EXPLAINING PATTERNS OF MALNUTRITON AMONG CHILDREN IN UGANDA

ABSTRACT

Child malnutrition is one of the most serious problems threatening people's lives in Uganda. This study assesses the factors associated with patterns of child nutritional outcomes in Uganda, as indicated by Z-scores for growth of children less than five years of age. The OLS estimates suggest that, among all the explanatory variables considered, child and mother variables play the most important role in explaining a child's nutritional status. Household wealth and dependency ratio are also significantly correlated with child Z-scores. The explanatory power of UNHS variables nested at the district level is mixed. Percentage of households using purchased inputs is positive correlated with child Z-scores. Factors associated with child malnutrition appear to differ across sub-regions. This underscores important spatial and idiosyncratic features of child malnutrition in Uganda, and limits our ability to draw general conclusions and policy recommendations regarding child health.

Among the many risk factors that threaten the quality of life for Ugandans, malnutrition is one of the most severe. According to Grebmer, et al. (2011) Uganda has a Global Hunger Index (GHI) score of 16.7 ranking it 42nd out of 122 countries in 2011. The country's hunger situation is categorized as *serious*. Even without the presence of a specific crisis, communities struggle with chronic malnutrition. Forty percent of child deaths in Uganda are due to malnutrition (Bridge, et al., 2006). The prevalence of stunting among children under five years is above 38% across the country, and is even higher in Karamoja and the southwest, where it places Uganda into a high malnutrition condition (WFP, 2011; FAO, 2010a). This paper examines factors that contribute to child malnutrition in Uganda. Specifically, we study the relationship between agricultural performance and child nutrition levels, contributing to research regarding the links between agricultural production, food security, and human nutrition.

Child malnutrition is assessed by indicators of height and weight (based on height, weight, and age compared to an international reference population), and by screening for clinical manifestations and biochemical markers. Inappropriate or insufficient food, health or care could result in a child becoming malnourished, as manifested by stunting, underweight, wasting, or low birthweight. Stunting and other forms of malnutrition could potentially increase the probability of child mortality, disease and disability. For example, a severely stunted child has a four times larger risk of dying, and a severely wasted child has a nine times larger mortality risk. The adverse effect of undernutrition on a child's brain and nervous system development could appear be as early as in pregnancy, and this could affect school performance and income in the future (UNICEF, 2013).

Past findings point to a number of factors that contribute to child malnutrition. These include mother's education, duration of breastfeeding, maternal health, and access to safe water and improved sanitation (Wamani et al., 2004; Hobcraft, 1993; Kikafunda, et al., 1998b; FAO, 2010; McKinney, 2009). Regional differences also exist in child nutritional status in Uganda. For example, children from rural areas have a higher incidence of being malnourished than children from urban areas (UBOS and Macro International Inc., 2007). This motivates an over-archiving question for this thesis, namely *which factors play the most important roles in improving child growth outcomes in Uganda?*

Although agriculture plays a dominant role in Uganda's economy, agricultural yields are less than one third of potential yields (Pender, et al., 2004). This is due to serious soil depletion, limited access to improved seeds and fertilizers, and high reliance on rainfall and weather conditions (UBOS and Macro International Inc., 2007; Nkonya, et al., 2005; FANTA-2, 2010). As higher agricultural productivity can result in increased abundance and diversity of food and diets, as well as many constraints handicapping Ugandan agricultural potential, a second, and more specific question this thesis tries to answer is *do differences in agricultural potential and productivity help to explain differences in rates of child malnutrition?* To answer this, analysis focuses on results from a series of OLS regression models using nationally representative data from 2006.

Background

Previous studies have suggested a variety of factors that affect Ugandan child health and nutritional status. Wamani et al. (2004) found that mothers' education is the most robust predictor compared with fathers' education, household assets and land ownership. Hobcraft (1993) argued that a woman's education level directly affected the household's decision to access modern healthcare and led to a greater emphasis on child health. Children receiving higher food and human capital investments are more likely to survive and to develop both physically and emotionally. Moreover, women's education is correlated with a woman's empowerment, her social identity, and her confidence, all of which encourage her to make greater use of health services for her family and children (Cleland, 1990).

Maternal health is another key determinant of a baby's health. One indicator closely related to maternal mortality is antenatal care coverage (FAO, 2010). Ugandan women as a whole receive antenatal care from skilled providers. However, only 17 percent receive antenatal care as WHO recommends before the fourth month of pregnancy, and only 23 percent of mothers receive postpartum care within the first two days after delivery. As many as 74% women who had given birth in the past five years reported receiving no postpartum care at all (UBOS and Macro International Inc., 2007). Studies show that the duration of breastfeeding is associated with the risk of stunting. For example, Kikafunda, et al. (1998b) report the risk of stunting was much lower for children breastfed to 18 months than for those breastfed only in early infancy. Although breastfeeding is widespread in Uganda, only 60% of women satisfied the guidelines proposed by the WHO that suggest exclusive breastfeeding for the first six months of a child's life (UBOS and Macro International, 2007).

The high average prevalence of malnutrition in Uganda hides differences aligned with geographical characteristics. Children from rural areas face a higher risk of being malnourished. For example, 39.5% of rural children under five years are stunted versus 25.5% of urban children, and 16.5% of rural children under five are underweight versus 10.6% of urban children. Despite that 15% of the Ugandan population is affected by insufficient calorie intake, diet patterns vary across the rural/urban divide. Urban Uganda has experienced a nutritional transition – from consumption of plantain, starchy roots, and cereals to large and increasing consumption shares for rice, pulses, nuts, and green leafy vegetables. In contrast, diets in rural areas are quite basic and monotonous, and depend on what is being grown and what is accessible in local markets. Consuming one meal a day is common in rural areas and among poor urban households during periods of food shortages. Overall, purchases and consumption of fruit, vegetables, and animal protein are infrequent due to high prices (FAO, 2010a).

Agriculture is the most important sector in Uganda's economy, supporting the most livelihoods and acting as the main source of exports (making up 85% of export earnings). Ninety percent of the total population lives in rural areas where 80% employment is in agriculture (RoU, 2004; FAO, 2009). The agrarian economy in Uganda is primarily based on smallholder farmers, eighty percent of whom own less than 2 hectares of land and together contribute 70% of agricultural production (RoU, 2004). Agricultural production is largely dependent on weather and soil fertility, and it is generally characterized as low-input/low-output. Factors associated with low agricultural productivity include lack of usage of improved inputs, soil erosion compounded by man-made factors, lack of irrigation facilities, over-dependence on rainfall, and lack of access to farm credit (FAO, 2010a).

Uganda's temperature shows little variance between 25 °C and 32 °C. Based on the rainfall distribution, four percent of the land area is classified as high (>1750 mm/annum), seventy percent is classified as moderate (1000-1750 mm/annum), and the other twenty six percent is classified as low (<1000 mm/annum). In the south Uganda around Lake Victoria, with an annual rainfall around 1200-1500 mm, there are two crop seasons. To the north, the annual rainfall gradually goes down between 900-1300 mm, and the two rainy seasons merge to one. Based the differences in ecological condition and farming system, Uganda can be divided into seven major ecological zones (see Figure 1). They are banana-coffee system, banana-millet-cotton system, Montane system, Teso system, northern system, West Nile system, and pastoral system (FAO, 2006). Each ecosystem related districts, major crop, and crop seasons are listed in Table 1.

Ugandan agriculture is highly vulnerable to weather shocks because it is mostly rain-fed. This heavy reliance on natural weather conditions is the primary factor that handicaps agricultural potential (FANTA-2, 2010). According to UHNS (2005/06) data, forty-two percent of households reported that crop production was affected by drought, while fifteen percent had experienced floods and hailstorms. Since Ugandan agriculture is small-farm based, weather shocks can be a heavy burden to low-income households, given the limited number of coping strategies (Asiimwe and Mpuga, 2007). The small–scale nature of Ugandan agriculture does not allow farmers to make large investments in irrigation, and a focus on traditional rain-fed farming undermines investment in irrigation. As of 2004, less than 15,000 ha of land was under formal irrigation and 67,000 ha were under informal irrigation, out of a total of 202,000 ha estimated to be potentially irrigable (Kabanda and Kahangire, 1994).

Civil unrest is also a problem in some areas. Unrest damages the food system by depressing production and income from cash crops, and further harms food security and coping strategies (Messer and Cohen, 2004). Starting from the mid-1980s, northern Uganda experienced a long period of conflict. Due to the conflict between the Ugandan People's Defense Forces and the rebel Lord's Resistance Army (LRA) and their direct attacks on local people, some households were displaced, and many became internally displaced persons (IDPs) followed by the government's 2002 relocation order (Birner, Cohen, and Ilukor, 2011). As people are inclined to stay within the relative safety of IDP camps, agricultural production has been crippled, leaving millions of people food insecure and malnourished. Vulnerable groups such as women, children, and those with HIV are more food–insecure. Meanwhile, coping capacity is weakened by the armed conflict and displacement, mainly due to the loss of various forms of wealth, including savings of livestock, draught animals, rural homes, grain stores, and trading centers. Warring parties also use hunger as a weapon to attract supporters and punish enemies, making food insecurity not only a result of conflict, but also a cause of conflict (Bukuluki etc, 2008; Messer and Cohen, 2004).

According to the Uganda food security watch issued by the Famine Early Warning System Network (FEWS NET) in May 2006, food insecurity remains a serious problem in Uganda. Most of the estimated 1.45 million IDPs faced moderate to high food insecurity with more than half of their food supplied by the World Food Program (WFP). Access to health, sanitation, shelter, and water services was greatly limited for IDPs. Moreover, the food security situation in other parts of Uganda is not good, especially in banana growing areas, due to the Banana Bacterial Wilt (BBW). Bananas are an important food source for a quarter of Ugandans. Between the years 2001 to 2004, banana production in general declined by 13 percent, with a decrease of 65-80% in the BBW infested areas (FEWS NET, 2006). Between 2006 and 2008, 22% of Uganda's population faced food deprivation, with an average food deficit of 240 kcal per person per day (FAO, 2011).

Most observers believe that agricultural productivity and practices are closely correlated with human health. Good agricultural performance could provide ample calories and nutrients that contribute to better health. Inappropriate farming practices, on the other hand, can lead to health problems. For example, improper food harvesting and storage practices could promote the growth of mycotoxins (Asenso-Okyere and Jemaneh, 2012). With a large proportion of the population living in rural areas and working in agriculture, improving agricultural productivity is an important path to solving widespread problems of hunger and malnutrition in Uganda.

