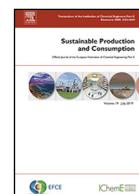




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Research article

Projecting food demand in 2030: Can Uganda attain the zero hunger goal?

Khondoker A. Mottaleb^{a,*}, Fazleen Abdul Fatah^b, Gideon Kruseman^c, Olaf Erenstein^c^a Socioeconomics Program, CIMMYT (International Maize and Wheat Improvement Center), Carretera México-Veracruz Km. 45, El Batán, Texcoco, México, C.P. 56237, Texcoco, México^b Faculty of Plantation and Agrotechnology, Universiti Teknologi MARA Cawangan Melaka Kampus Jasir, 77300 Merlimau, Melaka, Malaysia^c Socioeconomics Program, CIMMYT, Texcoco, México, C.P. 56237, Texcoco, México

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ABSTRACT

A precarious food security situation implies that many countries in the Global South may not achieve the United Nations Sustainable Development Goal 2 (SDG2) of zero hunger by 2030. We focus on the case of Uganda and explore food demand and food security implications for 2030, where 33% (15 million) of the population of 44 million are poor. *Matooke* (cooking bananas), cassava, and (sweet) potatoes are traditional foods in Uganda; however, the consumption of maize, wheat, and rice has been rising with increases in income and urbanization. Using the Living Standards Measurement Study (LSMS) datasets of Uganda, this study estimated the demand for matooke, cassava and potatoes, maize/coarse grains, wheat and rice, vegetables, and meat and fish in 2030. Our findings confirm that with increases in income and demographic changes, the demand for these food items will increase drastically. To attain SDG2 of zero hunger, as well as food and nutrition security, this study calls for further investments in Uganda's agricultural sector to enhance domestic production capacity to meet the growing demand for food.

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1. Introduction

To achieve the United Nations Sustainable Development Goal 2 (SDG2) of zero hunger by 2030, it is imperative to ensure basic food security for millions of people in the Global South. Globally, nearly 2 billion people are moderate to severely food insecure (FAO et al., 2019), of which 135 million people are severely food insecure (FSIN, 2020). Those who are food insecure are mostly concentrated in Africa, Asia, and Latin America (FAO et al., 2019). Since 2015, the absolute number of hungry people has increased, particularly in sub-Saharan Africa and South Asia (FAO et al., 2017;

WHO, 2018). It is thus becoming increasingly challenging for many of the countries in the Global South to eliminate hunger by 2030. Moreover, the World Food Program (WFP) has cautioned that in the absence of swift and effective action, an additional 265 million people may become severely food insecure due to COVID-19-induced economic turmoil (WFP, 2020). How then to ensure basic food security for people in the Global South by 2030?

For a start, we need to understand the food choices of food-insecure populations. Food consumption patterns are context-specific, calling for grounded, country-level case studies to examine food choices. In this study, we focus on Uganda - a rapidly developing, landlocked country in sub-Saharan Africa, where one-third of the total population is classified as poor (World Bank, 2016a).

Uganda is one of the fastest economically growing nations in sub-Saharan Africa and is in the midst of socio-economic transition. From 2000–2019, the gross domestic product (GDP) of

* Corresponding author.

E-mail addresses: k.mottaleb@cgiar.org (K.A. Mottaleb), fazleen5201@uitm.edu.my (F.A. Fatah), g.kruseman@cgiar.org (G. Kruseman), o.erenstein@cgiar.org (O. Erenstein).

the country expanded on average by more than 6% per annum (World Bank, 2020a). Consequently, the per capita GDP reached US\$ 710 in 2019, up from US\$ 632 in 2011 (at 2010 prices) (USDA, 2021). It is projected that from 2020 to 2031, the real GDP (at 2010 prices) of Uganda will further grow by an average of 5.6% per annum (USDA, 2020), and thereby the real per capita GDP of the country will reach US\$ 984 by 2031 (USDA, 2021). Population growth and urbanization are also rapid in Uganda. In 2019, out of a total population of 44.3 million, 24.4% were residing in urban areas (World Bank, 2020a). By 2030, Uganda's population is projected to be 58–61 million¹ depending on the fertility rate assumptions (United Nations, 2019), of which more than 31% will reside in urban areas (World Bank, 2021). These economic and demographic changes will have significant impacts on the agricultural sector (Alexandratos, 2005), generating the challenge of producing and supplying more and better food at affordable prices (FAO, 2018).

The objective of this study is to assess the future demand for major food items in Uganda by 2030. The study relies on information from 8,424 households, collected through three rounds (2010–11, 2013–14, 2015–16) of Uganda's Living Standards Measurement Study-Integrated Surveys on Agriculture (LSMS-ISA). The major food items of Uganda are *matooke* (cooking bananas), cassava and (sweet) potatoes, and cereals such as maize, wheat, and rice. This study assessed the nation-wide demand in Uganda for *matooke*, cassava, and (sweet) potatoes, maize/coarse grains (including sorghum and millet), wheat and rice, vegetables, and fish and meat in 2030. To achieve this, the study applied the endogeneity-corrected Quadratic Almost Ideal Demand System (QUAIDS) estimation approach separately for rural and urban households. From the QUAIDS model, we estimated the price and expenditure elasticities for the sampled foods. We then estimated the aggregate demand in Uganda for the sampled food items considering population projections and GDP growth rates up to 2030.

The study is important for two crucial reasons: Firstly, Uganda's rapid economic growth has resulted in a marked decline in poverty – in 1993 68% of the population were living on less than US\$ 1.90/day (World Bank, 2016a), down to 33% in 2020 (14.7 out of 44.3 million, (World Bank, 2020b). Nonetheless, FAO et al. (2018) found that in Uganda in the period from 2015 to 2017, 17.2 million (41.4%) people were undernourished, 0.3 million (3.6%) children under five years of age were wasted, and 2.2 million (28.9%) children under five were stunted; and in 2016, 2.6 million (37.2%) women of reproductive age (15–49 years) were anemic. In the 2020 Global Hunger Index, Uganda is classified as a country under a serious threat of hunger (Grebmer et al., 2020). Understanding the future demand for major food items and investing accordingly from now on can be instrumental in ensuring the food and nutrition security of Uganda.

Secondly, Uganda aims to become a middle-income country by 2040, with zero hunger, a major share of earnings coming from the non-farm sector, and the majority of citizens residing in urban areas (Government of Uganda, 2015, 2011; World Bank, 2016a). To achieve the status, Uganda has to secure more food with the increase in population and economic progress (Fukase and Martin, 2017). As a developing nation, it is not desirable for Uganda to rely primarily on substantive imports to meet growing food demands. Supply failures can generate food price hikes and the “Ricardo-Schultz” trap, in which increased food prices can generate unrest and reduce incentives to invest in industrial development, hampering economic progress. A number of African countries, including Uganda, witnessed riots linked to food and fuel price hikes during 2007–2011 (Kron, 2011; Sneyd et al., 2013). To avoid future food riots, ensuring food security for the urban poor is par-

ticularly crucial for Uganda (Kamara and Renzaho, 2014), yet the COVID-19 pandemic is aggravating food insecurity in urban areas (FEWSN, 2021). It is thus imperative to produce more food to avoid future food-related riots and to achieve Uganda's desire of becoming a middle-income country.

This study is organized as follows: the next section explains the conceptual framework, including a brief literature review. Section 3 presents the data and methods used for estimating the expenditure and price elasticities of the food groups and projects the aggregate demand for them by 2030. Section 4 presents the results, including general findings, estimated elasticities, and projected aggregate consumption of the sampled food items, considering the projected GDP and population rates. Section 5 presents the conclusion and policy implications.

2. Conceptual framework

It is widely acknowledged that a nation's dietary intake evolves with changes in demography, income, and urbanization (Béné et al., 2019; Cockx et al., 2018; Huang and Bouis, 2001; Huang and David, 1993; Kearney, 2010; Mason et al., 2015; Mittal, 2007; Mottaleb et al., 2018a, 2018b; Pingali, 2006; Pinstrup-Andersen et al., 1999; Popkin, 2008; Regmi, 2001; Regmi and Dyck, 2001; Wilde, 1989). A country in the early stages of its development tends to consume a high proportion of energy-dense staple food items, such as cereals and roots and tubers, which are relatively cheap sources of dietary energy (Gerbens-Leenes et al., 2010; Mottaleb et al., 2018b).

As development progresses, with increases in income and urbanization, the lifestyle and dietary intake of households change. For example, with an increase in income and urbanization, households tend to increase their consumption of diverse and expensive foodstuffs, such as more plant- and animal-based food items (Mottaleb et al., 2018b; Pingali, 2006; Reardon et al., 2019, 2012). This dietary transition is popularly known as the “nutrition transition” (Drewnowski and Popkin, 2009; Jakicic and Davis, 2011; Pingali, 2006; Pingali et al., 2019; Popkin, 2003, 1999; Reardon et al., 2014; Semba et al., 2008). Population growth provides a further driver, by affecting the aggregate food demand both directly and indirectly through its interlinkages with urbanization and income growth. We use these stylized changes affecting food demand as our overarching conceptual framework (Fig. 1), with these processes playing out differently in rural and urban settings and affecting both the aggregate food demand and the composition of food demand in the Global South.

The nutrition transition has led to calls for more diverse agri-food systems but also concerns about the environmental footprint and affordability (Hirvonen et al., 2020; Willett et al., 2019). There are also concerns about the triple burden of undernutrition, micronutrient malnutrition, and overnutrition (overweight/obesity and non-communicable diseases (Poole et al., 2021).

For most developing nations, continued population growth and the nutrition transition call for increased investment in domestic agri-food systems to enhance food security in all its dimensions: (food availability; food accessibility; utilization; stability; FAO, 2006). This typically requires additional investments in both energy-dense staple foods and nutrient-rich foods as complements, and increased attention for the one should not thereby replace attention for the other (Poole et al., 2021). Ignoring the role of energy-dense staple foods can have devastating impacts, particularly on the food security of economically emerging and developing countries, where such staples are and remain the major sources of dietary energy.

Currently, out of the 7.7 billion global population, 821 million people (10.9%) go to bed hungry (FAO et al., 2019). By 2050 the global population is expected to increase to 8.9–10.6 billion, de-

¹ FAOSTAT, 2021c.

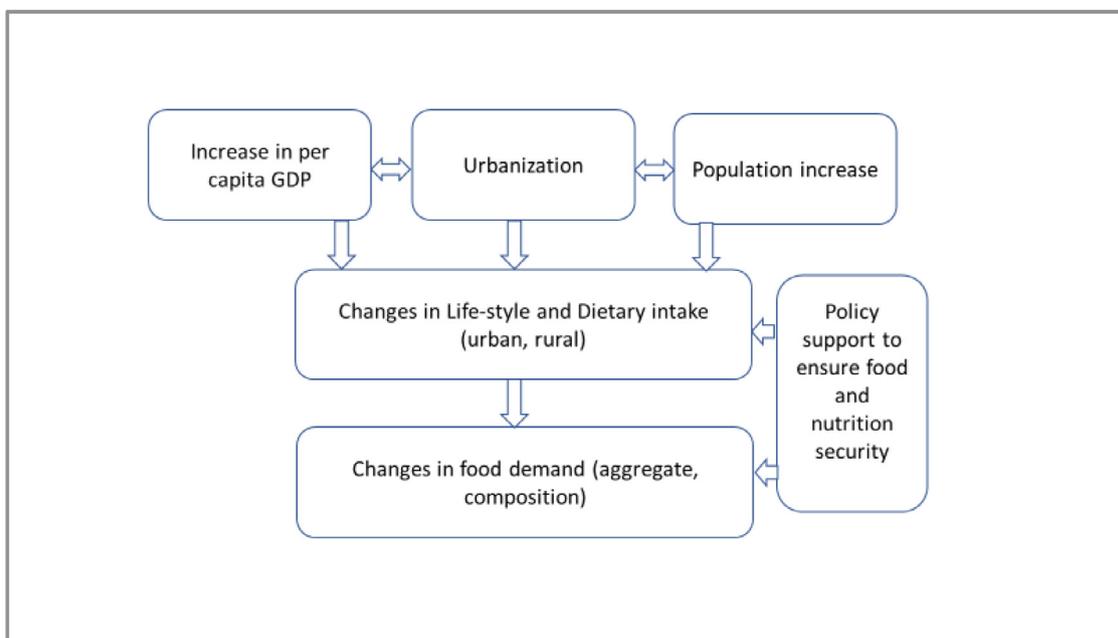


Fig. 1. Conceptual framework of changing food demand in the Global South.

Table 1

Food items considered in this study for estimating elasticities.

