.2)
	Child is underweight (WAZ<-2)	13	13
	Child is anemic	61	58
	Child ate animal source food in last 24 hours	11	9
	Child had any illness in past 2 weeks	70	55
	Child had diarrhea in past 2 weeks	17	18
	Child had cough in past 2 weeks	53	37
	Child had difficult or fast breathing in past 2 weeks	13	9
	Child had fever in past 2 weeks	55	29
	Child malaria infection status	35	8

[1] Values are means (SD) or percentages.

Table 3. Household agricultural practices and technologies by region.

Category	Characteristic	Region	
		North (n=1234)	Southwest (n=648)
Land	Land owned (acres)	3.5 (2.7)	2.2 (2.7)
	Land cultivated (acres)	3.4 (2.1)	1.9 (1.7)
Crops	Grew cereals	92	90
	Grew bananas	12	62
	Grew roots or tubers	77	92
	Grew legumes	85	95
	Grew vegetables	25	15
	Grew fruits	18	9
	Grew crops rich in vitamin A	26	10
	Grew cash crops	66	25
Livestock	Has livestock	90	64
	Has cattle	45	13
	Has small ruminants	60	47
	Has poultry	79	41
	Total livestock value (UShs)	991,852 (1,777,720)	546,700 (2,372,833)
Crop Technologies	Used improved seed or seedlings	39	7
	Used inorganic fertilizer	1	9
	Used organic fertilizer	1	39
	Used any fertilizer	2	44
	Used agrochemicals in field	12	23
	Used agrochemicals for post-harvest	5	4
	Used any agrochemicals (including inorganic fertilizer)	15	31
	Used local pest management practices	4	17
	Used integrated pest management	3	7
	Used integrated soil fertility management	6	8
	Used irrigation	0	0
Livestock Technologies	Has improved livestock	1	4
	Vaccinated livestock	12	4
	Used improved livestock feed	1	0
	Used aquaculture	0	0
Other Technologies and Practices	Left land fallow	27	28
	Burned to clear land	29	16
	Planted in rows	83	42
	Used intercropping	68	75

Category	Characteristic	Region	
		North (n=1234)	Southwest (n=648)
	Used crop rotation	88	79
	Used long-handled hoe	64	90
	Used wheelbarrow	4	4
	Used animal traction	57	0
	Used mechanization	1	0
	Hired farm labor	60	36
Post-harvest	Used improved drying methods	15	23
	Used improved storage techniques	14	1
	Used improved processing technologies	3	4
	Added value to agricultural production	6	4
	Used improved transportation	38	4
Commercialization	Sold crop production	82	88
	Percent of crop production value sold	32 (26)	28 (21)
	Sold livestock products	44	32
	Used improved marketing	28	4
	Used distant or larger market for sale	21	10
	Used farmers' group for sale	4	1
Diversification	Number of crop species	6.0 (2.8)	5.9 (2.2)
	Number of livestock species	2.2 (1.3)	1.3 (1.2)
	Per capita total income (Ushs/person)	92,855 (303,154)	94,775 (151,809)
	Per capita farm income (Ushs/person)	65,761 (224,739)	71,699 (131,198)
	Has off-farm income	79	66
	Percent of household income from off-farm	26 (28)	21 (26)

[1] Values are means (SD) or percentages.

Table 4. Pairwise effects of household agricultural practices and technologies on child height-for-age Z-score, controlling for potential confounders identified through stepwise selection: parish, child sex, child age, child multiple birth, child's consumption of animal source foods in the preceding 24 hours, child anemia status, child's difficult or fast breathing in the preceding two weeks, caregiver's current age, caregiver's age at the birth of her eldest surviving child, caregiver's attendance at four or more antenatal care visits during her latest pregnancy, caregiver's overweight or obese status, household having a metal roof, household having brick or concrete walls, household having grid electricity, household having its own toilet, and household having access to a bicycle. [Note: These models are still under review.]