Data

In order to investigate the connection between child malnutrition and low agricultural performance in Uganda, this study combines data from three sources: (1) the 2006 Uganda Demographic and Health Survey (UDHS), (2) the 2005/06 Uganda National Household Survey (UNHS), and (3) the Normalized Difference Vegetation Index (NDVI) observed by NASA's Moderate Resolution Imaging Spectroradiometerlites (MODIS) provided by Dr. Molly Brown and the National Aeronautics and Space Administration (NASA). The 2006 UDHS provides information on basic demographic and health characteristics of children, mothers, fathers, and households. To include the information on agricultural performance and potential, we need to combine the 2005/06 UNHS, which provides household level information on agricultural productivity and other characteristics. NDVI as a proxy for rainfall vegetative health and agricultural potential, is processed from Aqua, one of two NASA satellites housing Moderate Resolution Imaging Spectroradiometer (MODIS) sensors. This provides remotely sensed data at a 5 km spatial resolution. To provide a comprehensive analysis for each child in the 2006 DHS, data from the 2005/06 UNHS have been aggregated and summarized and matched to DHS households based on a set of key characteristics. The 2006 DHS and NDVIs are matched based on GPS coordinates and cluster numbers provided in DHS.

Since DHS did not provide indicators of agricultural productivity, the 2005/06 UNHS serves as the second data source to provide such information. In order to match the UNHS and DHS datasets of different household samples and use DHS children as the unit of analysis, information from the UNHS was summarized at the district level according to an 8-level nesting.1 These nests are urban/rural, large/small farm2, and female/male head of household. With 56 districts in total, this generates 448 potential observations for each UNHS variable of interest. By summarizing UNHS data by the defined 8-level nests, we are able to create a profile of representative households for purposes of matching to similar household in the DHS dataset.3 All the DHS observations are matched accurately to UNHS districts; however, 223 UNHS observations are not used because 40 rural and 183 urban nestings do not exist in the DHS dataset.

[1] Three binary variables (urban/rural, large/small farm size, and female/male headed household) generate a 2^3=8 level nesting.
[2] In the DHS dataset, the median value of agricultural land is 8.09 hectares per household. Every child living in a household with agricultural land larger than 8.09 hectares is defined as "large", otherwise "small". In the UNHS dataset, the median size of agricultural land owned by each household is 1.01 hectares observed in the UNHS dataset.

[3] If any missing value is encountered at a nesting level during the process, it is replaced by the value of its nearest level. For example, if in a particular district no large farms with female heads are observed, then the UNHS information used for matching to the corresponding DHS household will represent large farms in the same district, but with male heads.

Two categories of variables are of interest from the UNHS: (1) agricultural potential; and (2) household income and expenditure. Agricultural potential is proxied by crop yields, sales ratio, and use of purchased inputs. Based on Uganda's crop map (see Figure 1), each district is assigned to a unique farming system, which has its representative crop and corresponding harvest season. Crop yield therefore is calculated through the harvested district representative crop (by kilogram) (Table 1) divided by the corresponding plot area (by hectare) in each household.[4, 5] To measure the level of crop products sold commercially, we generate a sales ratio variable by calculating the proportion of crop sales (in quantity) over total crop harvest (in quantity). Use of purchased inputs is measured at the household level as a binary variable (1=used, 0=not used) and the overall sample percentage within the district and 8-level nest is computed. The use of purchased non-labor inputs refers to the use of at least one purchased input (manure, pesticides, or fertilizer) during the past two crop seasons at the time surveyed.

The second group of UNHS variables include household income and household expenditure in the past twelve months at the time surveyed. Household income refers to the annual sum of income net of costs from livestock, crop production, sale of assets excluding livestock, ag-business income, non-ag business income, agricultural wage income, non-agricultural wage income, remittances and assistance, and other income. Reported income below zero is set to zero. This constrains the share from each category to fall between zero and one. Household expenditure includes education expenditure, consumption expenditure of semi-durable and non-durable goods, rent expenditure, food and tobacco expenditure, and non-consumption expenditure. For the purpose of this analysis, we generate the mean, minimum, maximum,

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[4] For harvests of maize and barley, which are not reported as dry grain, we convert to dry grain by multiplying 0.79. We treat sorghum and millet similarly using a multiplier of 0.70.

[5] Where two harvest seasons have been reported, harvested quantities are summed within each household, and then divided by the total planted area in the two seasons.

median, and standard deviation for each variable of interest in each district at each of 8–level nests.

Agricultural potential can also be estimated through vegetative density. One measurement of the difference in vegetation is NDVI, a monthly average of greenness based on daily observations from the MODIS on NASA's satellite, ranging from -1 to 1.[6] For this study, monthly NDVI values from January 2000 to December 2011 are available for analysis. These are matched to DHS data based on GPS coordinates of the 2006 UDHS clusters. The entire sample of DHS children being studied is covered.

Figure 5 shows that the average NDVIs for the growing season are above 5.5 NDVI points in all of the farming systems except for the Karamoja Dry Zone, where the average NDVIs are greater than 4.0 NDVI points. Moreover, the available monthly NDVIs from Jan 2001 to Dec 2011 are all positive. This implies that Uganda could be extremely green in every part and every month from 2001 to 2011. The rainfall plots for 2001 to 2006 shown in Figure 7 suggest a rainy condition in most of ecological zones, especially during the growing months. In this case, vegetation in Uganda could be very green overall, but the NDVI might not fully reflect the agricultural potential arising from lack of moisture in specific situations. In fact, NDVI is potentially associated with rainfall shocks. For example, the average NDVI values for the growing months in Karamoja for dry and wet zones are extremely low in 2002 and 2004 compared to other years (see Figure 21). Rainfalls for the growing seasons in Karamoja are also below the short-run average (see Figure 22). We therefore have a bold assumption that NDVI anomalies could reflect weather shocks, especially rainfall shocks.

The NDVI anomalies are generated by calculating the ratio of a monthly NDVI value in a specific year over the long-run monthly average value for the same cluster, based on observation

[6] For convenience of analysis and to avoid rounding errors, original NDVI values are multiplied by 1000 for use in this research.

over the period 2001-2010. The long-run monthly average value refers to the average NDVI value for a specific month, say January, from 2000 to 2011. Anomalies greater than 1 indicate positive rainfall shocks and less than 1 indicate a negative rainfall shocks. For each child, the NDVI monthly anomaly in his/her birth year and the year prior to birth are generated and used to control HAZ. NDVI anomalies in 2005 and 2006 are used to control WHZ. The processed NDVI dataset was merged to the DHS-UNHS dataset by DHS cluster.[7] Only observations that have both NDVI and DHS data are kept, resulting in 2,176 children with both Z–scores and GPS/NDVI information.[8] The dataset containing DHS observations with merged NDVI-UNHS information is referred to as the "DHS-UNHS-NDVI" dataset.

In this study, children's Z-scores are used as indicators of child nutritional status. These Z-scores are available for 2,419 children in the 2006 UDHS. According to the World Health Organization (WHO, 2012b), a Z-score (also known as a standard deviation score) is widely recognized as the best approach for analysis and presentation of anthropometric data. In particular, children under five-years old with a height-for-age Z-score (HAZ) less than -2 SD are classified as low height-for-age, indicating "stunting"; and children under five-years old with a weight-for-height Z-score (WHZ) less than -2 SD are classified as having low weight-for-height, indicating "wasting". Stunting and wasting result from moderate or severe chronic and acute malnutrition, respectively. Chronically malnourished children could also be acutely malnourished, in which case they would be both stunted and wasted (Waterlow, 1973). Children with Z-scores between -2

[7] A total of 204 children were not matched. Among those, 194 were not matched because DHS did not provide GPS coordinates for 32 clusters, and we could not obtain NDVI values for those observations. Another 10 observations were not matched there no no DHS observation to match NDVI clusters. These observations are in clusters 12, 39, 111, 147, 198, 199, 199, 200, 203, 204, 216 (in fact, clusters 198, 199, 200, 203, 204 and 216 do not appear in any of the DHS data files).

[8] To see whether these children are "nationally representative," we compare the means for HAZ, WAZ, and WHZ for three groups of children (< 5 years): Group A – all children (< 5 years) with Z scores; Group B – children (<5 years) with Z scores and GPS/NDVI; and Group C – children (<5 years) with Z score but no GPS/NDVI. The t–test results show that the differences between Group A and groups B and C are not significant at the 95% confidence level (Table 2), meaning the subset of 2,176 children (<5 years) with NDVI data are not statistically different from the full DHS sample of 2,419 children with Z-scores.

SD and +2 SD are identified as healthy. For the analysis presented below, child Z-score is used as the unit of analysis. The formula for calculating the Z-score is:

$$Z_i = \frac{X_i - \bar{X}}{\sigma}, \qquad [2.1]$$

where X_i = observed value; $\bar{X}$ = median value in the reference population; and σ = the standard deviation value of the reference population (WHO, 2012b).

Table 3 lists the summary statistics of HAZ, WAZ, and WHZ. Distributions for each are plotted in figures 3. According to WHO (2012b), there are two ways of interpreting child growth results by Z-scores. One way relies on the descriptive statistics. If the mean Z-score is lower than zero, especially for HAZ and WAZ, this suggests the entire distribution has been shifted downward and most individuals have been affected. In the case of the standard deviation values of Z-score distributions, all three fall below their expected ranges,9 meaning the distribution of the selected sample has a wider spread than the reference distribution of the sample. The other way to use this information is to use a cut-off of -2 to measure the prevalence of low Z-scores, by which measure 33% of children in this sample are stunted, 21% are underweight, and 6% are wasted. WHO classifies Uganda's situation of stunting and underweight as a "high" severity of malnutrition (WHO, 2012b).

The average Z-scores and frequency of stunting, wasting, and overweight are computed with respect to eleven characteristics of the household, mother, and father. These comparisons are provided in Table 4. The entries show that child age but not gender is associated with nutritional status. Children over one year and less than two years have the lowest average Z-scores and highest prevalence of stunting (39%) and wasting (13%). There is an obvious pattern of improved nutritional status with a higher level of education achieved by mother. A similar pattern is also observed for the father's educational level and the household wealth index, but the relationships

[9] The expected ranges of standard deviations suggested by WHO are: Height-for-age Z-score: 1.10 to 1.30; weight-for-age Z-score: 1.00 to 1.20; weight-for-height: 0.85-1.10 (WHO, 2012b).

are not as distinct as for mother's educational level. An uneven distribution of child malnutrition is found between urban and rural settings, with stunting rates of 33% and 22% stunting respectively. Children in the central region seem to have a healthier growing environment, while those in Karamoja and the southwest face severe nutritional problems, with almost half stunted. Data in Table 4 also indicate that children from households with large farms do better than those from small farms; children with access to a safe source of drinking water do better than those without.

To further explore patterns in the data, ten bivariate plots are constructed with fitted child Z-scores plotted against continuous variables from DHS (Figure 4) and UNHS (Figure 5). As an indicator of household economic status, wealth index[10] has a positive correlation with child Z-scores. The household dependency ratio is calculated using DHS data as the number of individuals aged below 15 or above 64 divided by the number of individuals aged between 15 and 64. It is negatively correlated with child Z-scores. It seems that until after the age of 24, mother's age is negatively associated with child Z-scores. There is an almost linear increase in child Z-scores with mother's education, which underscores its important role. Child Z-scores increase with mother's body mass index (BMI)[11], indicating that a child's nutritional status is strongly correlated with the mothers' health status. It shows that a longer period of breastfeeding decreases child Z-scores, which agrees with Kikafunda et al.'s (1998) finding, namely that children who were breastfed more than 18 months and up to 24 months had an almost sevenfold increase in stunting over those who were breastfed only in early infancy. Possible explanations include prolonged breast-feeding being associated with a lower intake of solid foods. Children who are

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[10] The wealth index factor score included in the DHS is based on the weight or factor score assigned to the ownership of assets in each household.