Food sub-group	Items included	Item codes in survey questionnaire
Matooke	Matooke (cooking bananas; brunch, cluster, heap, others)	101-104
Cassava and (sweet) potatoes	Sweet potatoes (fresh/dry/flour), cassava (fresh/dry/flour), Irish potatoes	105-109
Maize/coarse grains	Maize (grains, cobs, flour, bread), millet, sorghum	111-114, 115, 116
Wheat and rice	Rice, wheat (flour, chapati)	110, 172-173
Vegetables	Onions, tomatoes, cabbages, dodo (<i>Amaranthus</i> spp.), other vegetables	135-139
Meat and fish	Beef, pork, goat meat, chicken, other meat, fish (fresh, dry/smoked)	117-123

Sources: (World Bank, 2019b, 2016b, 2014).

pending on the fertility rate assumptions (United Nations, 2019). The concern is that under the business-as-usual scenario, the number of hungry people may increase to 2 billion by 2050. Thus, to ensure basic food security and to advance on eliminating hunger by 2030 as per SDG2, and to ensure basic food security of the burgeoning population of the world by 2050, it is imperative to supply more basic food items such as energy-dense staple foods at an affordable price.

For Uganda, investing in cereals is particularly important. This is because, even though Uganda has been highly successful in fighting abject poverty by achieving rapid economic growth in recent years, 41.4% of its population is still undernourished (FAO et al., 2018). Also, it is projected that by 2030 the population of the country will be 58–61 million depending on the fertility rate assumptions (United Nations, 2019), from 43 million in 2018 (World Bank, 2020a), of which more than 44% will reside in urban areas (World Bank, 2021).

In Uganda, matooke (cooking bananas), cassava and (sweet) potatoes, cereals such as maize, wheat, and rice, vegetables, and fish and meat are the major food items (FAOSTAT, 2021a). For the triennium ending in 2018 (TE2018), the daily per capita calorie intake in Uganda was 2,012 kcal, of which 1,057 kcal (53%) came solely from matooke, cassava and (sweet) potatoes, maize, wheat, and rice (FAOSTAT, 2021c). In TE2018, the yearly matooke consumption was 80 kg per capita (pc), and the corresponding aggregate national consumption 3.3 million metric tons (MMT) (FAOSTAT, 2021a). Consumption of cassava and potatoes was 114 kg pc and the corresponding national consumption 4.7 MMT. Maize, millet, and sorghum consumption was nearly 48 kg/year/capita, and the corresponding national consumption 1.97 MMT. Wheat

and rice consumption was 23 kg/year/capita and the corresponding national consumption 939 thousand metric tons. Vegetable consumption was 31.2 kg pc, and the corresponding national consumption 1.3 MMT. Finally, fish and meat consumption was nearly 23 kg pc and the national consumption 947.2 thousand metric tons (FAOSTAT, 2021a). As Uganda is rapidly developing economically and demographically, it is important to examine the future of the food demand in Uganda considering the economic and demographic changes.

Several studies have estimated the future demand for major staples at the global level in the context of demographic changes (Godfray et al., 2010; Ray et al., 2013; Tilman et al., 2011). Projections for global food demand show increases from 70% (FAO, 2009) to 110% (Tilman et al., 2011) by 2050. Ray et al. (Ray et al., 2013) suggested that to meet the surge in demand, average yield growth rates for any agricultural commodity should be at least 2.4% per year compared with rates in 2005.

While existing studies provide broad, important insights into the future demand for agricultural commodities, conducting commodity-specific studies at the country level is imperative given the heterogeneity of dietary intake, cropping patterns, urbanization, population, and economic dynamics across countries. This study assessed Uganda’s demand for major food groups: matooke; cassava and (sweet) potatoes; maize and other coarse grains; wheat and rice; vegetables; and fish and meat in 2030.

There are only a few studies that assess Uganda’s demand for major food items. Boysen (2016) examined the price and income elasticities of 14 food items in Uganda using data from the 2012-13 Ugandan National Household Survey comprised of 6,887 households. The study found that for rural households in

Table 2
Background information of the sampled households by their rural-urban location and by the LSMS rounds.

Household affiliation	All	Rural			Urban		
		2010-11	2013-14	2015-16	2010-11	2013-14	2015-16
Years							
No. of observations	8,424	1,880	2,228	2,250	535	796	735
Total food expenditure (1000 UGX/week)	41.3 (38.4)	42.3 (45.2)	39.7 (28.9)	35.0 (22.8)	53.7 (46.1)	47.8 (63.2)	47.3 (36.0)
Expenditure on the sampled foods (1000 UGX/week)	34.1 (53.7)	35.0 (65.5)	32.9 (27.7)	30.8 (69.3)	42.2 (47.0)	38.7 (49.2)	34.3 (26.4)
No. of family members	5.7(3.2)	7.3 (3.5)	5.3 (2.8)	5.2 (2.9)	7.1 (3.8)	4.6 (2.7)	4.6 (2.8)
% Male-headed households	68.0	70.3	67.9	68.0	65.2	68.0	64.2
Age, household head	45.9(15.6)	47.4 (15.2)	46.3 (15.7)	46.3 (15.9)	45.0 (14.3)	43.1 (15.7)	43.0 (14.8)
Age, spouse	24.3(20.9)	26.2 (20.6)	25.1 (20.8)	24.4 (21.5)	22.7 (20.7)	21.9 (20.1)	20.4 (20.6)
% Household head educated up to primary level (7 years)	54.4	58.7	58.0	60.5	40.9	40.1	39.3
% Household head educated up to secondary level	21.9	13.1	18.6	19.1	23.2	39.9	42.0
% Household head educated beyond secondary level	3.4	2.9	1.8	0.07	8.6	9.3	7.3
% Spouse educated up to primary level (7 years)	37.6	41.5	42.3	40.9	25.0	26.8	24.2
% Spouse educated up to secondary level	11.3	6.3	8.6	8.6	15.3	26.8	22.9
% Spouse educated beyond secondary level	1.2	1.1	0.06	0.02	3.6	24.7	2.9
% Household head engaged in farming	46.5	50.5	55.0	58.1	9.7	3.0	19.7
% Spouse engaged in farming	39.6	44.1	43.8	46.3	10.8	29.9	14.1
% From central region and Kampala	29.1	24.7	22.4	21.2	50.3	40.8	47.3
% From eastern region	24.1	27.0	28.3	26.4	15.3	49.7	14.1
% From northern region	25.2	26.7	27.6	27.5	20.0	49.7	18.0
% From western region	21.6	21.6	21.6	24.8	14.4	14.3	20.5

Sources: Authors' calculation based on (World Bank, 2019b, 2016b, 2014)

Note: Values in parentheses are standard deviations. All monetary values are computed in terms of real Ugandan Shillings (UGX) using the consumer price index 2010 = 100.

Uganda, income-elastic food items included maize, potatoes, matooke, fruit, meat, fish, milk, and sugar, whereas other cereals, cassava, legumes, and fats were income-inelastic. In contrast, for urban households in Uganda, Boysen (2016) showed that only meat, fish, and milk were income-elastic food items, whereas all other sampled food items were income-inelastic. However, Boysen's study did not assess Uganda's future food demand. The novelty of our study is that, in addition to updating estimates of price and expenditure elasticities, we examine Uganda's future demand for the major food items by 2030, using the estimated expenditure elasticities and projected population and GDP growth rates. Also, unlike that of Mottaleb et al. (2018a), the present study follows the approach of Deaton (1990), McKelvey (2011), and Gibson and Kim (2013) in dealing with issues related to zero consumption and prices of the sampled food items.

The world's GDP increased on average by 3.5% per annum during the period from 1961 to 2019, and consequently, the per capita nominal GDP increased from less than US\$ 452 in 1961 to US\$ 11,428 in 2016 (World Bank, 2020a). Like Uganda, several countries in South Asia and sub-Saharan Africa have been rapidly developing economically due to high GDP growth rates and rapid urbanization (USDA, 2021; World Bank, 2020a). Nevertheless, out of the world's total population of 7.7 billion people, 821 million are extremely poor (WHO, 2018) and live on less than US\$ 1.90/day - 86% of these reside in sub-Saharan Africa and South Asia (World Bank, 2019a). Alarming, an additional 420-580 million people may fall into poverty due to the recent COVID-19 pandemic and associated economic fallout (Sumner et al., 2020). How to ensure the basic food security of the extremely poor people in economically emerging nations is a major policy issue. As in Uganda, the majority of the extremely poor in developing countries rely mainly on staples for their daily dietary energy. Thus, although this study is Uganda-specific, the policy implications are broader and wide-ranging.

3. Material and methods

3.1. Data

The study is based on information collected from 8,424 households from Uganda. In collaboration with the Uganda Bureau of Statistics (UBOS), the World Bank collected data for the Liv-

ing Standard Measurement Study-Integrated Survey on Agriculture (LSMS-ISA). This study is based on LSMS-ISA datasets 2010–11, 2013–14, and 2015–16. The LSMS-ISA survey sampled data and the sampling process can be seen in (World Bank, 2019b, 2016b, 2014). In the case of Uganda, a questionnaire with 19 sections was used to collect household-level data on the demographic composition, labor allocation, education, and food consumption. Excluding cigarettes and alcoholic drinks, the datasets include information on weekly household-level consumption and expenditure for 66 food items. In this study, we examined the consumption of six major food items: matooke; cassava and potatoes; maize/coarse grains; wheat and rice; vegetables; and fish and meat (Table 1).

The original LSMS sample size of 2010-11 was 2,716 households, 2013-14's was 3,119 and 2015-16's was 3,305. Because of incomplete information on consumption and expenditure, this study retained 8,424 households. For sample details see Table 1A, Annexure A. Of the total samples, 6,358 (75.5%) were from rural areas and 2,066 (24.5%) from urban areas (Table 1A, Annexure A). Among the households in this study, 5,726 (68%) were headed by males, and the remaining 2,698 by females (32%).

The background information of the sampled households is presented in Table 2. In this study, all monetary values are converted from nominal to real terms using the Consumer Price Index (CPI) reported by the World Bank (2020a), setting CPI 2010 as the base (=100). The weekly average household-level total expenditure on food in real terms was UGX 41.3 thousand; however, there is a large gap in food expenditure between rural and urban households². The weekly household expenditure on the sampled food items considered in this study was UGX 34.1 thousand, which was nearly 83% of the weekly household total food expenditure (Table 2). Both rural and urban households spent at least 73% of their weekly total food budget on the sampled food items, which shows some similarity in the eating behavior of rural and urban households in Uganda. Households consisted on average of nearly six family members, household heads were older than 45 years, and spouses were older than 24 years (Table 2). Nearly 80% of the sampled household heads were formally educated, and of these,

² The official exchange rate between UGX per US dollar was US\$ 1 = UGX 2523 in 2011; US\$ 1 = UGX 2600 in 2014; and US\$ 1 = UGX 3420 in 2016 (World Bank, 2020a).

Table 3
Consumption of sampled food items of the sampled households by their rural-urban location and sampled years.

Sampled commodity consumed (kg/week)	All	Rural			Urban		
		2010-11	2013-14	2015-16	2010-11	2013-14	2015-16
Years							
<i>Matooke</i>	20.1	22.08	15.91	15.4	37.14	23.35	25.64
Cassava and potatoes	20.2	14.46	20.44	27.97	11.44	18.83	17.78
Maize/coarse grains	3.8	3.69	3.57	4.31	4.45	3.45	3.42
Rice and wheat	0.82	0.50	0.82	0.62	0.94	1.21	1.78
Vegetables	4.7	5.55	5.86	3.15	5.42	5.52	2.90
Fish and meat	1.3	1.35	1.21	1.10	1.60	1.68	1.59
Total consumption (kg)	50.9	47.6	47.8	52.6	61.0	54.0	53.1
Expenditure (in UGX) on the sampled commodities (UGX/ capita/day)							
<i>Matooke</i>	213.1 (17.1%)	158.5	227.1	242.7	127.1	307.3	180.7
Cassava and potatoes	232.9 (8.7%)	195.7	214.2	144.6	408.4	380.0	369.0
Maize/coarse grains	169.4 (13.6%)	138.8	167.0	190.7	231.6	194.5	117.2
Rice and wheat	57.0 (4.6%)	32.2	57.6	39.8	61.8	105.9	114.7
Vegetables	308.5 (24.8%)	255.7	415.1	216.3	235.7	510.0	237.7
Fish and meat	264.2 (21.2%)	198.4	272.3	211.8	233.7	491.1	344.3
Total expenditure (UGX/capita/day)	1245.1	979.3	1353.3	1045.9	1298.3	1988.8	1363.6

Sources: Authors' calculation based on (World Bank, 2019b, 2016b, 2014)

Notes: All monetary values are computed in terms of real UGX using the consumer price index 2010 = 100.