		Effect on HAZ	
Category	**Characteristic**	**Estimate**	**P-value**
Land	Land owned (acres)	0.0	0.87
	Land cultivated (acres)	0.0	0.86
Crops	Grew cereals	-0.1	0.40
	Grew bananas	0.1	0.47
	Grew roots or tubers	0.0	0.93
	Grew legumes	0.0	0.74
	Grew vegetables	-0.1	0.37
	Grew fruits	-0.1	0.46
	Grew crops rich in vitamin A	0.0	0.62
	Grew cash crops	0.1	0.24
Livestock	Has livestock	0.0	0.98
	Has cattle	0.1	0.47
	Has small ruminants	0.0	0.52
	Has poultry	0.0	0.63
	Total livestock value (100,000 UShs)	0.0	0.13
Crop Technologies	Used improved seed or seedlings	0.1	0.33
	Used inorganic fertilizer	0.5	0.01
	Used organic fertilizer	0.1	0.37
	Used any fertilizer	0.2	0.04
	Used agrochemicals in field	-0.1	0.27
	Used agrochemicals for post-harvest	0.1	0.55
	Used any agrochemicals (including inorganic fertilizer)	0.0	0.97
	Used local pest management practices	0.0	0.83
	Used integrated pest management	0.0	0.98
	Used integrated soil fertility management	0.2	0.09
	Used irrigation	0.5	0.42
Livestock Technologies	Has improved livestock	0.3	0.25
	Vaccinated livestock	0.0	0.69
	Used improved livestock feed	-0.3	0.48

Category	Characteristic	Effect on HAZ	
		Estimate	P-value
	Used aquaculture	0.6	0.47
Other Technologies and Practices	Left land fallow	0.1	0.10
	Burned to clear land	0.1	0.18
	Planted in rows	0.0	0.61
	Used intercropping	0.0	0.58
	Used crop rotation	0.2	0.11
	Used long-handled hoe	-0.2	0.05
	Used wheelbarrow	0.0	0.83
	Used animal traction	-0.1	0.17
	Used mechanization	0.1	0.72
	Hired farm labor	0.0	0.95
Post-harvest	Used improved drying methods	0.0	0.80
	Used improved storage techniques	0.2	0.18
	Used improved processing technologies	0.0	0.90
	Added value to agricultural production	0.0	0.91
	Used improved transportation	0.0	0.80
Commercialization	Sold crop production	0.0	0.73
	Percent of crop production value sold	0.0	0.49
	Sold livestock products	0.1	0.33
	Used improved marketing	0.0	0.61
	Used distant or larger market for sale	0.0	0.71
	Used farmers' group for sale	0.2	0.40
Diversification	Number of crop species	0.0	0.57
	Number of livestock species	0.0	0.44
	Per capita total income (10,000 Ushs/person)	0.0	0.05
	Per capita farm income (10,000 Ushs/person)	0.0	0.08
	Has off-farm income	-0.2	0.03
	Percent of household income from off-farm	0.0	0.91

Table 5. Multivariable regression of agricultural practices and technologies and potential confounders on child HAZ. [Note: This model is still under review.]

		Effect on HAZ	
Category	**Characteristic**	**Estimate**	**P-value**
Agriculture	Total livestock value (100,000 UShs)	0.0	0.46
	Used inorganic fertilizer	0.5	0.04
	Used any fertilizer	0.1	0.29
	Used integrated soil fertility management	0.2	0.12
	Left land fallow	0.1	0.27
	Burned to clear land	0.0	0.63
	Used crop rotation	0.2	0.12
	Used long-handled hoe	-0.2	0.05
	Used animal traction	-0.2	0.07
	Used improved storage techniques	0.1	0.29
	Per capita total income (10,000 Ushs/person)	0.0	0.27
	Per capita farm income (10,000 Ushs/person)	0.0	0.91
	Has off-farm income	-0.2	0.06
Child	Child is female	0.4	0.00
	Child age (0-5 months)	-	-
	Child age (6-11 months)	-0.1	0.18
	Child age (12-17 months)	-0.6	0.00
	Child age (18-23 months)	-1.1	0.00
	Child was multiple birth	-1.5	0.00
	Child ate animal source food in last 24 hours	0.2	0.04
	Child is anemic	-0.1	0.09
	Child had difficult or fast breathing in past 2 weeks	-0.2	0.14
Caregiver	Caregiver's age (years)	0.0	0.22
	Caregiver's age at first live birth	0.0	0.34
	4+ ANC visits during last pregnancy	0.1	0.04
	Caregiver overweight or obese	0.3	0.04
Household	Household has metal roof	0.2	0.06
	Household has brick or concrete walls	-0.2	0.10
	Household has grid electricity	0.7	0.28
	Household has own toilet	0.2	0.05
	Bicycle available	0.1	0.17