[11] BMI is defined as the weight in kilograms divided by the square of the height in meters (kg/m^2), and is commonly used to classify underweight (<18.50), overweight (>25.0) and obesity (>30.0) among adults (WHO, 2012a).

still being breast-fed are reluctant to accept other foods. Also, these children may belong to families with poorer socioeconomic conditions.

As for the bivariate plots against UNHS variables (see Figure 5), Child Z-scores increase with a falling share of food expenditure and increased household income. This is consist with Engel's law, the percentage of income allocated for food purchases decreases as income rises. Moreover, the share of expenditure on tobacco is negatively correlated with Z-scores, revealing that parents' health and spending behavior might be correlated with a child's growth. Child Z-scores rise and then fall with yields. This is possibly for the reason that agricultural intensity initially benefits children, perhaps when output of food crops rises, but may be harmful when a large share of household attention or resources are directed at agriculture, or the focus shifts toward cash crops. No specific patterns are found in the plots between Z-scores and district average percentage use of purchased input, improved seeds or irrigation. Multivariate analysis follows to see if any relationship exists between agricultural productivity and child Z-scores.

Method

Taking the Z-scores as dependent variables, a series of OLS regressions are applied to identify factors associated with child Z-scores. Based on the relationships with the child and their source, explanatory variables are categorized into four groups: (A) DHS child, (B) DHS mother, (C) DHS father and household, and (D) UNHS. Descriptions, descriptive statistics, and hypothesized Z-score correlations for variables selected for regression analysis are summarized in Table 5. To investigate the robustness of relative effects played by each group of variables on HAZ and WHZ, regressions are run using each block of variables and all variables together, as a check of robustness. In addition, to examine results for specific sub-groups of the population, separate regressions are run for the sample of urban children, children from IDP camps, and children from rural areas but not IDP camps. The regression equations are:

$$Z_i = \alpha_1 + \beta_{1i}A_i + \varepsilon_{1j}, \qquad [3.1a]$$

$$Z_i = \alpha_2 + \beta_{2i}A_i + \tau_{2i}B_i + \varepsilon_{2j}, \qquad [3.2a]$$

$$Z_i = \alpha_3 + \beta_{3i}A_i + \tau_{3i}B_i + \gamma_{3i}C_i + \varepsilon_{3j}, \qquad [3.3a]$$

$$Z_i = \alpha_4 + \beta_{4i}A_i + \tau_{4i}B_i + \gamma_{4i}C_i + \eta_{4i}D_i + \varepsilon_{4j}, \qquad [3.4a]$$

$$Z_i = \alpha_5 + \beta_{5i}A_i + \tau_{5i}B_i + \gamma_{5i}C_i + \eta_{5i}D_i + \delta_{5i}E_i + \varepsilon_{5j}; \text{ where} \qquad [3.5a]$$

i – child case id;

Z_i - Z-score (HAZ or WHZ) of the ith child;

A_i – the group of DHS variables describing the child characteristics of the ith child;

B_i – the group of DHS variables describing the mother characteristics of the ith child;

C_i – the group of DHS variables describing the father and household characteristics of the ith child;

D_i – the group of UNHS variables at the 8-level nesting district level corresponding with the ith child;

E_i – the group of NDVI variables at the cluster level corresponding with the ith child;

and with the assumption of $\varepsilon_{ij} \sim N(0, \sigma^2)$, i=1, 2, …, n.

A set of control variables is included to control for factors that might explain some of the overall variance in nutrition levels. These are ecological zone (or agricultural farming system), DHS reporting area, and NDVI monthly anomalies in child birth year and utero for HAZ, and 2005 and 2006 for WHZ. An NDVI monthly anomaly is the deviation of monthly NDVI values for each cluster from long-term average monthly values. These anomalies allow for controlling weather shocks that might affect child Z-scores. All regressions repeated in the full sample include these variables. In addition, we are interested in subgroups of children living in urban, IDP camps, and rural but not IDP camps. These sub-groups are analyzed in separate, parallel regressions.

Results

Tables 5A (HAZ) and 5B (WHZ) present results from the OLS approach for the full sample. Each column represents a regression with a specific group of independent variables, which allows for comparison of regression coefficients across models, as a check of robustness. Table 7 provides regression results for subgroups of children.

For effects of child factors on both HAZ and WHZ, the regression results address the effects of child's age, whether the child is a twin or not, and whether a child has anemia or does not. For each one month increase in child age, there is a 0.014 unit decrease in HAZ, indicating older children have greater chance of being stunted. This confirms Kikafunda et al.'s (1998b) finding that older children were more likely to be stunted than younger children. In contrast, for each one month increase in child age, WHS has a 0.013 unit increased. Whether the child is a twin is significantly correlated with both HAZ and WHZ. It shows that a single born child has a 0.809 unit lower HAZ and a 0.285 unit lower WHZ than a child who has a twin brother/sister. As expected, anemia is negatively correlated with child Z-scores. A child with anemia has a HAZ that is 0.35 points lower and a WHZ that is 0.17 points lower. The regression results also highlight several significant effects of vaccinations for WHZ. BCG, or anti-tuberculosis, as expected, is positively correlated with WHZ. However, vaccinations for polio and measles are negatively correlated with WHZ, which is unexpected. We are not aware of any previous research that explains this pattern.

As for mother's characteristics, age of mother has significant and positive correlation with HAZ. For each one year increase in mother's age, HAZ increases by 0.022 point. This effect of mother's age is mostly significant within the regression that has DHS child and mother variables, and becomes weaker when groups of father and household variable, or UNHS variables are included in the regression equation. Mother's BMI is positively correlated with both HAZ and WHZ, indicating mother's health is crucial to child's growth. With each one kg/m^2 increase in mother's BMI, there is 0.022 point increase in HAZ and 0.078 point increase in WHZ. As expected, mother's pregnancy is negatively associated WHZ. A child whose mother is pregnant has a 0.013 points lower WHZ than a child whose mother is not. This might be because a pregnant mother spends less time and allocates fewer resources in taking care of children, resulting in a lower WHZ, which reflects a worse quality of child nutrition intake in short term. Mothers who are breastfeeding tend to have children with lower HAZ, and cumulative months of breastfeeding is negatively associated with both HAZ and WHZ. With only 60% of Ugandan women satisfying WHO's suggestion of breastfeeding for the first six months of a child's life (UBOS and Macro International, 2007), suggesting the problem of inappropriate breastfeeding practice could be widespread among Ugandan mothers. With prolonged breastfeeding time, a child may be reluctant to take other food with essential nutrients. This is also associated with a family with low socio-economic status and poor knowledge, which is hinders the child's health. Therefore, these significantly negative correlations are not surprising.

Among the father and household variables, the wealth index has significant correlation with child Z-scores. For each one unit increase in the wealth index score (/10000), HAZ increases by 0.014 points. Regional differences are shown in HAZ. A child from an urban area has 0.227 points higher in HAZ than a child from rural area and from an IDP camp child has 0.589 points lower HAZ than a non-IDP child. This provides rationales for further analysis of children from subsamples with regional differences. Moreover, a negative association is found between altitude and WHZ. Each 100 masl increase in altitude is associated with 0.023 point decrease in WHZ.

In terms of UNHS variables, the percentage of households in each district using purchased inputs, a reflection of potentially higher farm productivity in an area, is positively and significantly associated with HAZ. For each one percentage point increase in the use of purchased inputs in the child's district, child HAZ increases by 0.693 points. Crop yield is unexpectedly negatively correlated with HAZ at a 90% confident level. Further insight comes from the significant and negative correlation with sales ratio, a measure of the proportion of harvested crop that is sold. By OLS results, if all the crop products kept in the households are sold, child HAZ will decrease by 0.893 points, one explanation might be that less food crops is grown for children to consume. Additionally, if labor is directed at commercial production, this may have deleterious effects on child health. If households mainly grow cash crops, a child could have an insufficient or monotonous diet, and this could lead to a negative correlation between crop yield and HAZ.

Table 6 displays results from multiple linear regressions among sub-groups of children with selected variables of particular interest. We find that household livestock holdings are positively and significantly associated with HAZ for rural children. Each one unit increase in the tropical livestock unit, it shows a 0.035 points increase in HAZ. Dependent ratio is found to have negative correlations with Z-scores for non-IDP children in both urban and rural areas, but a positive correlation for children from IDP camps.[12] If the household members turn from independent (aged 15-64) only to dependent (aged < 15, or >64), HAZ decreases by 0.095 points for a rural child, WHZ decreases by 0.329 for an urban child, but an IDP child could have 0.164 point increased in HAZ, possibly because that in IDP camps, even a household member at an independent age cannot work normally. Mother's education is particularly important for an urban child. Each one year increase in mother's education is associated with a 0.04 point increase in HAZ. Urban children are also more sensitive to wealth and father's working status. With respect to IDP children, those who have access to safe water have a 0.547 points higher HAZ.

Conclusions and Further Research

Among the DHS child, mother, father and household variables, we find that the child's and mother's characteristics most effectively explain children's nutritional status. Among child characteristics, child age is positively associated with the incidence of stunting, and negatively

[12] Result for regression with dep_ratio and dep_ratio^2 suggest non-significance for both terms.

associated with wasting. If a child is twin, he/she has a greater probability of being stunted or wasted than a single child. Vaccination of bcg (anti-tuberculosis) is associated with greater WHZ, while other forms of vaccinations such as polio and measles are found to be correlated lower WHZ in the studied sample, which is unexpected and difficult to explain. Children with anemia have significantly lower Z-scores. This research also addresses the mother's key role in improving children's nutrition and health status. Mother's BMI is found to be positively correlated with both HAZ and WHZ, indicating healthier mothers have greater ability to improve children's health. A mother who is pregnant might have vulnerable health status and less time and resources to take care of her children, resulting in lower WHZ. As for children's chronic nutritional status, mother's age is particularly important. Children with an older mother tend to have higher HAZ, and mothers who are breastfeeding have children with lower HAZ. Longer duration of breastfeeding leads to lower HAZ and WHZ, and this is found in all of the subsamples. Although short-term breastfeeding is crucial to babies' growth, extensive duration of breastfeeding could prevent children from obtaining other essential nutrients, which is reflecting in an overall negative estimated regression coefficient. For the urban sample, mother's education is positively associated with HAZ. Compared to child and mother characteristics, whether the father is working and household characteristics have relatively weak correlations with child Z-scores. Among the DHS household variables, family's economic status estimated by a wealth index is a key determinant of children's nutritional status. Dependency ratio, a reflection of household productivity in terms of available labor force, has negatively association with Z-scores for non-IDP children.