The official exchange between UGX per US dollar was US\$ 1 = UGX 2523 in 2011; US\$ 1 = UGX 2600 in 2014; and US\$ 1 = UGX 3420 in 2016 (World Bank, 2020a).

nearly 55% had completed at least a primary level of education (7 years of schooling), nearly 22% had completed secondary-level schooling, and 3% had completed higher than secondary-level education (Table 2). More than 50% of spouses were formally educated, of which nearly 38% had completed at least primary-level education, more than 11% had completed secondary-level education, and a little over 1% had completed higher than a secondary level of education (Table 2). The percentage share of household heads and spouses who were educated up to secondary level and above was higher in urban areas than in rural areas. The share of household heads and spouses who were engaged in agriculture was also higher in rural areas (Table 2). Furthermore, in general, the weekly household-level total food expenditure was higher in any given LSMS round for an urban household than for a rural one (Table 2). These indicators indicate that poor and food-vulnerable people in Uganda are mostly concentrated in rural areas and are mostly engaged in agriculture. Considering these inequalities between rural and urban households in Uganda, we estimated expenditure and price elasticities of the sampled food items separately by rural and urban affiliation of the households.

3.2. Modeling of food demand

In modeling demand for the sampled food items, we followed several steps. We assumed a rational household head who allocated the daily per capita total food budget X_{UGX} to different food items in a way that maximized utility. The allocation of the daily food budget (for the household as well as per capita) can be endogenously determined by several factors. Thus, X_{UGX} can be a function of a number of exogenous variables. This study, therefore, considers a two-stage budgeting procedure, in which it is assumed that a household first decides on the per capita daily total food budget. In the next stage, a household decides how much of the daily per capita total food budget will be allocated to each of the six food items. We assume that prices of the food items, household demographic structure, and the major source of livelihood can affect the daily per capita budget allocation to the sampled food items. The specific functional form of the expenditure function used in the two-stage budgeting process is given below:

$$X_{UGXic}^s = \delta_0 + \delta_1(PI)_i + (HHdemographics)_i\sigma_i + \sum_{y=1}^2 \theta_i(Year)_i + \zeta_i \tag{1}$$

Where X_{UGXic}^s is the daily per capita expenditure on the six sampled food items ($c=1-6$), by household i , who resides in a rural ($s=1$) or urban area ($s=0$); ζ_i is the error term; and δ_0 , δ_1 , σ_i and θ_t , are the parameters to be estimated.

Among the independent variables in equation (1), PI is Stone's Price Index³ calculated using six prices for six food items and the share of expenditure on each food item. $HHdemographics$ is a vector of independent variables that include:

- age of the household head and spouse;
- a female household head dummy that assumes a value of 1 if the head is a female, and 0 otherwise;
- two primary level education dummies that assume values of 1 if the household head and, separately, spouse are educated up to primary level, or 0 otherwise;
- two secondary-level education dummies that assume values of 1 if the household head and, separately, spouse are educated up to secondary level, or 0 otherwise;
- two higher than secondary-level education dummies that assume values of 1 if the household head and, separately, spouse are educated above the secondary level;
- two higher than secondary level education dummies that assume values of 1 if the household head and, separately, spouse are educated above secondary level, or 0 otherwise;
- two livelihood dummies that assume values of 1, if the household head and, separately, spouse are engaged in agriculture, or 0 otherwise;
- two year dummies for the year 2013-14 and 2015-16, setting the year 2010-11 as the base (=0).

It is important to mention here that the imputed sampled food prices are calculated as expenditures on a specific food divided by the quantity consumed, typically reported in kilograms. The problem is that the use of imputed prices in estimating income and price elasticities can lead to bias estimates due to the presence of selection bias and measurement errors and the problem of missing values (Deaton, 1990; Gibson and Kim, 2013; McKelvey, 2011). In the sample data, consumption of vegetables was nearly universal in Uganda, but a significant share of the sampled households reported zero expenditure on five of the sampled food items (from

³ Stone's Price Index is calculated as $\sum_{c=1}^6 \{ \ln(\text{Price of commodity } c) \times \text{Expenditure share on commodity } c \}$

nearly a third not consuming maize/coarse grains or meat and fish to 62% not consuming wheat and rice).

We elaborate on the procedure of how we dealt with the issues of imputed price and zero consumption in Annexure B. In brief, firstly we estimated a multivariate probit model, explaining the consumption choices of the sampled food items (did not consume=1, consumed=0) by the households (Eq. 2B, Table 2B, Annexure B). Secondly, after estimating a multivariate probit model (did not consume=1, consumed=0), we calculated five generalized inverse Mill's ratios for the five sampled food items based on whether or not that food item was consumed, following Vella's (1998) procedure (Annexure B). To deal with the imputed price issue, following Deaton (1990), McKelvey (2011), and Gibson and Kim (2013), we estimated the prices of the six sampled commodities (Table 3B, Annexure B). In the estimation process, we plugged in six inverse Mill's ratios for six sampled food items calculated after estimating the multivariate probit model (Annexure B). After estimating price functions (Table 3B, Annexure B), we calculated residuals for each commodity price and added them to the reported prices of each sampled food item. Finally, we took into account the sample years for each commodity price and the rural or urban status of the sampled households in averaging the commodity prices. The Stone's Price Index used in Eq. (1) was therefore estimated using the estimated prices following the procedure elaborated in Annexure B.

In estimating Eq. (1), we applied the ordinary least square (OLS) estimation procedure, replicating the estimation process 100 times using the bootstrap method to correct the issues related to distorted standard errors. The estimated daily per capita expenditure on the sampled foods for rural and urban households was used to formulate the demand system separately. This process allowed us to avoid the endogeneity problem (if any) in daily per capita food budget allocation to the six foods. Finally, in modeling demand for the food items, we followed Banks et al., (1997) and Deaton and Muellbauer (1980). Using the formula and methods in Stata software developed by Poi (2021), we calculated the expenditure, price, and cross-price elasticities.

Considering that poverty is more widespread in rural areas and that urban consumers may have more options and different preferences, we estimated the demand model separately for rural and urban households. After estimating the expenditure elasticities following Poi's (2021) specification, and using the GDP growth rate projected by USDA (2020) and the population projection by the United Nations (2019), we estimated the demand for the six foods in 2030. In projecting food demand in 2030, following Khanal et al., (2016) we applied the following formula:

$$C_{yc} = C_{TE2017} \times P_y (1 + r_y \times \eta_c)^{y-2010} \quad (2)$$

where C_{yc} is the total consumption of commodity c in year y ; C_{TE2017} is the daily per capita consumption of commodity c in TE2017 in grams; P_y is the projected population in year y ; r_y is the annual net GDP growth rate after deducting the national savings rate; and η_c is the income (expenditure) elasticity for commodity c .

In projecting the consumption of the sampled food items using Eq. (2), we used the population projected by the United Nations under high, medium, and low fertility rates (United Nations, 2019). For the GDP growth rate (r_y), we used USDA's (USDA, 2015) projection. Fig. 2 presents the projected population and GDP growth rate (%) of Nepal until 2030. Further, we deducted the GDP growth rate from the national savings rate. The national savings rate was calculated at 18.2%, which is the average national savings rate during 2010–2019 reported by the World Bank (2020a).

It is assumed that the national savings rate will be constant at 18.2% of the GDP until 2030. We did not have disaggregated data on GDP and population growth separated by rural and ur-

ban areas in Uganda. Therefore, in estimating demand for the sampled foods, we projected the demand at the national level, taking the weighted averages of the estimated expenditure elasticities for each commodity by the proportion of rural-urban samples in the LSMS datasets.

4. Results and discussion

4.1. General findings

The average diet of a Ugandan household is predominantly based on matooke, cassava and (sweet) potatoes, maize/coarse grains, and vegetables (Table 3). Matooke and cassava consumption have been declining in recent years (Fig. 3), but they remain the major sources of daily dietary energy. On average, a household consumes nearly 51 kg of the six sampled food groups in a week (fresh weight, i.e., the marketed form, not dried to a common standard or dry matter, so including varying amounts of water), including 20 kg of matooke, an equal amount of cassava and potatoes, nearly 4 kg of maize/coarse grains, less than 1 kg of rice and wheat, nearly 5 kg of vegetables, and 1.3 kg of fish and meat (Table 3). The daily per capita expenditure on the six food groups was more than UGX 1,245 of which the highest expenditure was on vegetables (UGX 309 or 25% of the total) followed by meat and fish (UGX 264 or 21% of the total, Table 3). This shows that rural households consumed lower quantities of food and spent less daily per capita on the sampled food items (Table 3). Rural households also spent less on fish and meat (Table 3). However, rural households consumed more cassava and potatoes than urban households. This indicates the importance of roots and tubers in the food security of rural households in Uganda.

The sampled households, on average, spent 17% of their daily per capita food budget on matooke, nearly 19% on cassava and potatoes, 25% on vegetables, and 21% on fish and meat (Table 3). Interestingly, an average of 4% of the daily per capita food budget of a rural household was spent on wheat and rice, whereas the share was 7.5% for an urban household (Table 3). This indicates a positive correlation between urbanization and the consumption of wheat and rice in Uganda. The average price of matooke in the sampled period was UGX 290/kg, UGX 367/kg for cassava and potatoes, UGX 1,530/kg for maize wheat and rice, UGX 2,114/kg for vegetables, UGX 4,850/kg for fish and meat (Table 4).

4.2. Econometric findings

In projecting the 2030 demand for the sampled food items, we first estimated the daily budget (X_{UGXic}^s) function specified in Eq. (1) allocated to the six sampled food groups at the per capita level separately for rural and urban households. The estimated functions explaining the daily per capita expenditure on the sampled foods are presented in Table 5.

The estimated results show that the coefficient of Stone's Price Index is positive and significant in explaining the daily per capita expenditure on the sampled foods (Table 5). This indicates that the sampled commodity prices, as well as the expenditure share for the sampled food items, positively affect the daily per capita budget allocation to the foods. Interestingly, only the age of the household head affects positively the daily budget allocation to the sampled food items of rural households (Table 5). Estimated functions demonstrate that the age of the spouse negatively affects the daily budget allocation for both rural and urban households (Table 5). The primary level education dummy of the spouse negatively affects the daily budget allocation to the sampled foods (Table 5). Household heads engaged in agriculture negatively affect the daily per capita expenditure on the six food items for both rural and urban households. This indicates that poverty in rural areas, and par-

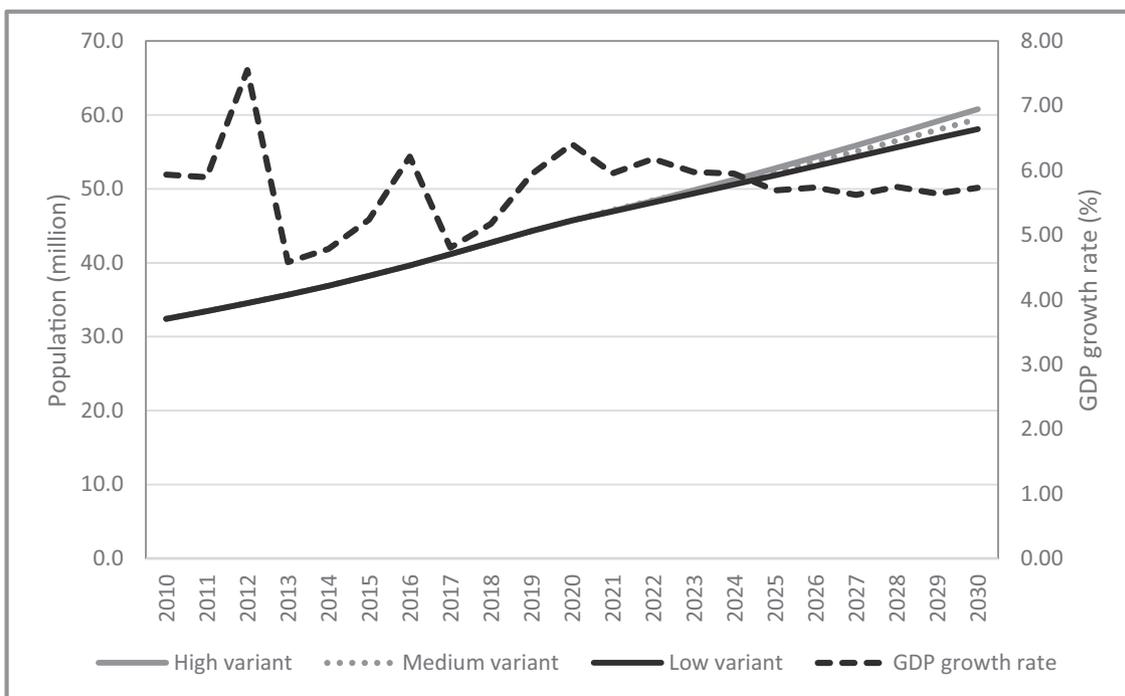


Fig. 2. Projected population under high, medium, and low fertility rate assumption and GDP rate (%) of Uganda by 2030. Sources: Population projection by United Nations (2019), GDP growth (%) projection by USDA (USDA, 2020).