The UNHS variables at the nested district level with agricultural performance indicators could explain differences in child Z-scores, and the explanatory power is mixed. Use of purchased inputs is strongly encouraged on behalf of better child nutritional outcome. Crop yield has a negative correlation with child Z-scores. At the same time, the sales ratio is negatively associated with HAZ, meaning that as the proportion of crops sold rises, child's growth falls. With a relatively lower proportion of food crops being grown, the overall positive nutritional effects of improvements in crop yield can be dragged down. Agricultural performance reflected by the percentages of households using purchased inputs (manure, pesticides, or fertilizer) in specific reference groups in the district has positive correlation with HAZ. There is no evidence support the view that shares of income from livestock business are positively correlated with child Z-scores.

Factors associated with child malnutrition differ across sub-samples of the population. By testing the robustness of overall patterns of regression outcomes across the sample of children from urban areas, IDP camps, and rural areas but not IDP camps, we found that TLU, an agricultural potential and wealth indicator, plays important role for rural, non-IDP children; social-economic indicators of mother's education time wealth index is more important for urban children; and access to safe source of water is crucial for children living in the IDP camps. Also, a negative correlation between dependency ratio and child Z-scores is existed in non-IDP areas.

This research sought to explain child malnutrition in Uganda and addressed factors associated with child Z-scores in a nationally representative sample and different sub-samples. This has implications for nutrition intervention programs with different focuses on the investment in child nutrition improvement. A mother's important role in improving the nutritional status of her children is emphasized in this research. We find that mother's health, experience and knowledge in taking care of children, and breastfeeding are crucial for the nutritional status of children under five years of age. These are reflected by the significant correlations between mother's age, mother's BMI, mother's education years, whether she is pregnant, and months of breastfeeding on child Z-scores. Our findings support an emphasis on women's education (in general) and trainings (with respect to breastfeeding practice) for women. Since women's health status directly affects the time and resources allocated to child feeding, nutrition intervention for females is strongly supported by these results.

With respect to how agricultural performance might influence child nutrition, an interesting finding is that higher rates of commercialization in a district, as measured by the share of crops sold, are negatively correlated with child Z-scores. One explanation might be that more family resources are allocated to farming and economic activity when household focus on sales, resulting in poor diet (in both quality and quantity) for children. Another explanation might be that agricultural sales ratios reflect cash crop rather than food crop orientation, and that cash incomes do not translate into nutritional gains. Unfortunately, neither hypothesis can be tested with the available data. In fact, the child health information obtained from 2006 DHS at the individual level and the information on agricultural performance obtained from 2005/06 UNHS at the household level are based on two different samples. The process of merging the two sources of information is based on district-level nestings. Children that fall into a particular nesting live in that their households that share similar characteristics in terms of district, urban or rural, farm land size, and sex of household with the households in the 2005/06 UHNS sample. However, it also means that the children in the same nesting with different health conditions and nutritional status are tagged with the same UNHS information, which restricts the overall explanatory power of the UNHS variables. A better approach would be to use observations on child growth that also provide information on agricultural performance in that child's household. Such data do not presently exist for Uganda.

Finally, this research attempted to find factors associated with child malnutrition using data from DHS and UNHS in 2006. The Uganda DHS includes surveys for multiple years (1988-89, 1995, 2000-01, 2006, and 2011); and UHNS data are available for 1999/2000, 2002/2003, 2005/2006, and 2009/2010. Utilizing these data would allow for further study of the same research questions with a larger time scope, and could also provide insights regarding drivers of changes in child nutritional status across years.

Table 1 Crop Calendar Based on Farming System (FAO, 2010b; Figure 1)

Agro Ecological Zone	Main Crop	Crop Season	District
Busoga Farming System	maize	June-Dec	Kayunga, Bugiri, Iganga, Jinja, Kamuli, Mayuge
Eastern Highlands	barley	June-Dec	Kapchorwa, Mbale, Sironko
Eastern Savannah	maize	July-Dec	Busia, Katakwi, Kumi, Pallisa, Soroti, Tororo, Kaberamaido
Karamoja Dry Zone	sorghum	July-Oct	Kodito, Moroto
Karamoja Wet Zone	millet,finger	July-Aug	Nakapiripirit
Lake Alber Crescent	maize	July-Dec	Kiboga, Mubende, Budibugyo, Hoima, Kabarole, Kibaale, Masindi, Kamwenge, Kyenjojo
Lake Victoria Crescent	maize	May-Dec	Kalangala, Kampala, Luwero, Masaka, Mpigi, Mukono, Rakai, Wakiso
Northern Farming System	millet,finger	July-Aug	Apac, Gulu, Kitgum, Lira, Pader
South Western Highlands	potato	April-Feb	Kabale. Kisoro, Rukungiri, Kanungu
West Nile Farming System	millet,finger	July-Aug	Adjumari, Arua, Moyo, Nebbi, Yumbe
Western Range Lands	maize	Dec-Jan	Nakasongola, Sembabule, Bushenyi, Kasese, Mbarara, Ntungamo

Table 2 Descriptive Statistics and Cut-off-based Prevalence of Z-scores.

Z-score	N	Mean	Std. Dev.	Min	Max	Median	No. of obs with SD <-2	Freq. of SD<-2	No. of obs with SD>2	Freq. of SD>2
HAZ	2176	1.36	1.46	5.92	5.17	-1.43	702	32.26%	45	2.07%
WHA	2176	-1.05	1.24	-5.1	5.31	-1.1	465	21.37%	29	1.33%
WHZ	2176	0.25	1.15	3.94	5.99	-.24	124	5.70%	71	3.26%

Table 3 Average Z-scores, Frequency of Stunting, Wasting, and Overweight by Characteristics of Household, Mother, and Father.

	HAZ	WAZ	WHZ	Freq.	No. of stunting	% of stunting	No. of wasting	% of wasting	No. of overweight	% of overweight
Sex of child										
male	-1.40	-1.07	-0.27	1097	363	33.09%	69	6.29%	34	3.10%
female	-1.33	-1.03	-0.23	1079	339	31.42%	55	5.10%	37	3.43%
child's age (years)										
0	-0.68	-0.60	-0.13	475	72	15.16%	30	6.32%	27	5.68%
1	-1.61	-1.48	-0.67	490	191	38.98%	65	13.27%	16	3.27%
2	-1.41	-1.12	-0.29	432	147	34.03%	18	4.17%	6	1.39%
3	-1.56	-1.02	-0.06	398	146	36.68%	6	1.51%	13	3.27%
4	-1.65	-1.02	-0.01	381	30	7.87%	5	1.31%	9	2.36%
urban/rural										
rural	-1.42	-1.10	-0.27	1944	650	33.44%	110	5.66%	62	3.19%
urban	-0.85	-0.62	-0.09	232	52	22.41%	14	6.03%	9	3.88%
size of agricultural land										
small	-1.40	-1.11	-0.29	1402	477	34.02%	86	6.13%	41	2.92%
large	-1.29	-0.95	-0.17	774	225	29.07%	38	4.91%	30	3.88%
Safe source of water										
unsafe	-1.41	-1.09	-0.26	1935	642	33.18%	109	5.63%	12	0.62%
safe	-0.94	-0.73	-0.15	241	60	24.90%	15	6.22%	59	24.48%

Table 3 Continued.

Region										
central 1	-1.38	-0.92	-0.07	172	49	28.49%	6	3.49%	4	2.33%
central 2	-1.05	-0.76	-0.13	206	46	22.33%	5	2.43%	6	2.91%
Kampala	-0.77	-0.64	-0.18	141	30	21.28%	11	7.80%	5	3.55%
east central	-1.38	-1.27	-0.53	286	97	33.92%	25	8.74%	4	1.40%
eastern	-1.33	-0.97	-0.15	285	85	29.82%	7	2.46%	5	1.75%
north	-1.55	-1.28	-0.38	386	135	34.97%	27	6.99%	14	3.63%
western	-1.42	-1.02	-0.15	255	87	34.12%	11	4.31%	9	3.53%
southwest	-1.61	-1.07	-0.06	259	112	43.24%	24	9.27%	19	7.34%
Highest education level achieved by mother										
no education	-1.54	-1.29	-0.41	511	188	36.79%	34	6.65%	13	2.54%
primary	-1.40	-1.04	-0.20	1357	458	33.75%	72	5.31%	47	3.46%
secondary	-0.99	-0.81	-0.22	258	53	20.54%	17	6.59%	6	2.33%
Higher	-0.46	-0.22	0.18	50	3	6.00%	1	2.00%	3	6.00%
Highest education level achieved by father										
no education	-1.68	-1.42	-0.45	104	35	33.65%	8	7.69%	2	1.92%
primary	-1.39	-1.02	-0.19	927	314	33.87%	53	5.72%	38	4.10%
secondary	-1.31	-1.03	-0.28	219	70	31.96%	14	6.39%	4	1.83%
Higher	-0.85	-0.68	-0.11	79	13	16.46%	3	3.80%	6	7.59%
wealth index										
Poorest	-1.55	-1.28	-0.38	534	187	35.02%	33	6.18%	15	2.81%
Poorer	-1.36	-1.05	-0.26	424	147	34.67%	24	5.66%	13	3.07%
Middle	-1.57	-1.14	-0.20	454	176	38.77%	25	5.51%	13	2.86%
Richer	-1.31	-1.03	-0.26	380	110	28.95%	26	6.84%	15	3.95%
Richest	-0.91	-0.65	-0.09	384	82	21.35%	16	4.17%	15	3.91%
Total	-1.36	-1.05	-0.25	2176	702	32.26%	124	5.70%	71	3.26%

Table 4 Summary of Explanatory Variables

						hypothesized effects	
Source and category	variable name	description	mean	min	Max	HAZ	WHZ
A. Child (DHS)	agemos	child age (month)	27.88	0	59	-	indeterminate
	twin	child is twin, 1=multiple, 0=single	.02	0	1	indeterminate	indeterminate
	sex	sex of child, 1=male, 0=female	.50	0	1	indeterminate	indeterminate
	bcg	1=received bcg, 0=not	0.89	0	1	+	+
	polio1	1=received polio 1, 0=not	0.87	0	1	+	+
	measles	1=received measles, 0=not	0.62	0	1	+	+
	vad	1=vitamin a deficiency, no=not	0.09	0	1	-	-
	anemia	1=anemia, 0=not	0.64	0	1	-	-
B. Mother (DHS)	agemom	mother's age (year)	29.04	15	49	+	+
	momedu	mother's education (year)	4.12	0	19	+	+
	numchild	number of total children ever born	4.82	1	14	indeterminate	indeterminate
	bmimom	body mass index (kg/m2)	21.84	13.41	39.51	+	+
	breastfeedmos	breastfeeding time (month)	14.99	0	56	indeterminate	indeterminate
	anemiamom	1= mother has anemia, 0=not	0.42	0	1	-	-
	vadmom	1=mother has vitamin deficiency, 0=not	0.10	0	1	-	-
	litmom	mother's literacy: 1=able to read, 0=cannot read	0.45	0	1	+	+
	oralmom	1=mother heard of or used oral rehydration, 0=not	0.88	0	1	+	+
	workmom	1=mother currently working, 0=not	0.86	0	1	+	+
	pregnant	1=current pregnant, 0=not	0.14	0	1	-	-
	breastfeeding	1=currently breastfeeding, 0=not	0.70	0	1	indeterminate	indeterminate

Table 4 Continued.

C. Father and household (DHS)	workdad	1=father currently working, 0=not	0.61	0	1	+	+
	agehoh	age of head of household (year)	37.12	17	94	indeterminate	indeterminate
	wealth	wealth index factor score (/1000)	-11.81	-130.818	409.55	+	+
	watertime	time to water and back (mins)	18.02	0	180	-	-
	watersafe	1=safe source of water, 0=not	0.11	0	1	+	+
	agland	agricultural land owened by household (ha)	10.11	0	93.08	+	+
	dep_ratio	houehold total dependent ratio	1.85	0.142857	9	-	-
	tlu	tropical livestock unit	0.86	0	29.10	+	+
	idp	1=internally displaced person, 0=not	0.095	0	1	-	-
	fhoh	sex of houehold: 1=female, 0=male	0.22	0	1	indeterminate	indeterminate
	altitude	altitude (masl, via GPS)	1222.68	620	2274	indeterminate	indeterminate
	urbrural	1=urban, 0=rural	0.10	0	1	+	+
	eligwork	number of household number between 15-64	2.58	1	11	+	+
D. UNHS	cropyields	crop yield (kg/ha)	338.01	0	2224.63	+	+
	sratio	sales ratio	0.21	0	0.64	indeterminate	indeterminate
	pchsinput	percentage of hh using purchased inputs in 8-level district	0.55	0	1	+	+
	sagbusiinc_livestock	household livestock income in the past 12 months	0.03	0	1	+	+
	sagwageinc	household ag wage income share in the past 12 months	0.00	0	0.028	+	+

Table 5A Multiple Linear Regression Results for the Full Sample, HAZ.

Category and source	variable	DHS child	DHS mother	DHS father and household	UNHS
	constant	-0.540	-0.743	-0.001	-0.031
		(0.49)	(0.79)	(0.00)	(0.03)
Child (DHS)	agemos	-0.016***	-0.014***	-0.014***	-0.014***
	(months)	(3.96)	(3.63)	(3.96)	(4.23)
	sex	-0.063	-0.091	-0.086	-0.075
	(1=male, 0=female)	(1.16)	(1.62)	(1.46)	(1.24)
	twin	-0.828***	-0.878**	-0.831***	-0.809***
	(1=multiple, 0=single)	(2.66)	(3.15)	(3.06)	(-3.61)
	bcg	-0.045	-0.051	-0.072	-0.058
	(1=yes, 0=no)	(0.33)	(0.35)	(0.50)	(-0.4)
	polio1	-0.089	-0.095	-0.078	-0.078
	(1=yes, 0=no)	(0.71)	(0.75)	(0.65)	(-0.65)
	measles	0.017	0.016	0.018	0.018
	(1=yes, 0=no)	(0.27)	(0.22)	(0.21)	(0.19)
	vad	-0.007	-0.038	-0.068	-0.07
	(1=yes, 0=no)	(0.07)	(0.39)	(0.91)	(0.92)
	anemia	-0.416***	-0.346***	-0.337***	-0.348***
	(1=yes, 0=no)	(6.25)	(5.16)	(4.70)	(4.69)
Mother (DHS)	agemom		0.027***	0.021*	0.02*
	(years)		(3.05)	(1.87)	(1.84)
	edumom		0.016	0.003	0.002
	(years)		(1.27)	(0.17)	(0.13)
	oralmom		0.045	0.050	0.018
	(1=yes, 0=no)		(0.44)	(0.52)	(0.18)
	workmom		-0.133	-0.091	-0.079
	(1=yes, 0=no)		(1.34)	(0.88)	(0.7)
	litmom		0.156	0.184	0.174
	(1=yes, 0=no)		(1.31)	(1.59)	(1.52)
	bmimom		0.029**	0.021	0.022*
	(kg/m2)		(2.38)	(1.54)	(1.98)
	vadmom		-0.025	-0.026	-0.036
	(1=yes, 0=no)		(0.24)	(0.25)	(0.33)
	anemiamom		0.033	0.035	0.041
	(1=yes, 0=no)		(0.46)	(0.49)	(0.61)
	pregnant		-0.095	-0.069	-0.065
	(1=yes, 0=no)		(0.79)	(0.53)	(0.47)
	breastfeedmos		-0.019***	-0.018***	-0.017**
	(months)		(3.20)	(3.06)	(2.85)
	breastfeeding		-0.224**	-0.203**	-0.193*
	(1=yes, 0=no)		(2.27)	(2.05)	(1.89)
	numchild		-0.034	-0.022	-0.021
			(1.18)	(0.70)	(0.65)

Table 5A Continued.

Father and	workdad			0.034	0.021
household	(1=yes, 0=no)			(0.38)	(0.23)
(DHS)	agehoh			0.003	0.003
	(years)			(0.63)	(0.71)
	fhoh			-0.044	-0.02
	(1=yes, 0=no)			(0.44)	(0.2)
	wealth			0.013**	0.014**
	(score: /10000)			(2.39)	(2.34)
	Eligwork			-0.007	-0.01
	(number of people)			(0.18)	(0.25)
	dep_ratio			-0.039	-0.042
				(0.60)	(0.69)
	watersafe			0.070	0.09
	(1=yes, 0=no)			(0.31)	(0.4)
	watertime			0.001	0.001
	(minutes)			(0.75)	(0.61)
	agland			0.002	0
	(hectare)			(0.40)	(0.00)
	tlu			0.025	0.023
				(1.63)	(1.44)
	urbrural			0.043	0.227*
	(1=urban, 0=rural)			(0.19)	(1.94)
	idp			-0.612*	-0.589**
	(1=yes, 0=no)			(1.72)	(3.11)
	altitude			-0.010	-0.01
	(100masl, via GPS)			(0.49)	(0.52)
UNHS	cropyields				-0.034*
	(kg/100ha)				(1.89)
	sratio				-0.893**
					(2.13)
	pchsinput				0.693**
	(%)				(2.23)
	sagbusiinc_livestock				0.139
	(%)				(0.23)
R^2		0.130	0.158	0.169	0.178
N		2,158	2,158	2,158	2,158

Note: *p<0.10, **p<0.05, ***p<0.01. Control variables include 24 monthly NDVI anomalies of child birth year and the year prior to birth, and 11 agro ecological zones. Standard errors are clustered by DHS reporting areas.

Table 5B Multiple Linear Regression Results for the Full Sample, WHZ.

Source and Category	variable	DHS child	DHS mother	DHS father and household	UNHS
	constant	-0.116	-2.743	-2.542	-2.200
		(0.05)	(1.25)	(1.26)	(1.06)
Child (DHS)	agemos	0.010***	0.013***	0.013***	0.013***
	(months)	(3.62)	(4.74)	(4.82)	(4.72)
	sex	-0.048	-0.071	-0.068	-0.065
	(1=male, 0=female)	(0.88)	(1.22)	(1.12)	(1.05)
	twin	-0.292**	-0.310**	-0.301**	-0.285**
	(1=multiple, 0=single)	(2.16)	(2.32)	(2.31)	(2.16)
	bcg	0.309**	0.268*	0.269*	0.271
	(1=yes, 0=no)	(2.02)	(1.85)	(1.79)	(1.84)
	polio1	-0.321***	-0.323***	-0.318***	-0.315***
	(1=yes, 0=no)	(3.28)	(3.73)	(3.49)	(3.5)
	measles	-0.187**	-0.146*	-0.147*	-0.147
	(1=yes, 0=no)	(2.26)	(1.88)	(1.86)	(1.82)
	vad	-0.022	-0.006	-0.008	-0.011
	(1=yes, 0=no)	(0.38)	(0.11)	(0.15)	(0.2)
	anemia	-0.216***	-0.147***	-0.162***	-0.167***
	(1=yes, 0=no)	(5.24)	(3.30)	(3.79)	(3.99)
Mother (DHS)	agemom		-0.001	-0.001	-0.001
	(years)		(0.39)	(0.23)	(-0.2)
	edumom		0.003	0.005	0.005
	(years)		(0.29)	(0.63)	(-0.61)
	oralmom		0.101	0.098	0.085
	(1=yes, 0=no)		(1.01)	(1.00)	(-0.87)
	workmom		0.126	0.111	0.114
	(1=yes, 0=no)		(1.62)	(1.36)	(-1.38)
	litmom		-0.037	-0.026	-0.028
	(1=yes, 0=no)		(0.77)	(0.56)	(-0.62)
	bmimom		0.075***	0.077***	0.078***
	(kg/m2)		(6.90)	(6.99)	(7.44)
	vadmom		-0.001	-0.002	-0.007
	(1=yes, 0=no)		(0.01)	(0.03)	(0.11)
	anemiamom		0.007	0.000	0.002
	(1=yes, 0=no)		(0.13)	(0.00)	(0.03)
	pregnant		-0.166**	-0.174**	-0.173**
	(1=yes, 0=no)		(2.52)	(2.50)	(2.54)
	breastfeedmos		-0.014***	-0.013***	-0.013***
	(months)		(4.18)	(4.21)	(4.06)
	breastfeeding		-0.011	-0.010	-0.006
	(1=yes, 0=no)		(0.15)	(0.14)	(0.07)
	numchild		-0.007	0.000	-0.001
			(0.75)	(0.00)	(0.04)

Table 5B Continued.

Father and	workdad			-0.001	-0.005
household	(1=yes, 0=no)			(0.01)	(0.07)
(DHS)	agehoh			0.000	0.000
	(years)			(0.02)	(0.06)
	fhoh			0.005	0.019
	(1=yes, 0=no)			(0.05)	(0.22)
	wealth			-0.003	-0.003
	(score: /10000)			(0.58)	(0.56)
	Eligwork			-0.041	-0.043
	(number of people)			(1.27)	(1.31)
	dep_ratio			-0.040	-0.041
				(0.77)	(0.79)
	watersafe			-0.069	-0.063
	(1=yes, 0=no)			(0.86)	(0.82)
	watertime			0.001	0.001
	(minutes)			(0.85)	(0.82)
	agland			0.001	0.000
	(hectare)			(0.33)	(0.07)
	tlu			0.000	-0.001
				(0.00)	(0.10)
	urbrural			0.070	0.152
	(1=urban, 0=rural)			(0.54)	(1.00)
	idp			-0.071	-0.048
	(1=yes, 0=no)			(0.81)	(0.43)
	altitude			-0.021	-0.023*
	(100masl, via GPS)			(1.63)	(1.93)
UNHS	cropyields				-0.009
	(kg/100ha)				(1.37)
	sratio				-0.055
					(0.16)
	pchsinput				0.262
	(%)				(1.65)
	sagbusiinc_livestock				-0.002
	(%)				(0.01
R^2		0.077	0.123	0.126	0.128
N		2,158	2,158	2,158	2,158

Note: *p<0.1, **p<0.05, ***p<0.01, n=2,158. Control variables include 24 monthly NDVI anomalies in 2005 and 2006, and 11 agro ecological zones. Standard errors are clustered by DHS reporting areas.