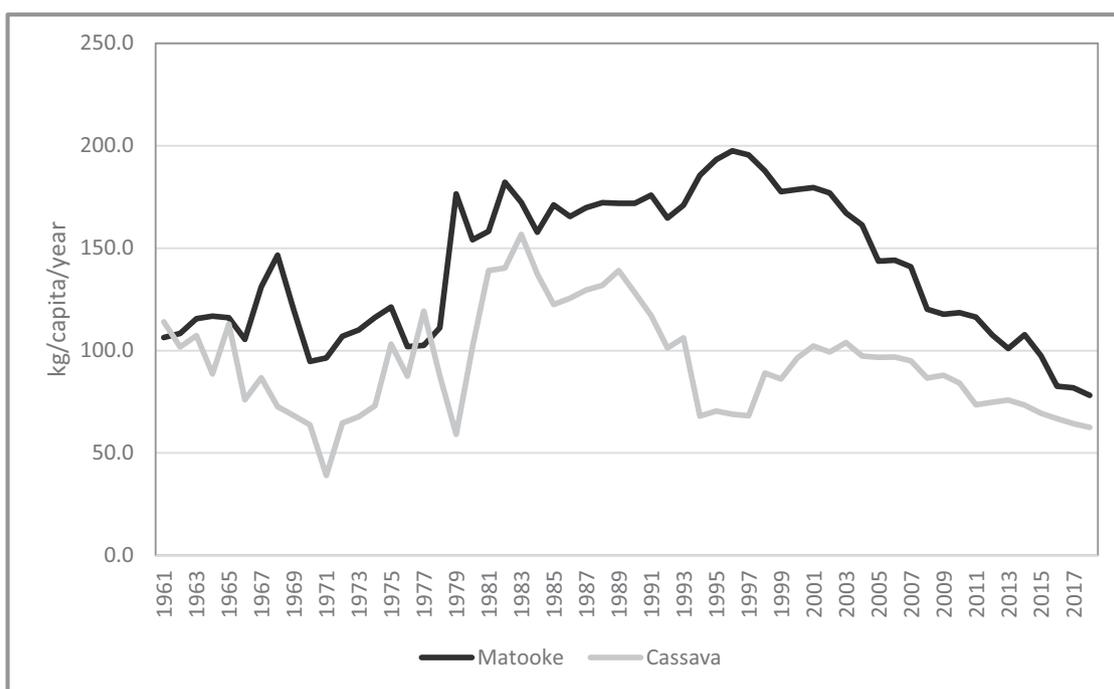


Fig. 3. Consumption trends for matooke and cassava in Uganda from 1961 to 2018 (kg/ capita/year). Source: FAOSTAT (2021a).

ticularly among agricultural households, is widespread in Uganda. Our estimation shows that a household in rural and urban areas spends on average UGX 1,140 and UGX 1,593 respectively on the sampled foods on a daily per capita basis (Table 5).

4.3. Expenditure and price elasticities

Following Poi (2021), the calculated compensated (Hicksian) and uncompensated (Marshallian) price and cross-price elasticities

for all six food items are presented separately for rural and urban households in Table 6. The original parameters from the QUAIDS estimation procedure can be seen for rural households in Table 4C and urban households in Table 5C in Annexure C.

Consistent with the demand theory, the own-price elasticities of all the food items are negative (Table 6), which confirms that an increase in the price of the sampled food items will lead to a reduction in the demand and vice versa (Deaton, 2018). The size

Table 4

Sampled commodity prices and the expenditure share (%) on the sampled food items by the sampled households by rural-urban location of the sampled households.

Reported prices (all rounds, UGX/kg)	All	Rural			Urban		
		2010-11	2013-14	2015-16	2010-11	2013-14	2015-16
Years							
<i>Matooke</i>	290	267	288	255	413	336	326
Cassava and potatoes	367	346	358	330	378	511	397
Maize/coarse grains	1530	1334	1283	2077	1629	1414	1159
Rice and wheat	1530	1372	1632	1287	1974	1853	1696
Vegetables	2114	1815	2083	2369	1676	2140	2477
Fish and meat	4850	4411	5112	4741	4826	5136	5220.1
Stone's Price Index	7.0	6.9	7.0	7.0	7.0	7.1	7.1

Sources: Authors' calculation based on (World Bank, 2019b, 2016b, 2014)

Note: All monetary values are computed in terms of real UGX using the consumer price index 2010 = 100.

The official exchange between UGX per US dollar was US\$ 1 = UGX 2523 in 2011; US\$ 1 = UGX 2600 in 2014; and US\$ 1 = UGX 3420 in 2016 (World Bank, 2020a).

Table 5

Estimated functions applying the Ordinary Least Square estimation procedure explaining the daily per capita expenditure (UGX) on the sampled food items by rural and urban households.

Dependent variable	Per capita daily expenditure (UGX) on the sampled food items	
	Rural household	Urban household
Independent variables		
Stone's Price Index	234.8***(51.54)	246.8*(132.12)
Age, household head	3.58**(1.81)	-7.62(6.42)
Age, spouse	-15.5***(1.59)	-12.5***(3.33)
Male-headed household dummy (yes = 1)	405.5***(81.84)	88.2(227.40)
A dummy for head educated up to primary level (7 years) (yes = 1)	70.7(59.74)	71.0(171.89)
A dummy for head educated up to secondary level (yes = 1)	147.0(104.09)	138.6(342.26)
A dummy for head educated beyond secondary level (yes = 1)	282.0(185.01)	178.7(210.65)
A dummy for spouse educated up to primary level (7 year) (yes = 1)	-280.5***(55.05)	-699.1***(120.37)
A dummy for spouse educated up to secondary level (yes = 1)	-44.4(191.76)	-657.8***(158.85)
A dummy for spouse educated beyond secondary level (yes = 1)	196.4(193.11)	-261.0(235.57)
A dummy for the head engaged in agriculture (yes = 1)	-109.5**(48.17)	-379.3**(155.84)
A dummy for the spouse engaged in agriculture (yes = 1)	-70.4(52.15)	-147.3(174.77)
Year 2014 dummy (yes = 1)	337.0***(67.18)	798.9***(248.64)
Year 2016 dummy (yes = 1)	50.8(64.68)	66.0(104.32)
Constant	-549.6(382.99)	407.1(1041.32)
No. of observations	6400	2078
F(14, 2122)	20.72	9.10
Prob > F	0.00	0.00
Estimated (expected) daily per capita expenditure (UGX)	1,140	1,593

Source: Authors' calculation.

Note: Values in parentheses are standard errors calculated based on the bootstrap method by replicating 50 times. *Significant at the 10% level. **Significant at the 5% level. ***Significant at the 1% level. All monetary values are computed in terms of real UGX using the consumer price index 2010 = 100.

Table 6

Estimated price and cross-price elasticities for rural and urban households (expenditure endogeneity corrected QUAIDS model).

Sampled food items by location	<i>Matooke</i>		Cassava and potatoes		Maize/coarse grains		Wheat and rice		Vegetables		Meat and fish	
	Com	Uncom	Com	Uncom	Com	Un-com	Com	Uncom	Com	Un-com	Com	Un-com
Rural household	(ϵ_{ij}^H)	(ϵ_{ij}^M)	(ϵ_{ij}^H)	(ϵ_{ij}^M)	(ϵ_{ij}^H)	(ϵ_{ij}^M)	(ϵ_{ij}^H)	(ϵ_{ij}^M)	(ϵ_{ij}^H)	(ϵ_{ij}^M)	(ϵ_{ij}^H)	(ϵ_{ij}^M)
<i>Matooke</i>	-0.89	-0.97	0.45	0.39	0.10	0.05	0.01	-0.002	0.20	0.09	0.13	0.06
Cassava and potatoes	0.62	0.53	-0.74	-0.80	0.06	0.003	0.03	0.01	0.05	-0.08	-0.02	-0.11
Maize/coarse grains	0.14	-0.13	0.07	-0.13	-0.43	-0.61	-0.01	-0.07	0.20	-0.20	0.03	-0.24
Wheat and rice	0.06	-0.16	0.10	-0.06	-0.05	-0.20	-0.24	-0.29	0.07	-0.27	0.05	-0.17
Vegetables	0.13	-0.12	0.03	-0.16	0.09	-0.08	0.01	-0.04	-0.35	-0.74	0.09	-0.16
Meat and fish	0.13	-0.11	-0.01	-0.20	0.02	-0.15	0.01	-0.04	0.14	-0.23	-0.29	-0.54
Urban household												
<i>Matooke</i>	-1.00	-1.15	0.58	0.38	0.10	-0.03	0.01	-0.06	0.12	-0.13	0.19	-0.03
Cassava and potatoes	0.43	0.37	-0.81	-0.90	0.09	0.03	0.12	0.09	0.11	0.002	0.06	-0.04
Maize/coarse grains	0.12	-0.04	0.13	-0.07	-0.40	-0.54	0.02	-0.06	0.11	-0.15	0.02	-0.20
Wheat and rice	0.03	-0.14	0.32	0.10	0.04	-0.11	-0.54	-0.62	0.25	-0.02	-0.10	-0.34
Vegetables	0.07	-0.11	0.09	-0.15	0.06	-0.10	0.08	-0.01	-0.39	-0.69	0.09	-0.17
Meat and fish	0.13	-0.04	0.05	-0.17	0.01	-0.13	-0.03	-0.12	0.11	-0.17	-0.27	-0.52

Source: Authors' calculation.

Note: Com (ϵ_{ij}^H) = Compensated (Hicksian), Uncom (ϵ_{ij}^M) = Uncompensated (Marshallian)

Table 7
Estimated income (expenditure) elasticities (η_j) for rural and urban households (expenditure endogeneity corrected QUAIDS model).

Food items	All sample average	Rural household				Urban household			
		2010-11	2013-14	2015-16	Rural average	2010-11	2013-14	2015-16	Urban average
Matooke	0.69	0.28	0.35	0.46	0.36	1.01	1.07	0.94	1.01
Cassava and potatoes	0.46	0.49	0.46	0.4	0.45	0.53	0.39	0.47	0.46
Maize/coarse grains	1.22	1.33	1.43	1.37	1.38	1.03	1.03	1.1	1.05
Wheat and rice	1.17	1.21	1.12	1.16	1.16	1.25	1.18	1.07	1.17
Vegetables	1.27	1.3	1.29	1.33	1.31	1.21	1.19	1.28	1.23
Fish and meat	1.21	1.28	1.23	1.3	1.27	1.18	1.11	1.17	1.15

Source: Authors' calculation.

of uncompensated own-price elasticities indicates the percentage change demand due to a one percent change in price. For example, for rural households, a 1% increase in the price of matooke will reduce the demand by 0.97%, and similarly by 0.80% for cassava and potatoes, and 0.61% for maize/coarse grains (Table 6). Similarly, for urban households, a 1% price increase reduces demand for matooke by 1.15%, for cassava and potatoes by 0.90%, and for maize/coarse grains by 0.54% (Table 6).

An analysis of cross-price elasticities demonstrates that there is a substitutability relationship among matooke and all the other sampled commodities, whereas wheat and rice have a complementarity relationship with maize/coarse grains. It suggests that under certain circumstances, a price-related shock on matooke can be mitigated by substituting other food items such as cassava and sweet potatoes. We also calculated the uncompensated (Marshallian) price and cross-price elasticities for the poorest and richest households by their rural-urban status, reported in Table 6C in Annexure C.

Similar to our findings, Boysen (2016) reported the unconditional uncompensated own-price elasticities for maize/coarse grains, cassava, and matooke for rural households in Uganda at -1.45, -0.57, and -0.95, respectively; and for urban Ugandan households at -1.51, -0.60, and -1.07, respectively.

The estimated expenditure elasticities (η_j) are presented in Table 7. In addition to the overall average expenditure elasticities, we also reported expenditure elasticities by rural-urban areas and years sampled. The overall expenditure elasticities reveal that matooke, cassava, and potatoes are normal and necessary food items in rural Uganda ($\eta_c < 1$), meaning that consumption is sticky and less affected by price, albeit, for urban households, matooke is a less necessary food item ($\eta_{\text{matooke}} > 1$). Maize/coarse grains, wheat and rice, vegetables, and meat and fish are less necessary food items in Uganda with expenditure elasticities greater than one ($\eta_c > 1$). Similar to our findings, Boysen (2016) reported that maize is a less necessary food item for rural households, and that meat and fish are luxury food items for all households in Uganda. Interestingly, in rural areas, maize/coarse grains had the highest expenditure elasticities of all the food groups. In general, these are hardly considered luxury goods but seem to be a preferred and affordable way of diversifying Ugandan rural diets from their matooke and roots and tubers base.