Table 6 Multiple Linear Regression Results for Children from Subgroups, HAZ and WHZ.

Source and category	variable	rural, non-IDP camps		urban only		IDP camps only	
		HAZ	WHZ	HAZ	WHZ	HAZ	WHZ
	constant	0.792	-2.817	-1.303*	-1.093	-2.685	-4.860**
		(0.57)	(1.48)	(2.01)	(1.41)	(0.92)	(2.05)
Child (DHS)	agemos	-0.014***	0.014***	-0.012**	0.001	-0.003	0.013**
	(months)	(3.15)	(4.50)	(2.55)	(0.22)	(0.40)	(2.27)
	sex	-0.055	-0.025	-0.150	-0.294	-0.191	-0.242
	(1=male, 0=female)	(0.74)	(0.39)	(1.52)	(1.47)	(0.93)	(1.46)
	twin	-1.059***	-0.177*				
	(1=multiple, 0=single)	(4.99)	(1.98)				
	bcg	0.039	0.211				
	(1=yes, 0=no)	(0.27)	(1.29)				
	polio1	-0.035	-0.257*				
	(1=yes, 0=no)	(0.25)	(2.34)				
	measles	-0.025	-0.124				
	(1=yes, 0=no)	(0.23)	(1.81)				
	vad	-0.085	0.018				
	(1=yes, 0=no)	(0.97)	(0.28)				
	anemia	-0.395***	-0.196***				
	(1=yes, 0=no)	(6.66)	(4.79)				

Table 6 Continued.

Mother (DHS)	agemom	0.021*	-0.002			0.024	-0.007
	(years)	(1.83)	(0.35)			(1.25)	(0.42)
	edumom	-0.007	-0.001	0.040*	0.018	-0.055	-0.023
	(years)	(0.41)	(0.06)	(1.78)	(0.53)	(1.19)	(0.62)
	oralmom	0.059	0.077				
	(1/0)	(0.57)	(0.68)				
	workmom	-0.179	0.137	0.334	0.047	-0.332	-0.057
	(1/0)	(1.49)	(1.15)	(1.64)	(0.28)	(0.54)	(0.12)
	litmom	0.192	0.020				
	(1/0)	(1.40)	(0.38)				
	bmimom	0.016	0.076***	0.016	0.067***	0.089*	0.156***
	(kg/m2)	(1.03)	(7.34)	(1.29)	(6.17)	(1.82)	(3.95)
	vadmom	-0.046	-0.002				
	(1=yes, 0=no)	(0.36)	(0.03)				
	anemiamom	0.022	0.009				
	(1/0)	(0.29)	(0.15)				
	pregnant	-0.164	-0.177**				
	(1/0)	(1.23)	(2.02)				
	breastfeedmos	-0.016***	-0.011***	-0.010	-0.026***	-0.049***	-0.029**
	(months)	(2.78)	(3.97)	(0.97)	(3.17)	(3.19)	(2.32)
	breastfeeding	-0.186	-0.013				
	(1/0)	(1.49)	(0.17)				
	numchild	-0.041	0.002				
		(1.53)	(0.10)				

Table 6 Continued.

Father and	workdad	0.092	-0.008	-0.199*	0.078	-0.112	-0.021
household	(1/0)	(0.88)	(0.10)	(1.71)	(0.27)	(0.44)	(0.10)
(DHS)	agehoh	0.003	-0.001			0.003	0.009
	(years)	(0.64)	(0.29)			(0.20)	(0.81)
	fhoh	-0.034	-0.033	-0.244	0.428	0.068	-0.016
	(1/0)	(0.22)	(0.28)	(0.99)	(1.22)	(0.21)	(0.06)
	wealth	0.012*	-0.001	0.040***	-0.018*	-0.005	0.053*
	(1/10000)	(1.74)	(0.31)	(3.93)	(1.79)	(0.12)	(1.70)
	eligwork	-0.015	-0.034				
	(person)	(0.33)	(1.22)				
	dep_ratio	-0.095*	-0.016	0.122	-0.329***	0.164*	0.011
		(1.66)	(0.39)	(1.52)	(9.93)	(1.78)	(0.15)
	watersafe	0.228	-0.147	-0.275*	-0.279	0.547*	0.116
	(1/0)	(1.08)	(1.59)	(1.90)	(1.29)	(1.94)	(0.51)
	watertime	0.001	0.002				
	(minutes)	(0.93)	(1.53)				
	tlu	0.035**	0.002	-0.026*	0.015		
		(2.60)	(0.27)	(1.70)	(1.12)		
	altitude	-0.006	-0.040*	0.011	0.003	-0.032	0.191
	(100masl)	(0.26)	(2.07)	(0.18)	(0.05)	(0.13)	(0.97)
UNHS	cropyields	-0.031	-0.016*	-0.075*	0.064		
	(kg/100ha)	(1.60)	(2.28)	(1.75)	(1.64)		
	sratio	-0.619	-0.181	-1.097	0.955		
		(1.22)	(0.24)	(1.16)	(1.60)		
	pchsinput	0.337	0.265				
	(%)	(1.23)	(0.79)				
	sagbusiinc_livestock	-0.072	-0.078				
	(%)	(0.16)	(0.22)				
R^2		0.199	0.134	0.124	0.173	0.156	0.150
n		1733	1733	204	204	221	221

Note: *p<0.10, **p<0.05, ***p<0.01. Standard errors are clustered by DHS reporting areas.

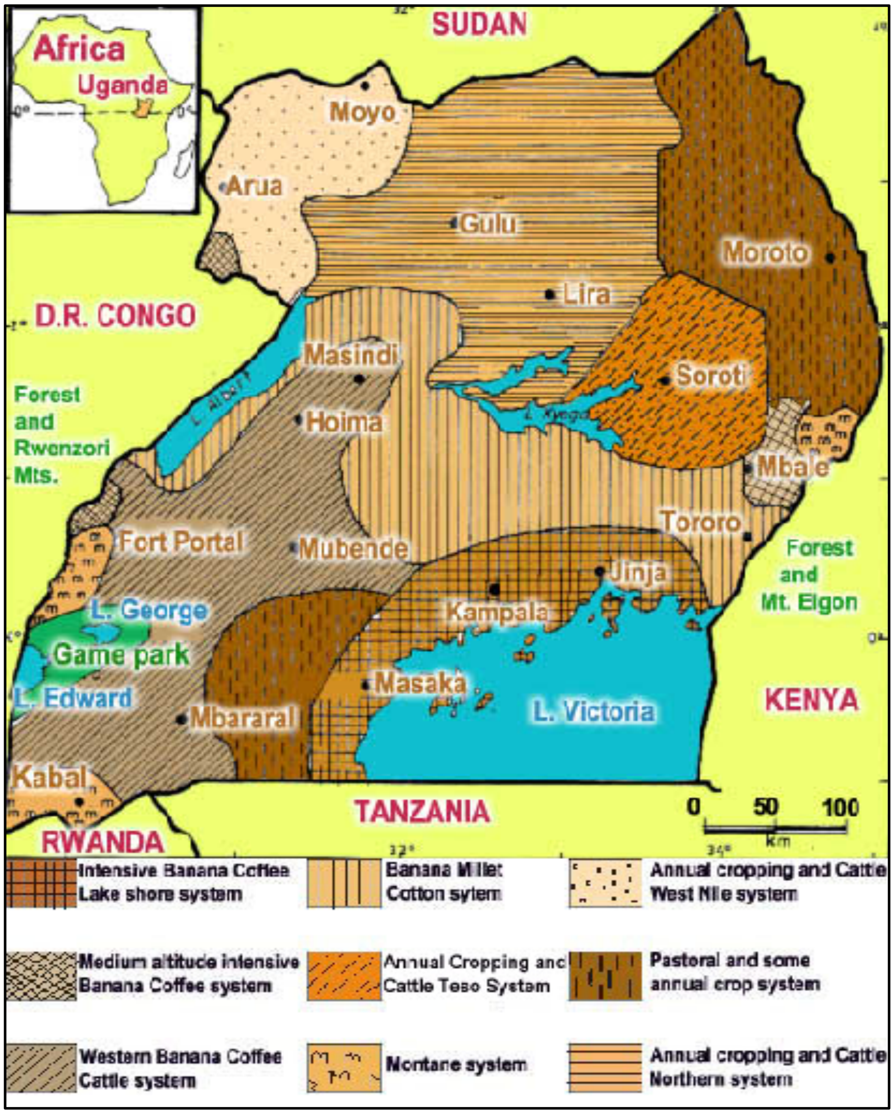


Figure 1 Crop Map of Uganda (FAO, 2006).

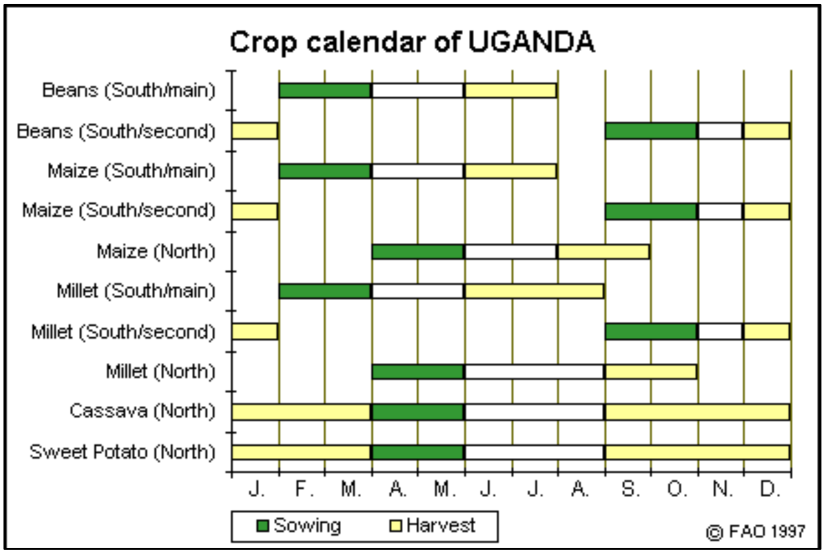
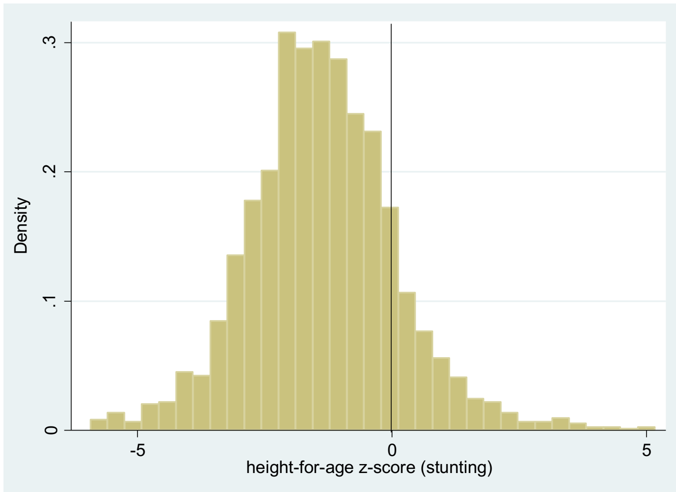
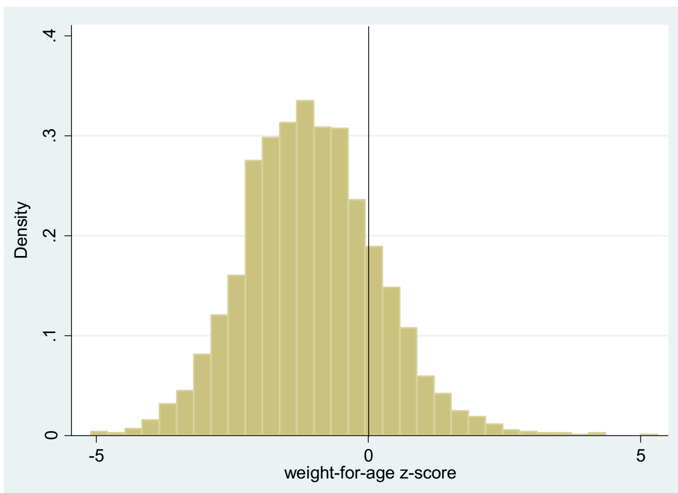