4.4. Food demand projections

Using the estimated expenditure elasticities and combining the projected GDP and population growth rates (see Table 8 for high, medium, and low fertility rates), this study projected the demand in Uganda for the six food groups by 2030. The daily per capita baseline consumption of the food groups (TE2018; FAOSTAT, (2021a); Table 8) was 221 grams of matooke, 312 grams of cassava and (sweet) potatoes, 131 grams of maize/coarse grains, 63 grams of wheat and rice, 85 grams of vegetables, and 63 grams of meat and fish (Table 8).

In projecting the demand for the sampled food items in 2030, we used the weighted average expenditure elasticities in which the rural and urban sample sizes were used as weights (Table 8). For example, the expenditure elasticity for matooke was 0.36 for rural households and 1.01 for urban households (Table 7). Considering that 75.5% of the sampled households were from rural areas and the remaining 24.5% were from urban areas, we calculated the weighted average expenditure elasticity for matooke at 0.52 (Table 8). The weighted average expenditure elasticities of all the other sampled foods are reported in Table 8.

In TE2018 the per capita matooke consumption was around 81 kg/yearly, cassava and (sweet) potatoes consumption was 114 kg/yearly, consumption of maize and other grains was less than 48 kg/yearly, wheat and rice consumption was less than 23 kg/yearly, consumption of vegetables was 31.2 kg/yearly and of fish and meat 23 kg/yearly (FAOSTAT, 2021a). Our projection shows that in 2030, the yearly per capita matooke consumption will be 134 kg; cassava and (sweet) potato consumption will be 173 kg; maize/coarse grains consumption will be 156 kg; wheat and rice consumption will be 66 kg; vegetable consumption will be 100 kg, and fish and meat consumption will be 71 kg.

The national TE2018 aggregate consumption was 3.3 MMT of matooke, 4.7 MMT of cassava and (sweet) potatoes, 1.97 MMT of maize/coarse grains, 0.94 MMT of wheat and rice, 1.3 MMT of vegetables, and 0.95 MMT of meat and fish (Table 9). Our projection shows that in 2030, depending on the population growth scenario, demand for matooke will be 7.8–8.1 MMT; for cassava and (sweet) potatoes, 10.0–10.5 MMT; for maize/coarse grains, 9.1–9.5 MMT; for wheat and rice 3.9–4.0 MMT; for vegetables, 5.8–6.1 MMT; and for meat and fish, 4.1–4.3 MMT (Table 9).

In TE2019 Uganda produced 3.5 MMT matooke from 811 thousand ha with a yield of 4.3 Mt/ha (FAOSTAT, 2021b). Our projections indicate that to meet matooke demand by 2030, Uganda must either increase matooke yields to 9.6–10 Mt/ha (assuming no increase in land for matooke) or expand land for matooke to 1.8–1.9 million ha (assuming no change in matooke yield). Along the same lines:

- In TE2019 production of cassava, sweet potatoes, and potatoes was 4.92 MMT from 1.71 million ha of land with a yield of 3.6 Mt/ha. To meet the growing demand for cassava and sweet potatoes by 2030, either yield must be increased to 5.9–6.1 Mt/ha assuming no increase in land for the crops, or land must be expanded to 2.8–2.91 million ha assuming no change in yield.
- In TE2019 production of maize/coarse grains was 3.3 MMT (1.61 million ha, 1.65 Mt/ha). Uganda is currently a net maize exporting country, exporting 0.37 MMT (TE2019). To meet the domestic demand in 2030 domestically, yields must be enhanced to 5.6–5.9 Mt/ha assuming no land expansion, or maize land must be expanded to 5.5–5.8 million ha assuming a constant yield.
- The current production of rice and wheat is 258.1 thousand tons (100 thousand ha, 2.15 Mt/ha). Uganda is currently net

Table 8
GPD and population growth dynamics of Uganda.

Year	Actual	Projected
	2019	2030
GDP per capita (constant 2010 US\$)	709.6 ^a	956.6 ^a
Annual GDP growth rate (%)	5.9 ^b	5.8 ^b
Total population (million) ^d	44.3	
Projected population (million) by fertility rate assumptions ^e		
High fertility		60.8
Medium fertility		59.4
Low fertility		58.1
Urban population (%) ^f	22.6	31.2
Daily per capita consumption (grams) TE2018 ^g		
<i>Matooke</i>	221.4	
Cassava and (sweet) potatoes	312.3	
Maize/coarse grains	131.2	
Wheat and rice	63.0	
Vegetables	84.9	
Meat and fish	63.0	
Sampled rural-urban weighted average expenditure elasticities ^h		
<i>Matooke</i>	0.52	
Cassava and (sweet) potatoes	0.45	
Maize/coarse grains	1.29	
Wheat and rice	1.16	
Vegetables	1.29	
Meat and fish	1.24	

^a USDA (USDA, 2021)^b (USDA, 2020)^d World Bank (2020a)^e United Nations (2019)^f World Bank (World Bank, 2021)^g FAOSTAT (2021a)^h Authors' calculation based on Table 7.**Table 9**

Baseline and projected consumption scenarios of the sampled food items by consumption and demographic projections in 2030 in Uganda (million tons; including projected adjustments to per capita consumption).

Base scenario (million tons), TE2018 ^a	Projected consumption in 2030 ^b			
	HF	MF	LF	
<i>Matooke</i>	3.3	8.1	7.96	7.8
Cassava & (sweet) potatoes	4.7	10.5	10.3	10.0
Maize/coarse grains	1.97	9.5	9.3	9.1
Wheat and rice	0.94	4.0	3.95	3.9
Vegetables	1.3	6.1	5.9	5.8
Fish and meat	0.95	4.3	4.2	4.1

^a FAOSTAT(2021a)^b Authors' calculation. Note: HF: High fertility; MF: Medium fertility; LF: Low fertility (demographic projections)

wheat- and rice-importing country, importing 576.5 thousand tons (TE2019). If the country continues to rely on imports to meet demand,

an additional 3–3.4 million tons will have to be imported in 2030. Furthermore, our projections indicate that the demand for vegetables and fish, and meat will also increase severalfold by 2030 above the current level of consumption (Table 9). The demand for fish and meat will increase by 4.3–4.5 times by 2030. Our findings on fish and meat demand are similar to those of FAO (2018), which projected that the consumption of beef will increase by 403%, mutton and goat by 347%, poultry by 419%, and pork by 412% by 2050 in Uganda compared to the 2012 consumption level.

With the nutrition transition, one would expect the consumption of luxury goods such as vegetables, meat, and fish to increase. More surprising perhaps is that the consumption of maize/coarse grains, and wheat and rice showed similar increases. These substantive increases reflect the affordability and versatility of these flexi foods. In contrast, basic foods such as cassava and sweet potatoes had relatively the lowest projected demand increases, although achieving these increases for all food crops to ensure food security remains daunting.

Table 10

Baseline and projected consumption of the sampled food items estimated only as a function of projected projections in 2030 in Uganda (million tons, assuming constant per capita consumption).

Base scenario (million tons), triennium average ending 2018 ^a	Projected consumption in 2030 ^b			
	HF	MF	LF	
<i>Matooke</i>	3.3	4.9	4.8	4.7
Cassava & (sweet) potatoes	4.7	6.9	6.8	6.6
Maize/coarse grains	1.97	2.98	2.91	2.8
Rice and wheat	0.94	1.39	1.35	1.3
Vegetables	1.3	1.90	1.85	1.8
Fish and meat	0.95	1.39	1.36	1.3

^a FAOSTAT(2021a)^b Authors' calculation. Note: HF: High fertility; MF: Medium fertility; LF: Low fertility (demographic projections)

As an alternative scenario, we also project future demand for the sampled food items assuming constant levels of per capita consumption and only considering population projections (Table 10). This scenario shows that even if we ignore the influence of the GDP growth rate and urbanization on food consumption and only consider the projected population, it will be imperative for Uganda to supply 42–48% more matooke, 40–47% more cassava and sweet potatoes, 42–51% more maize/coarse grains, 38–48% more wheat and rice, 38–46% more vegetables, and 37–46% more meat and fish by 2030 (Table 10).

To compare our elasticity estimation, we calculated the expenditure elasticities of the sampled foods applying the left-censored Tobit estimation procedure separately for rural and urban households (Tables 7D and 8D, Annexure D). Similar to the expenditure elasticities reported in Table 7 after the QUAIDS model estimation, the expenditure elasticities calculated from the alternative specification of the demand model also show that the sampled foods are normal food items with positive income elasticities (Tables 7D and 8D, Annexure D). The expenditure elasticities reported in Tables 7D and 8D are larger in absolute size than the expenditure elasticities reported in Table 7. This is probably because the two-limit Tobit model is a single-equation model, which cannot capture the complementarity and substitutability effects among different items. Furthermore, we checked our projected per capita consumption, comparing it with the actual yearly per capita consumption (in kg) of the six food items.

The model validation graphs (Figs. 1E to 6E) are presented in Annexure F. Similar consumption trends during the period from 2010 to 2018 between projected and actual consumption of matooke and cassava validate our demand projection. However, the demand projections for wheat and rice, vegetables, and fish and meat seem over-projected in the long term. The seemingly over-projection of demand is a major limitation of demand forecasting using elasticities calculated applying the QUAIDS model estimation procedure. In addition, we have assumed that the estimated expenditure elasticities will be constant until 2030, which provides a linear projection of the sampled food times. In reality, expenditure elasticities can change due to different exogenous factors. Therefore, it is suggested that the future demand for major commodities at the country level should be examined regularly.

5. Conclusion and policy implications

This study examined projected food demand and consumption patterns in Uganda in 2030. The consumption of the six main food groups in Uganda will increase substantively in relation to increases in per capita GDP and population. To attain the SDG2 of zero hunger by 2030 it is imperative to invest more in agricultural productivity, to ensure both an adequate food supply and an adequate income for agricultural households in Uganda while staying within planetary boundaries.

Despite tremendous progress in poverty alleviation due to rapid economic growth, Uganda is still classified as a country with a serious hunger threat (Grebmer et al., 2020). Currently, 33% of the total population of the country is classified as poor. As 72% of the total employed labor force of the country is directly engaged in agriculture, and as agriculture contributes nearly 24% to the GDP, investment in enhancing agricultural productivity can have a significant impact on the overall economic development of the country.

Alarmingly, while it is imperative to produce more matooke, cassava, and other agricultural commodities to ensure food security, agricultural productivity is severely challenged by land degradation, climate extremes, and rural outmigration (Call et al., 2019; Call and Gray, 2020; Mubiru et al., 2017; Nkonya et al., 2008). In fact, the matooke and cassava yield growth rates have stagnated (reduced to -0.90% per annum for matooke and -3.1% for cassava between 1990 and 2019, compared to +0.21% per annum for matooke and +5.4% for cassava between 1962 and 1989 (FAOSTAT, 2021b)). As the demand for all the sampled foods will increase by 2030, and as the yield growth rate of some of the major food items is stagnating, investment in the overall agricultural sector in Uganda is needed to enhance food security and to improve the livelihoods of resource-poor farmers.

This study projected that Uganda's demand for six main food items, including cassava, maize/coarse grains, wheat, and rice, would increase in line with its projected increase in income and population. Increasing the productivity of the associated crops will be key to enhancing food security, but additional investments are warranted to enhance the nutritional value of the projected diets. Promising in that respect are the introduction and scaling of vitamin- and mineral-enriched biofortified staple foods, including cassava, maize, wheat, rice, and beans. As an emerging landlocked economy, increasingly relying on imports to meet growing food demand is not a feasible policy option. It is important to invest in the agricultural sector to ensure food and nutrition security. In addition, as more than 70% of Uganda's employed labor force is directly engaged in agriculture, revitalizing agricultural productivity and raising incomes by investing in the sector can also substantially contribute to sustainable development. This study therefore strongly urges the international donor agencies and the government of Uganda to further invest in the agricultural sector, to unleash the growth potential of the country, and to ensure its food and nutrition security.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:[10.1016/j.spc.2021.07.027](https://doi.org/10.1016/j.spc.2021.07.027).

Annexure A

Table A1

Table A1
Information on sampling and the sampled households by the LSMS rounds and the rural-urban affiliation of the sampled households.

	LSMS 2010-11		LSMS 2013-14		LSMS 2015-16		Overall	
	No. of observations							
	Actual	Used	Actual	Used	Actual	Used	Actual	Used
No. of observations	2716	2415	3119	30	3305	2985	9,140	8,424
Rural	2105	1,880	2,303	2,228	2470	2,250	6,878	6,358
Urban	611	535	816	796	835	735	2,262	2,066

Sources: (World Bank, 2019b, 2016b, 2014).

Annexure B

Calculating commodity prices and dealing with zero expenditure on the sampled food items

Based on the information on the weekly household consumption expenditure on the sampled food items (in UGX), and quantity consumed in kilograms (kg), we first calculated the unit prices as follows:

$$p_c^i = \frac{xp_c^i}{q_c^i} \tag{1B}$$

Where p is the per kilogram unit price of food item c ($c=1---$ 6) that a household h faced; xp is the expenditure on food item c , and q is the quantity consumed in kilograms (kg). After calculating the unit price, we deflated the price using the consumer price index setting 2010 = 100.