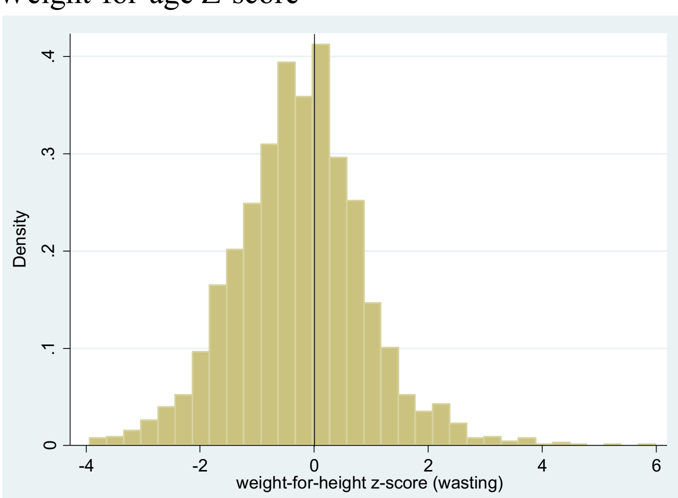
Figure 2 Crop Calendar Based on Crop and Region (FAO, 2010a).



Height-for-age Z-score



Weight-for-age Z-score



Weight-for-height Z-score

Figure 3 Histogram of child Z-scores.

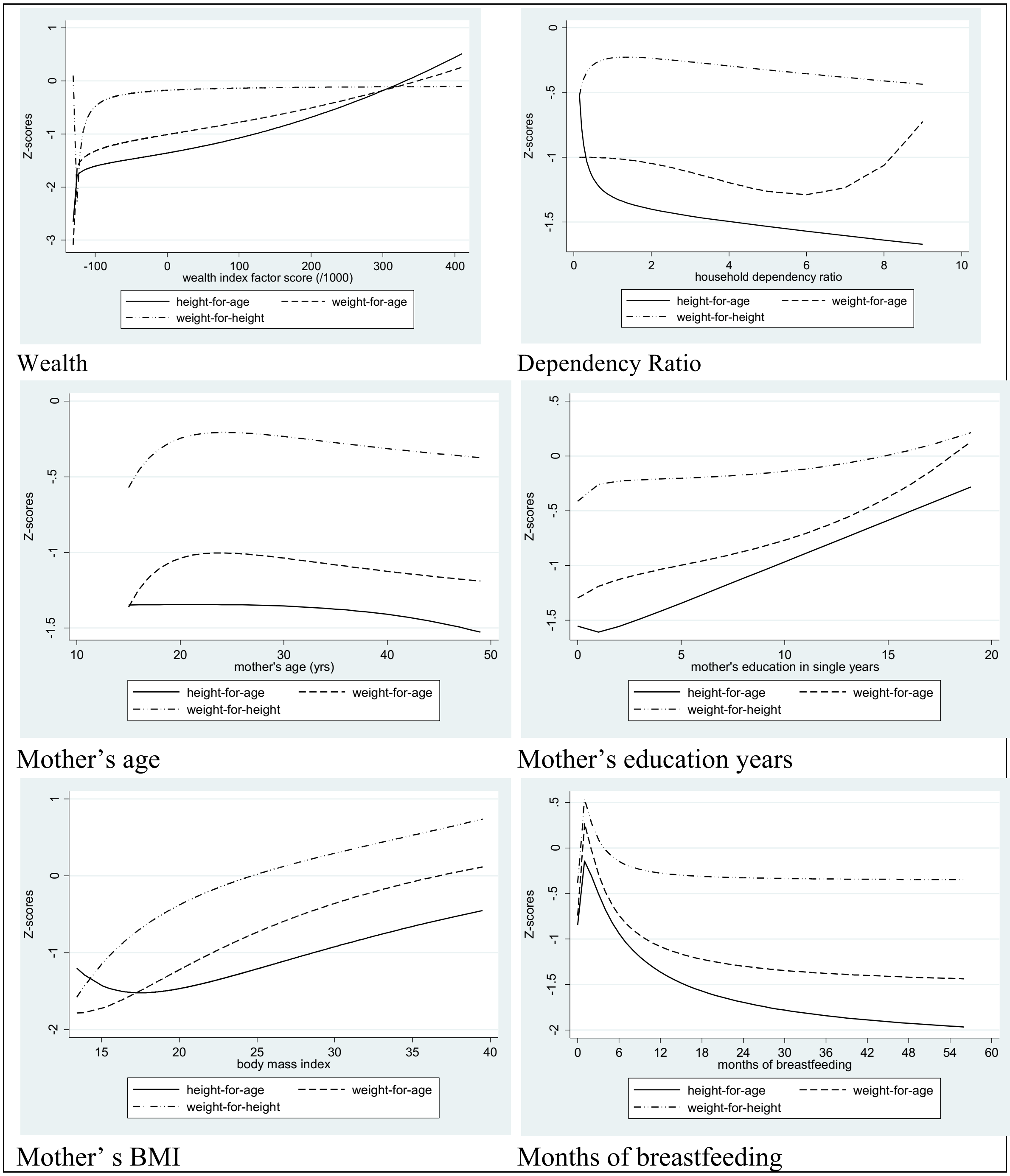
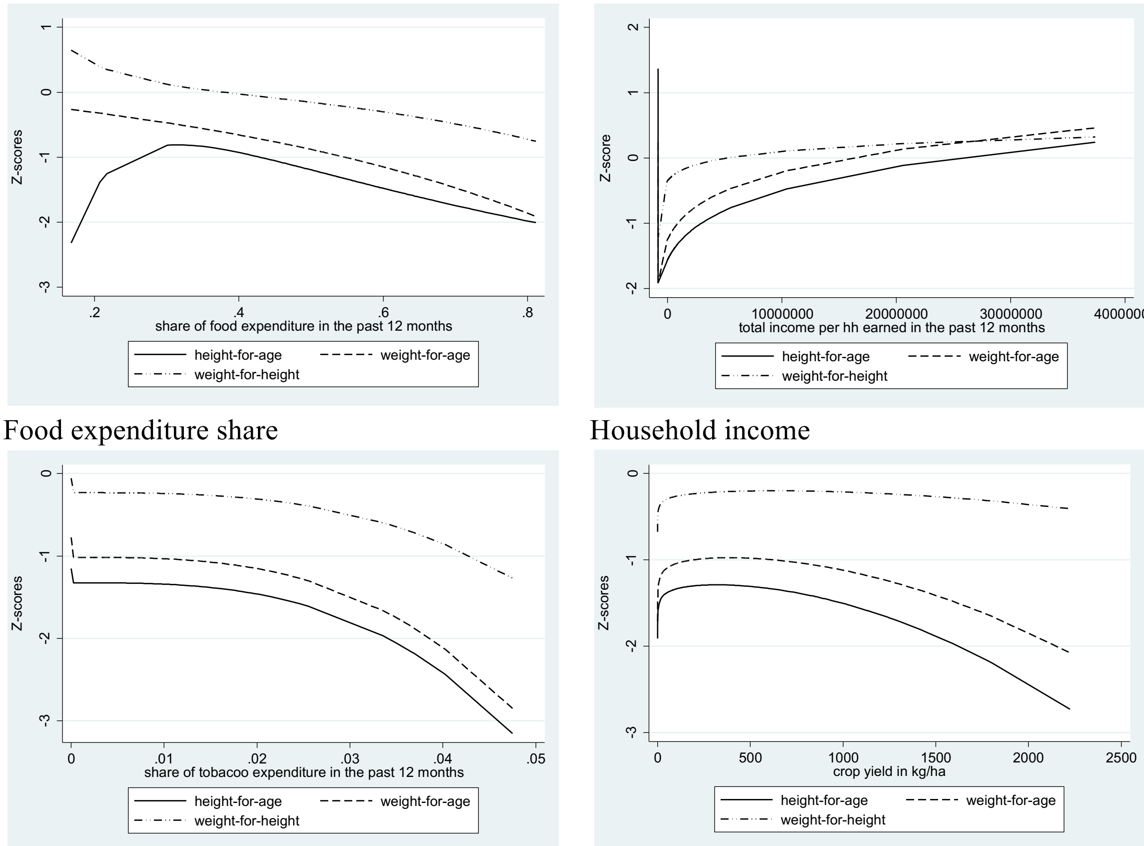


Figure 4 Fractional Polynomial plot of Z-score against DHS variables.



Food expenditure share

Household income

Tabacoo expenditure

Crop yield

Figure 5 Fractional Polynomial Plot of Z-score against UHNS variables.

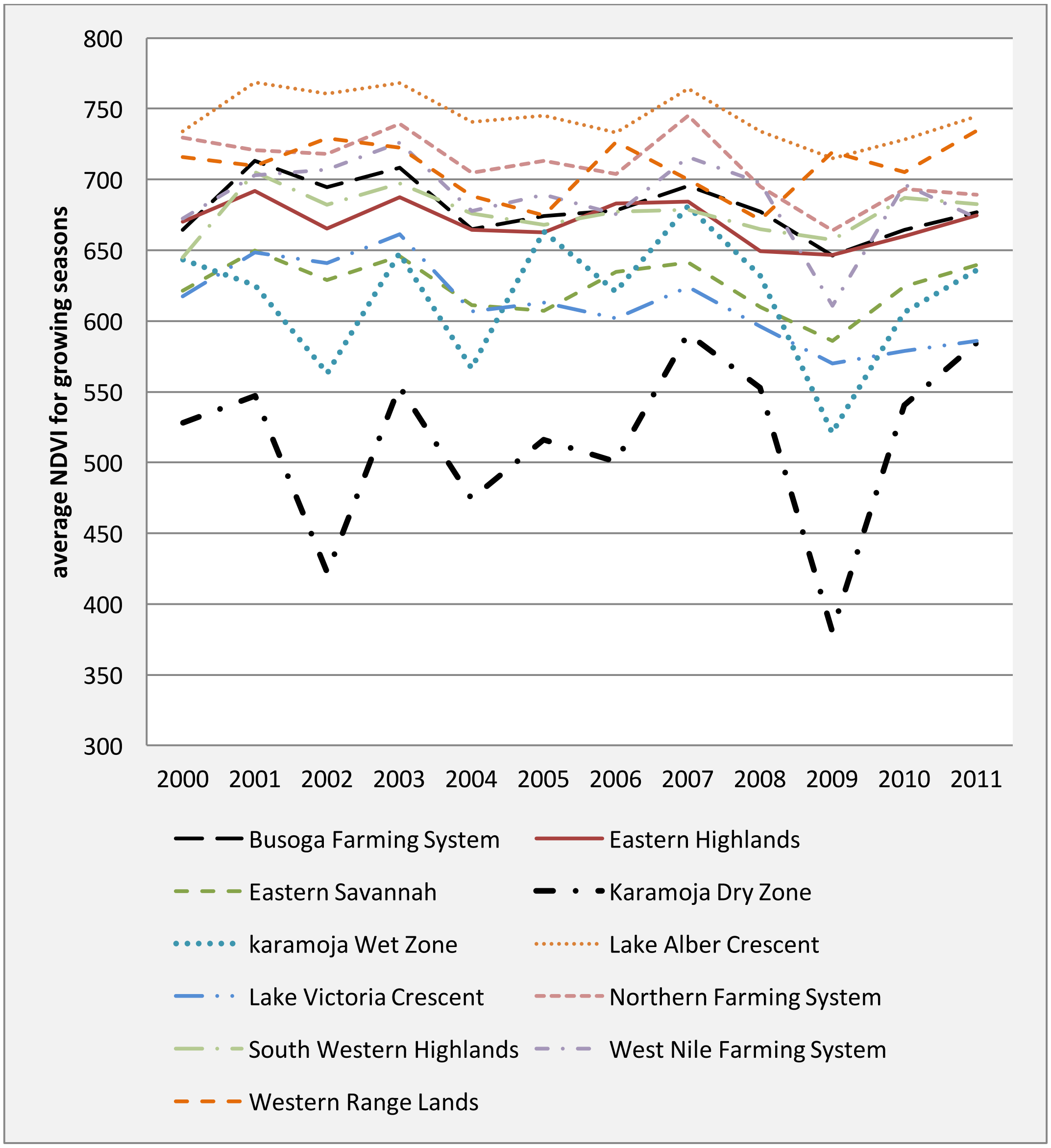


Figure 6 Average NDVI Values for Ecological-system-specific Growing Months, 2001-2011.

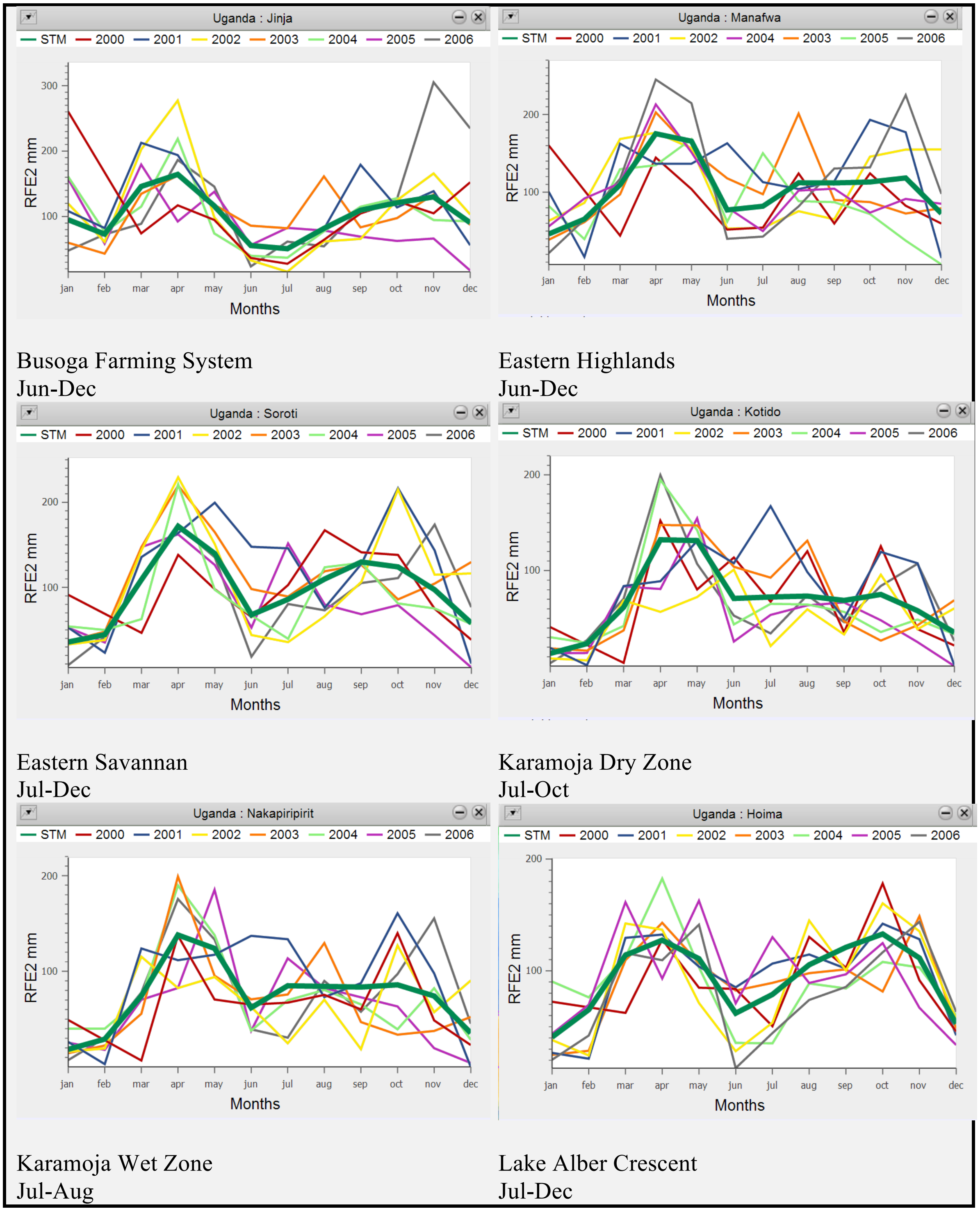
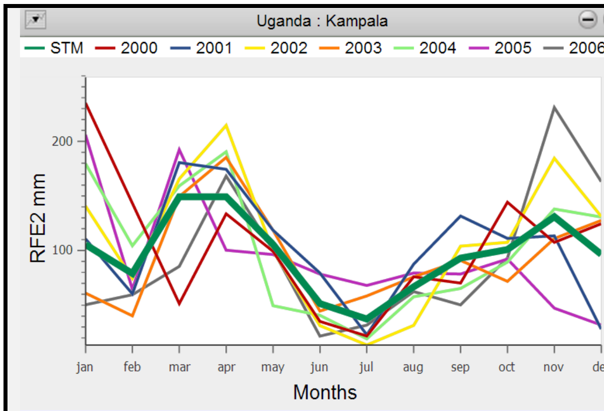
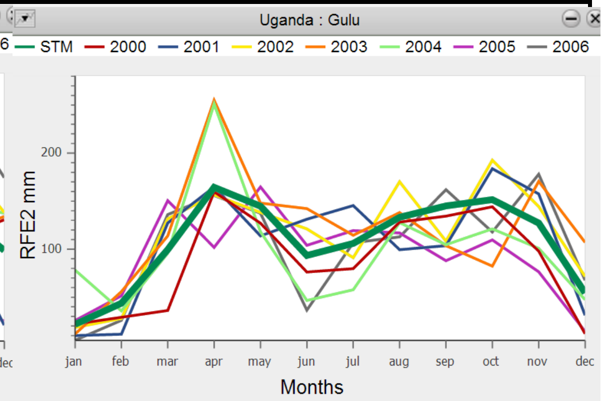


Figure 7 Monthly rainfall estimates (RFE2) for 11 Districts and Their Represented Ecological System and Growing Months, 2001-2006 and 2001-2010 Short-term Mean (STM) (FEWS-NET, 2013).

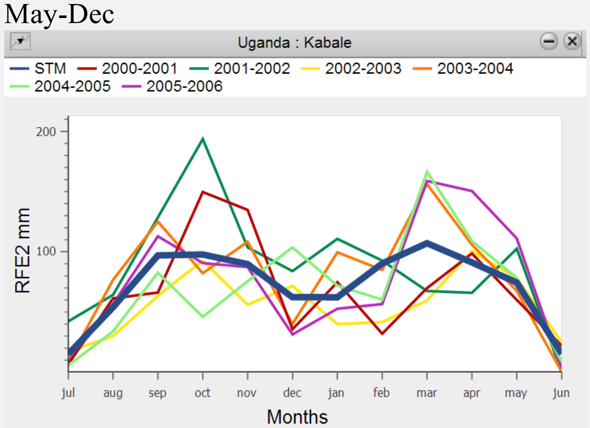
Figure 7 Continued.

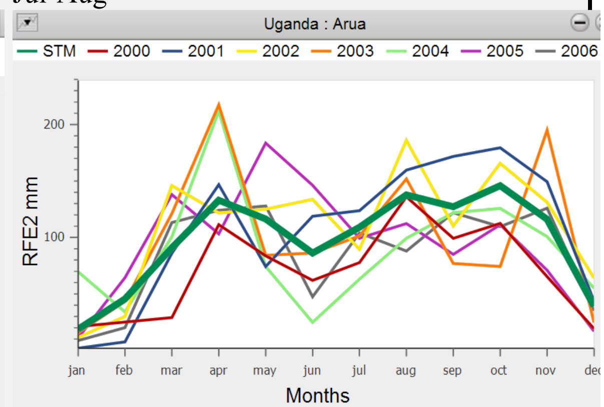




Lake Victoria Crescent
May-Dec

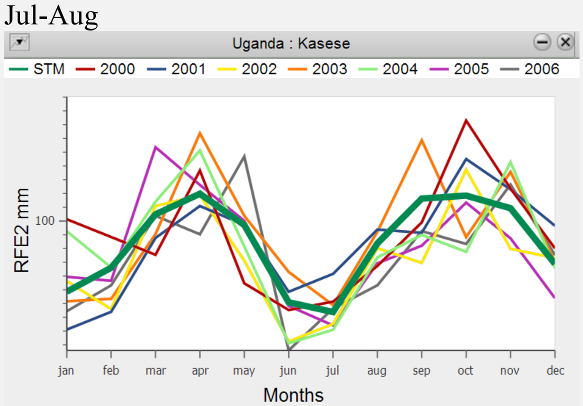
Northern Farming System
Jul-Aug





South Western Highlands
Jul-Aug

West Nile Farming System
Jul-Aug



Western Range Lands
Dec-Jan

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