The problem is that a significant proportion of the sampled households did not consume the sampled food items (zero expenditure). Table 1B presents the information.

Table B1
Table B2
Table B3

This shows that almost all the sampled households consumed vegetables, but nearly 47% of them did not consume matooke, 26% did not consume cassava or potatoes, nearly 32% did not consume maize, more than 61% did not consume wheat or rice, and 32% did not consume meat or fish (Table 1B). At this stage, since a number of households did not consume all food items, the missing prices ($\frac{xp_{ct}^i}{q_{ct}^i} = 0$) are replaced using the mean unit values of prices considering the year and the rural-urban affiliation of the households. These prices are defined as imputed prices.

The use of imputed prices in estimating income and price elasticities can lead to biased estimates due to selection bias, measurement errors, and the problem of missing values (Deaton, 1990; Gibson and Kim, 2013; McKelvey, 2011). Moreover, as the imputed prices are the reported actual prices, these prices are the combination of both prices and the economic status of the households revealed by the product quality. To handle the issue, we estimated the prices of the six sampled commodities.

In the price estimation process, we first estimated a multivariate probit model for not consuming the sampled food items (did

not consume an item = 1, consumed = 0). Symbolically:

$$C_{ic} = \alpha_0 + \sum_{xp=1}^4 \phi_c(Exp)_{ic} + (HHdemographics)_{ic}\sigma_{ic} + \sum_{y=1}^2 \theta_c(Year)_{ic} + \sum_{r=1}^3 \nu_c(Region)_{ic} + \beta_c(Rural\ dummy)_{ic} + \zeta_c \tag{2B}$$

where C_{ic} is a vector of dependent variables that assumes a value of 1 if the i^{th} household did not consume a sampled food item c (matooke, cassava, and potatoes, maize, wheat and rice, vegetables, meat, and fish) in any of the years sampled (2010, 2014, 2016), and 0 otherwise. Among the independent variables, Exp includes four dummies for five expenditure quintiles based on the weekly total food expenditure in UGX at the household level, in which the poorest quintile (Q1) is set as the base (Q1=0). $HHdemographics$ is a vector of variables that includes the following:

- the age in years of the household head and spouse;
- a sex dummy of the household head that assumes a value of 1 if the head is male, and 0 otherwise;
- three education-level dummies of the head that assume a value of 1 if the head is educated up to primary level (7 years); if the head is educated up to secondary level; if the head is educated beyond the secondary level; and 0 otherwise;
- three education-level dummies of the spouse that assume a value of 1 if the spouse is educated up to primary level (7 years); if the spouse is educated up to secondary level; if the spouse is educated beyond the secondary level; and 0 otherwise;
- a livelihood dummy of the head that assumes a value of 1 if the head is employed in the agriculture sector, and 0 otherwise;
- a livelihood dummy of the spouse that assumes a value of 1 if the spouse is employed in the agriculture sector, and 0 otherwise;

$Year$ includes two year dummies for 2014 (yes = 1) and 2016 (yes = 1) setting the year 2010 as the base (= 0).

$The\ region$ includes three dummies for the eastern region (yes = 1), northern region (yes = 1), and western region (yes = 1), setting the central and the capital Kampala region as the base (= 0)

Table B1
Share of the sampled households that did not consume the food items.

Food items	% of Households that did not consume the sampled food items		
	All households	Rural	Urban
Matooke	46.6	49.9	36.7
Cassava and (sweet) potatoes	26.1	25.4	28.2
Maize/coarse grains	31.7	33.4	26.5
Wheat and rice	61.5	67.2	43.7
Vegetables	0	0	0
Meat and fish	32.2	34.1	26.1

Source: Authors' calculation based on (World Bank, 2019b, 2016b, 2014).

Table B2
 Estimated functions applying the multivariate probit model estimation procedure explaining the consumption choice of the sampled food items by households in Uganda.

Food items	Dependent variables: 1 = Did not consume the listed food item, 0 = otherwise				
	Matooke (1)	Cassava and potatoes (2)	Maize/coarse grains (3)	Rice and wheat (4)	Meat and fish (5)
Independent variables					
Expenditure quintile dummies (base, Q1 = 0)					
Household located in the second expenditure quintile (Q2)	-0.34***(0.05)	-0.19***(0.05)	-0.30***(0.04)	-0.46***(0.05)	-0.59***(0.04)
Household located in the third expenditure quintile (Q3)	-0.52***(0.05)	-0.31***(0.05)	-0.43***(0.05)	-0.66***(0.05)	-0.91***(0.05)
Household located in the fourth expenditure quintile (Q4)	-0.79***(0.05)	-0.40***(0.05)	-0.62***(0.05)	-0.96***(0.05)	-1.20***(0.05)
Household located in the fifth expenditure quintile (Q5)	-1.05***(0.05)	-0.59***(0.05)	-0.73***(0.05)	-1.30***(0.05)	-1.55***(0.05)
Age, household head	-0.00084(0.00)	0.0014(0.00)	-0.0016(0.00)	0.0034***(0.00)	0.00024(0.00)
Age, spouse	0.0001(0.00)	-0.001(0.00)	0.001(0.00)	0.003***(0.00)	0.002(0.00)
Male-headed household dummy (yes = 1)	0.034(0.04)	0.061(0.04)	0.081*(0.04)	-0.00018(0.04)	-0.036(0.04)
Education dummies, no formal education is the base = 0					
A dummy for head educated up to primary level (7 years) (yes = 1)	-0.040(0.04)	-0.024(0.04)	-0.058(0.04)	-0.080*(0.04)	-0.0063(0.04)
A dummy for head educated up to secondary level (yes = 1)	-0.035(0.05)	0.0070(0.05)	-0.011(0.05)	-0.11**(0.05)	-0.100*(0.05)
A dummy for head educated above secondary level (yes = 1)	-0.12(0.10)	-0.11(0.10)	0.0056(0.09)	-0.26***(0.09)	-0.21**(0.10)
A dummy for spouse educated up to primary level (7 years) (yes = 1)	0.033(0.04)	-0.041(0.04)	-0.067(0.04)	-0.029(0.04)	-0.043(0.04)
A dummy for spouse educated up to secondary level (yes = 1)	-0.060(0.06)	-0.036(0.06)	-0.079(0.06)	-0.16***(0.06)	-0.13**(0.06)
A dummy for spouse educated above secondary level (yes = 1)	-0.053(0.16)	-0.070(0.14)	-0.20(0.16)	-0.20(0.15)	-0.086(0.15)
Occupation dummies: base occupation, other than agriculture=0					
Dummy for the household in agriculture (yes = 1)	-0.039(0.03)	-0.12***(0.03)	0.0014(0.03)	0.13***(0.03)	0.015(0.03)
Dummy for the spouse in agriculture (yes = 1)	0.015(0.03)	-0.036(0.04)	-0.022(0.03)	0.14***(0.03)	0.021(0.03)
Year dummies (base 2010=0)					
Year 2014 dummy (yes = 1)	-0.026(0.04)	-0.66***(0.04)	0.070*(0.04)	-0.24***(0.04)	0.087**(0.04)
Year 2016 dummy (yes = 1)	0.074*(0.04)	-0.64***(0.04)	0.0060(0.04)	-0.29***(0.04)	0.14***(0.04)
Region dummies (central and Kampala regions are the base=0)					
Eastern region dummy (yes = 1)	0.80***(0.04)	0.100*(0.04)	0.11**(0.04)	0.20***(0.04)	-0.26***(0.05)
Northern region dummy (yes = 1)	1.29***(0.04)	0.079*(0.04)	0.56***(0.04)	0.81***(0.04)	-0.30***(0.04)
Western region dummy (yes = 1)	-0.20***(0.05)	0.076*(0.04)	0.42***(0.04)	0.62***(0.04)	0.33***(0.04)
Rural household dummy (yes = 1)	0.069*(0.04)	-0.16***(0.04)	0.064*(0.04)	0.31***(0.04)	0.093**(0.04)
Constant	-0.046(0.09)	0.15*(0.09)	-0.34***(0.09)	0.38***(0.09)	0.26***(0.09)
atrho21	0.0057(0.02)	atrho51	0.068***(0.02)	atrho32	-0.081***(0.02)
atrho31	0.12***(0.02)	atrho52	0.11***(0.02)	atrho53	0.00021(0.02)
atrho41	0.12***(0.02)	atrho43	0.18***(0.02)	atrho54	0.23***(0.02)
atrho42	0.012(0.02)				
Observations	8,480				
Log pseudolikelihood	-23120.02				
Wald chi2(105)	5819.28				
Prob > chi2	0.00				
Likelihood ratio test of rho21 = rho31 = rho41 = rho51 = rho32 = rho42 = rho52 = rho43 = rho53 = rho54 = 0:	367.58				
chi2(10)					
Prob > chi2	0.00				

Source: Authors' estimation.

Note: Values in parentheses are standard errors calculated based on the robust standard errors. *Significant at the 10% level. **Significant at the 5% level. ***Significant at the 1% level.

Table B3
Estimated functions applying the Generalized Linear Model (GLM) estimation method explaining the prices of the sampled commodities.

Food items Independent variables	Dependent variables: price of the sampled food items (UGX/kg)					
	Matooke	Cassava and potatoes	Maize/coarse grains	Rice and wheat	Vegetables	Meat and fish
Total real expenditure on all food at the household level/weekly (UGX)	0.0011***(0.00)	0.0010***(0.00)	0.0030***(0.00)	0.0032***(0.00)	0.0027***(0.00)	0.0052***(0.00)
Age, household head	0.0063(0.12)	0.33(0.41)	-1.16(1.65)	2.22***(0.78)	-0.27(0.91)	1.12(1.04)
Age, spouse	0.23**(0.12)	0.29(0.29)	-0.57(1.39)	0.0042(0.77)	0.46(0.85)	2.53**(1.23)
Male-headed household dummy (yes = 1)	-2.30(4.66)	-1.84(8.98)	-1.92(49.65)	27.9(28.71)	-52.9(34.47)	-53.0(42.38)
<i>Education dummies, no formal education is the base = 0</i>						
A dummy for head educated up to primary level (7 years) (yes = 1)	-1.50(4.41)	19.0(13.62)	110.3**(53.63)	15.4(30.60)	15.1(34.09)	83.3**(37.63)
A dummy for head educated up to secondary level (yes = 1)	-1.75(5.78)	4.89(13.00)	115.4*(65.06)	9.53(40.41)	32.6(42.82)	109.3**(53.17)
A dummy for head educated above secondary level (yes = 1)	22.8(14.36)	-4.16(21.04)	161.4**(62.68)	16.9(59.33)	72.2(73.22)	18.3(75.18)
A dummy for spouse educated up to primary level (7 years) (yes = 1)	-7.55(4.82)	10.3(15.58)	84.9(67.42)	-17.5(32.93)	34.1(36.17)	-9.60(41.37)
A dummy for spouse educated up to secondary level (yes = 1)	1.97(7.22)	-10.8(17.62)	-24.4(59.34)	3.45(42.94)	53.5(47.54)	81.0(57.39)
A dummy for spouse educated above secondary level (yes = 1)	24.9(21.33)	-23.4(25.55)	142.0(93.49)	-58.7(56.83)	-33.6(94.26)	-25.6(104.50)
<i>Occupation dummies: base occupation, other than agriculture=0</i>						
Dummy for the household in agriculture (yes = 1)	4.88(3.10)	-19.5(13.89)	70.1(49.32)	48.2*(26.05)	-39.0(25.38)	-7.29(26.94)
Dummy for the spouse in agriculture (yes = 1)	4.97(3.52)	1.20(15.66)	-55.7(46.97)	11.0(28.69)	4.79(28.91)	-54.6*(28.24)
<i>Year dummies (base 2010=0)</i>						
Year 2014 dummy (yes = 1)	19.6***(4.30)	-92.0***(19.30)	-25.2(21.41)	201.5***(30.59)	284.3***(33.03)	654.7***(28.40)
Year 2016 dummy (yes = 1)	-9.79**(4.10)	-153.5*** (10.22)	282.1***(63.47)	-152.8***(27.29)	837.2***(29.65)	381.1***(32.21)
<i>Region dummies (Central and Kampala regions are the base = 0)</i>						
Eastern region dummy (yes = 1)	-87.8***(5.11)	-68.0***(10.09)	-322.3***(31.06)	-540.3***(27.73)	15.6(28.72)	-696.1***(42.19)
Northern region dummy (yes = 1)	-132.6***(5.35)	-159.3***(10.61)	279.6***(70.16)	-631.2***(35.26)	429.7***(35.87)	-1030.7***(48.28)
Western region dummy (yes = 1)	2.66(5.15)	57.0*(33.93)	9.30(39.16)	-47.9**(24.29)	-78.3***(33.54)	-277.9***(35.05)
Rural household dummy (yes = 1)	-22.5***(4.78)	-54.4(34.21)	103.2**(41.23)	-220.5***(33.57)	-40.2(31.28)	-144.3***(38.01)
Generalized inverse mills ratio	-73.6***(1.89)	-64.7***(5.89)	-328.9***(28.35)	-850.7***(23.24)		-1278.0***(16.17)
Constant	229.1***(14.96)	361.3***(28.59)	809.1***(112.00)	1686.5***(55.97)	1361.6***(68.83)	4263.2***(94.70)
No. of observations	8480	8480	8480	8480	8480	8480

Note: Values in parentheses are standard errors calculated based on the bootstrap method by replicating 100 times. *Significant at the 10% level. **Significant at the 5% level. ***Significant at the 1% level.

All monetary values are converted into real terms using the Consumer Price Index reported by the World Bank(2020a) setting 2010 = 100

Rural dummy is a dummy variable that assumes a value of 1 if a household is from a rural area, and 0 otherwise.

Table 2B presents the estimated functions applying the multivariate probit model estimation procedure explaining household consumption choices of the sampled food items. The likelihood ratio test of the joint significance of the correlation of the error terms of all the consumption equations $\chi^2 = 367.6, p=0.00$ indicates the suitability of the application of the multivariate probit model estimation procedure to identify the factors that affect the decision to not consume a sampled food. The estimated functions demonstrate that economically affluent households are progressively more likely to consume the sampled five commodity food items in Uganda, as the dummies for the expenditure quintiles (Q1–Q5) were highly significant and increased progressively

over the quintiles. In other words, relatively economically affluent households are more likely to consume the sampled five food items than the poorest households located in the first expenditure quintile (Q1). While the age of the household and spouse are not significant determinants in deciding consumption of the sampled five food items, household heads and spouses with above a secondary level of education are more likely to consume wheat and rice, and meat and fish (Table 2B). The regional heterogeneity in food consumption is seen in Table 2B. For example, compared to the households from the central and Kampala regions, households in the eastern, northern, and western regions are more likely not to consume cassava and potatoes, maize, rice, and wheat (Table 2B). On the other hand, households in the eastern and northern regions are more likely to consume meat and fish than households in the

central and Kampala regions. Finally, while rural households are more likely to consume cassava and potatoes, they are less likely to consume other food items such as matooke, maize, wheat, rice, meat, and fish compared to urban households. This is probably because poverty in Uganda is more widespread in rural areas than in urban ones.

After estimating Eq. (2B), we calculated five generalized inverse Mill's ratios for five food items, following the procedure suggested by Vella (1998). Finally, we specified the price equations as follows:

$$\begin{aligned}
 p_{ic} = & \mu_0 + \sigma_p (\text{Weekly food expenditure})_{ip} + (\text{HHdemographics})_{ip} Q_p \\
 & + \sum_{y=1}^2 \theta_p (\text{Year})_{ip} + \sum_{r=1}^3 v_p (\text{Region})_{ip} + \sum_{o=1}^3 \psi_o (\text{Occupation})_i + \sum_{b=1}^2 \beta_p (\text{Belt})_p \\
 & + \sum_{y=1}^2 \theta_p (\text{Year})_p + \sigma_p (\text{Rural dummy})_p + \beta_p (\text{Inverse Mills ratio})_p + \epsilon_{ic}
 \end{aligned}
 \tag{3B}$$

Where p_{ic} is the real imputed price of food item c reported by household i ; *weekly food expenditure* is the weekly total food expenditure at the household level in real terms. All monetary values are converted into real terms by setting the consumer price index at 2010 = 100 reported by the World Bank (2020).

In estimating Eq. (3B) we applied the Generalized Linear Model (GLM) estimation method. To correct the standard error, we bootstrapped the estimation method by replicating it 100 times. In

addition, we clustered the standard error at the household level. Table 3B presents the estimated functions explaining the prices of the sampled food items.

After estimating Eq. (3B), we calculated residuals ($\hat{\epsilon}_{ic}$) from all six price functions. Finally, we estimated the quality-adjusted unit price of the sampled food items (\hat{p}_{ic}^h) as follows:

$$\hat{p}_{ic}^h = p_c^i + \hat{\epsilon}_{ic}
 \tag{4B}$$

It is likely that the households in the same primary sample unit (PSU) may inform the same prices for the sampled food items since usually the sampled households in a PSU are surveyed at the same time (Deaton, 1988). To handle this issue, we further demeaned the prices separately by year, food item, and rural-urban affiliation of the households. This estimated unit price from Eq. (4B) is used in estimating Eq. (1) to calculate price and expenditure elasticities.

Annexure C

Parameter estimation from QUAIDS model

Table C4

Table C5

Table C6

Table C4

Parameter estimates from QUAIDS model for rural households.

	Matooke	Cassava and potatoes	Maize/coarse grains	Rice and wheat	Vegetables	Fish and meat
Constant (α_i)	-0.017(0.14)	0.29*(0.17)	0.57***(0.10)	0.055(0.33)	0.74***(0.07)	-0.64(0.50)
Expenditure (β_i)	-0.014(0.03)	0.033(0.04)	0.077***(0.02)	0.00034(0.07)	0.081***(0.02)	-0.18(0.11)
Expenditure 2	0.0063***(0.00)	0.0063***(0.00)	0.0015(0.00)	-0.00032(0.00)	-0.00050(0.00)	-0.013***(0.01)
Prices (γ_i)	0.035***(0.02)	0.092****(0.01)	-0.031****(0.01)	-0.0078(0.01)	-0.059****(0.01)	-0.028***(0.01)
		0.042****(0.01)	-0.016(0.01)	-0.0032(0.01)	-0.050****(0.01)	-0.064****(0.01)
			0.087****(0.01)	-0.0060(0.02)	0.024****(0.01)	-0.058*(0.03)
				0.029(0.05)	-0.0069(0.02)	-0.0048(0.01)
					0.15****(0.01)	-0.062*(0.03)
						0.22****(0.07)
Age of the household head (Hage)	0.0001***(0.00)	0.00001(0.00)	-0.00002(0.00)	-0.000001(0.00)	-0.00002(0.00)	-0.00004(0.00)
Age of the spouse (Sage)	-0.000023(0.00)	0.000044(0.00)	0.0000018(0.00)	0.000016(0.00)	-0.000015(0.00)	-0.000023(0.00)
Household head educated up to primary level (yes = 1) (Hpri)	-0.0016(0.00)	-0.0018(0.00)	0.0011(0.00)	-0.0011***(0.00)	0.0026*(0.00)	0.00078(0.00)
Household head educated up to secondary level (yes = 1) (Hsec)	-0.00090(0.00)	-0.0014(0.00)	0.0013(0.00)	-0.0014****(0.00)	0.0047***(0.00)	-0.0023(0.00)
Household head educated up to tertiary level (yes = 1) (Hter)	0.00021(0.01)	-0.0086(0.01)	-0.00084(0.00)	-0.0019(0.00)	0.0058(0.00)	0.0053(0.01)
Spouse educated up to primary level (yes = 1) (Spri)	0.00041(0.00)	-0.00024(0.00)	0.00094(0.00)	-0.000024(0.00)	-0.00037(0.00)	-0.00071(0.00)
Spouse educated up to secondary level (yes = 1) (Ssec)	0.0048(0.00)	-0.0037*(0.00)	0.0012(0.00)	-0.0028***(0.00)	0.0016(0.00)	-0.0011(0.00)
Spouse educated up to tertiary level (yes = 1) (Ster)	0.0021(0.01)	-0.0063(0.01)	0.0068*(0.00)	-0.0068***(0.00)	0.0017(0.01)	0.0025(0.01)
No. of family members (Hsize)	0.00037*(0.00)	-0.000063(0.00)	-0.00032***(0.00)	0.00015***(0.00)	-0.00016(0.00)	0.000022(0.00)
Household head in agriculture (yes = 1) (Hagri)	-0.0035***(0.00)	-0.00061(0.00)	0.00089(0.00)	0.00075***(0.00)	-0.00065(0.00)	0.0032***(0.00)
Spouse in agriculture (yes = 1) (Sagri)	0.001(0.00)	0.002(0.00)	-0.001(0.00)	0.001(0.00)	0.0003(0.00)	-0.002(0.00)
Male-headed household (yes = 1) (Hm)	-0.00061(0.00)	-0.0018(0.00)	0.0010(0.00)	-0.00075***(0.00)	0.00068(0.00)	0.0015(0.00)
Scaling parameters for demographics (ρ)						
	Coefficients	Standard error		Coefficients	Standard error	
ρ_{Hage}	0.01***	0.00	ρ_{Ssec}	0.060	0.09	
ρ_{Sage}	-0.015***	0.01	ρ_{Ster}	0.26	0.75	
ρ_{Hpri}	0.013	0.10	ρ_{Hsize}	-0.01	0.01	
ρ_{Hsec}	0.03	0.08	ρ_{Hagri}	-0.11**	0.05	
ρ_{Hter}	0.27	0.55	ρ_{Sagri}	-0.01	0.04	
ρ_{Spri}	-0.19***	0.05	ρ_{Hm}	0.33***	0.08	
No. of observations	6358					
Log likelihood	14994.0					
α_0	7.04					

Note: Values in parentheses are standard errors calculated based on the bootstrap method by replicating 50 times. *Significant at the 10% level. **Significant at the 5% level. ***Significant at the 1% level.

Table C5
Parameter estimates from QUAIDS model for urban households.

	<i>Matooke</i>	Cassava and potatoes	Maize/coarse grains	Rice and wheat	Vegetables	Fish and meat
Constant (α_i)	1.02***(0.32)	-0.14(0.17)	-0.07(0.21)	0.22(0.22)	0.32(0.21)	-0.35(0.32)
Expenditure (β_i)	0.20***(0.07)	-0.068(0.04)	-0.06(0.05)	0.022(0.04)	0.0060(0.05)	-0.100(0.08)
Expenditure 2	0.012***(0.00)	0.0030(0.00)	-0.0041(0.00)	0.00091(0.00)	-0.0033(0.00)	-0.0087*(0.00)
Prices (γ_i)	0.10**(0.04)	0.022(0.02)	-0.040*(0.02)	0.0060(0.01)	-0.018(0.02)	-0.071*(0.04)
		0.04***(0.01)	-0.0003(0.02)	0.002(0.01)	-0.04***(0.01)	-0.02(0.02)
			0.071*(0.04)	-0.011(0.01)	-0.016(0.02)	-0.0031(0.02)
				0.03(0.02)	0.002(0.01)	-0.030(0.02)
					0.098***(0.03)	-0.024(0.02)
						0.15***(0.04)
Age of the household head (Hage)	0.000044(0.00)	0.00018(0.00)	-0.000018(0.00)	0.000059(0.00)	-0.00012(0.00)	-0.00014*(0.00)
Age of the spouse (Sage)	0.0001(0.00)	0.00003(0.00)	-0.000020(0.00)	0.000058*(0.00)	-0.000033(0.00)	-0.00012(0.00)
Household head educated up to primary level (yes = 1) (Hpri)	-0.00078(0.00)	-0.0041(0.01)	0.0013(0.00)	-0.0021*(0.00)	0.0062(0.00)	-0.00061(0.00)
Household head educated up to secondary level (yes = 1) (Hsec)	0.0031(0.00)	-0.0012(0.01)	0.0047**(0.00)	-0.0046***(0.00)	0.0054(0.00)	-0.0074*(0.00)
Household head educated up to tertiary level (yes = 1) (Hter)	0.0081*(0.00)	-0.014*(0.01)	0.01***(0.00)	-0.0046(0.00)	0.018***(0.01)	-0.015***(0.01)
Spouse educated up to primary level (yes = 1) (Spri)	-0.004(0.00)	0.004(0.01)	0.002(0.00)	0.001(0.00)	-0.001(0.01)	-0.0013(0.00)
Spouse educated up to secondary level (yes = 1) (Ssec)	-0.0033(0.00)	-0.0096(0.01)	0.0028(0.00)	0.002 (0.00)	0.01(0.01)	0.002(0.00)
Spouse educated up to tertiary level (yes = 1) (Ster)	-0.00060(0.02)	-0.0044(0.04)	0.0012(0.00)	0.002(0.00)	0.002(0.02)	-0.001(0.01)
No. of family members (Hsize)	0.00024(0.00)	0.00030(0.00)	-0.00041**(0.00)	0.00037**(0.00)	-0.00065**(0.00)	0.00015(0.00)
Household head in agriculture (yes = 1) (Hagri)	-0.0029(0.00)	0.0075(0.01)	-0.0022(0.00)	0.0033**(0.00)	-0.0042(0.00)	-0.0015(0.00)
Spouse in agriculture (yes = 1) (Sagri)	-0.003(0.00)	0.01*(0.00)	-0.002(0.00)	0.003***(0.00)	-0.01(0.00)	-0.0001(0.00)
Male headed household (yes = 1) (Hm)	0.004*(0.00)	0.01(0.01)	-0.002(0.00)	-0.002(0.00)	-0.002(0.00)	-0.002(0.00)
Scaling parameters for demographics (ρ)						
	Coefficients	Standard error		Coefficients	Standard error	
ρ_{Hage}	0.002	0.01	ρ_{Ssec}	-0.43	0.32	
ρ_{Sage}	-0.01	0.02	ρ_{Ster}	-0.19	7.40	
ρ_{Hpri}	-0.09	0.32	ρ_{Hsize}	-0.012	0.03	
ρ_{Hsec}	0.13	0.42	ρ_{Hagri}	-0.05	0.58	
ρ_{Hter}	-0.24	0.37	ρ_{Sagri}	0.06	0.16	
ρ_{Spri}	-0.23	0.61	ρ_{Hm}	0.06	0.27	
No. of observations	2066					
Log likelihood	4481.2					
α_0	7.4					

Note: Values in parentheses are standard errors calculated based on the bootstrap method by replicating 50 times. *Significant at the 10% level. **Significant at the 5% level. ***Significant at the 1% level.

Table C6
Estimated uncompensated price and cross-price elasticities for the poorest and richest rural and urban households (expenditure endogeneity corrected QUAIDS model).

Rural household	Matooke		Cassava and potatoes		Maize/coarse grains		Wheat and rice		Vegetables		Meat and fish	
	Q1	Q5	Q1	Q5	Q1	Q5	Q1	Q5	Q1	Q5	Q1	Q5
<i>Matooke</i>	-0.98	-0.94	0.33	0.51	0.05	0.04	-0.004	0.0003	0.08	0.08	0.04	0.07
Cassava and potatoes	0.76	0.40	-0.73	-0.85	0.01	-0.01	0.01	0.01	-0.11	-0.07	-0.17	-0.08
Maize/coarse grains	-0.12	-0.17	-0.12	-0.16	-0.63	-0.53	-0.07	-0.08	-0.21	-0.22	-0.23	-0.28
Wheat and rice	-0.33	-0.11	-0.13	-0.05	-0.43	-0.14	0.49	-0.51	-0.57	-0.18	-0.35	-0.12
Vegetables	-0.09	-0.19	-0.11	-0.24	-0.06	-0.11	-0.03	-0.06	-0.81	-0.61	-0.11	-0.23
Meat and fish	-0.20	-0.09	-0.34	-0.15	-0.26	-0.10	-0.07	-0.03	-0.40	-0.16	-0.19	-0.67
Urban household												
<i>Matooke</i>	-1.11	-1.22	0.30	0.48	-0.02	-0.03	-0.05	-0.08	-0.11	-0.17	-0.03	-0.01
Cassava and potatoes	0.54	0.33	-0.86	-0.91	0.04	0.02	0.13	0.08	0.003	0.00	-0.07	-0.04
Maize/coarse grains	-0.03	-0.04	-0.06	-0.10	-0.65	-0.41	-0.04	-0.07	-0.11	-0.19	-0.15	-0.26
Wheat and rice	-0.30	-0.12	0.21	0.08	-0.23	-0.08	-0.19	-0.70	-0.06	-0.02	-0.73	-0.27
Vegetables	-0.07	-0.15	-0.10	-0.20	-0.07	-0.13	-0.01	-0.02	-0.79	-0.58	-0.11	-0.22
Meat and fish	-0.08	-0.02	-0.33	-0.14	-0.25	-0.10	-0.23	-0.09	-0.33	-0.13	-0.06	-0.64

Source: Authors' estimation.

Note: Q1= poorest expenditure quintile Q5= richest expenditure quintile

Annexure D

Table D7
Table D8

Table D7

Estimated functions applying the left-censored Tobit estimation procedure, explaining per capita/daily expenditure in UGX on the sampled food items of rural households.

Sampled food items	ln(expenditure UGX/capita/day on)					
	Matooke	Cassava and potatoes	Maize/coarse grains	Rice and wheat	Vegetables	Fish and meat
ln (expenditure on all sampled foods UGX/capita/day)	1.49***(0.03)	1.78***(0.05)	1.43***(0.02)	1.39***(0.03)	0.99***(0.01)	1.55***(0.02)
Price of the commodity	-0.001***(0.00)	-0.0001(0.00)	0.000012***(0.00)	0.000039***(0.00)	0.000041***(0.00)	0.000026***(0.00)
Stone's price index	-1.01***(0.01)	-1.55***(0.03)	-0.51***(0.01)	-0.50***(0.02)	-0.42***(0.01)	-0.59***(0.01)
Age, household head	-0.0036*(0.00)	-0.0017(0.00)	0.0017(0.00)	0.00080(0.00)	0.00013(0.00)	0.00072(0.00)
Age, spouse	0.0030*(0.00)	0.00083(0.00)	0.0016(0.00)	0.00032(0.00)	0.00026(0.00)	0.0033****(0.00)
Male-headed household dummy (yes = 1)	-0.12(0.07)	-0.13(0.13)	-0.18****(0.04)	-0.18****(0.05)	-0.036*(0.02)	-0.18****(0.03)
<i>Education dummies, no formal education is the base = 0</i>						
A dummy for head educated up to primary level (7 years) (yes = 1)	-0.043(0.07)	0.033(0.11)	0.070*(0.04)	0.13****(0.05)	0.013(0.02)	0.13****(0.03)
A dummy for head educated up to secondary level (yes = 1)	0.0075(0.10)	0.14(0.14)	0.13****(0.05)	0.25****(0.06)	0.035(0.03)	0.16****(0.04)
A dummy for head educated above secondary level (yes = 1)	-0.19(0.24)	-0.19(0.29)	0.096(0.13)	0.41****(0.14)	-0.038(0.08)	0.29****(0.09)
A dummy for spouse educated up to primary level (7 year) (yes = 1)	0.084(0.07)	0.037(0.13)	-0.015(0.04)	0.050(0.05)	0.014(0.03)	0.043(0.03)
A dummy for spouse educated up to secondary level (yes = 1)	0.065(0.11)	0.43***(0.18)	0.20****(0.06)	0.39****(0.07)	-0.0025(0.03)	0.26****(0.04)
A dummy for spouse educated above secondary level (yes = 1)	0.25(0.29)	0.091(0.48)	0.061(0.15)	0.086(0.23)	0.094(0.08)	0.13(0.11)
<i>Occupation dummies: base occupation, other than agriculture = 0</i>						
Dummy for the household in agriculture (yes = 1)	0.073(0.05)	-0.040(0.08)	-0.016(0.03)	-0.017(0.04)	0.00036(0.02)	0.038(0.03)
Dummy for the spouse in agriculture (yes = 1)	0.030(0.06)	0.059(0.09)	0.11****(0.03)	-0.040(0.04)	0.013(0.02)	-0.0099(0.02)
No. of family members	0.11****(0.01)	0.19****(0.02)	0.11****(0.01)	0.11****(0.01)	-0.0014(0.00)	0.12****(0.00)
<i>Region dummies (central and Kampala regions are the base = 0)</i>						
Eastern region dummy (yes = 1)	0.010(0.07)	-1.12****(0.10)	-1.49****(0.04)	-1.80****(0.06)	0.089****(0.02)	-1.64****(0.03)
Northern region dummy (yes = 1)	0.053(0.07)	-2.17****(0.14)	-2.82****(0.05)	-3.31****(0.07)	0.084****(0.02)	-2.80****(0.04)
Western region dummy (yes = 1)	-0.27****(0.07)	-0.093(0.09)	0.22****(0.03)	0.39****(0.06)	0.094****(0.02)	0.30****(0.03)
Generalized inverse Mills ratio	0.24****(0.04)	0.52****(0.05)	-3.34****(0.03)	-4.04****(0.04)		-3.34****(0.04)
Year dummies (year 2010 is base = 0)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)
Year 2014 dummy (yes = 1)	1.19****(0.06)	0.95****(0.09)	0.33****(0.04)	0.45****(0.05)	0.10****(0.02)	0.45****(0.03)
Year 2016 dummy (yes = 1)	1.21****(0.07)	0.73****(0.09)	0.090***(0.04)	0.16****(0.06)	0.054****(0.02)	0.30****(0.03)
Constant	-1.53****(0.29)	-1.39****(0.48)	-4.82****(0.17)	-4.93****(0.21)	0.24****(0.08)	-5.30****(0.16)
var(e.lnmax)	3.59****(0.08)	7.43****(0.23)	0.84****(0.03)	0.83****(0.03)	0.39****(0.02)	0.57****(0.02)
No. of observations	6,358	6,358	6358	6358	6358	6358
Left censored	1,635	3,180	2,137	4,276	75	2,171
Wald chi2(21)	10972.94	9801.92	23766.06	19,369	199983.58	37707.03
Pro>Chi2	0.00	0.00	0.00	0.00	0.00	0.00
Pseudo R2	0.19	0.22	0.55	0.67	0.44	0.63
Log pseudolikelihood	-11203.28	-9345.70	-5904.07	-2935.30	-6099.14	-5061.91

Note: Values in parentheses are standard errors calculated based on the bootstrap method by replicating 100 times. *Significant at the 10% level. **Significant at the 5% level. ***Significant at the 1% level.

All monetary values are in real terms converted using the Consumer Price Index 2010=100.

Table D8

Estimated functions applying the left-censored Tobit estimation procedure, explaining per capita/daily expenditure in UGX on the sampled food items of urban households.

Sampled food items	ln(expenditure UGX/capita/day on)					
	Matooke	Cassava and potatoes	Maize/coarse grains	Rice and wheat	Vegetables	Fish and meat
In (expenditure on all sampled foods in UGX/capita/day)	1.60***(0.06)	1.82***(0.07)	1.31***(0.03)	1.27***(0.04)	1.05***(0.03)	1.49***(0.03)
Price of the commodity	-0.00066***(0.00)	0.000023(0.00)	0.000045***(0.00)	0.000057***(0.00)	0.000043***(0.00)	0.000026(0.00)
Stone's price index	-1.22***(0.04)	-1.29***(0.05)	-0.53***(0.02)	-0.54***(0.02)	-0.48***(0.01)	-0.58***(0.01)
Age, household head	0.00055(0.00)	0.0022(0.00)	0.0022(0.00)	0.0029(0.00)	0.0020(0.00)	0.0036***(0.00)
Age, spouse	0.0067*(0.00)	0.0058(0.00)	0.0013(0.00)	-0.0016(0.00)	-0.00069(0.00)	0.0015(0.00)
Male-headed household dummy (yes = 1)	-0.13(0.14)	-0.17(0.15)	-0.14*(0.06)	0.013(0.07)	0.015(0.05)	-0.069(0.05)
<i>Education dummies, no formal education is the base = 0</i>						
A dummy for head educated up to primary level (7 years) (yes = 1)	0.085(0.18)	0.35*(0.19)	0.089(0.08)	0.055(0.10)	0.021(0.05)	0.056(0.07)
A dummy for head educated up to secondary level (yes = 1)	0.32*(0.19)	0.42**(0.21)	0.11(0.08)	0.19*(0.10)	0.035(0.05)	0.14*(0.07)
A dummy for head educated above secondary level (yes = 1)	0.57***(0.24)	0.84****(0.28)	0.30****(0.08)	0.45****(0.11)	0.050(0.07)	0.30****(0.08)
A dummy for spouse educated up to primary level (7 years) (yes = 1)	0.17(0.17)	0.19(0.21)	-0.025(0.09)	0.15(0.09)	0.088(0.06)	0.078(0.05)
A dummy for spouse educated up to secondary level (yes = 1)	0.24(0.19)	0.13(0.21)	0.28****(0.09)	0.42****(0.09)	0.090(0.06)	0.32****(0.05)
A dummy for spouse educated above secondary level (yes = 1)	0.10(0.33)	0.31(0.36)	0.12(0.13)	0.36****(0.13)	-0.029(0.15)	0.31****(0.09)
<i>Occupation dummies: base occupation, other than agriculture = 0</i>						
Dummy for the household in agriculture (yes = 1)	-0.040(0.11)	0.16(0.16)	0.031(0.05)	0.0014(0.08)	0.025(0.04)	0.050(0.05)
Dummy for the spouse in agriculture (yes = 1)	-0.14(0.14)	-0.22(0.13)	0.090(0.06)	-0.13*(0.07)	-0.082***(0.04)	0.030(0.05)
No. of family members	0.15****(0.02)	0.18****(0.02)	0.093****(0.01)	0.095****(0.01)	0.026****(0.01)	0.11****(0.01)
<i>Region dummies (central and Kampala regions are the base = 0)</i>						
Eastern region dummy (yes = 1)	0.043(0.14)	-1.15****(0.20)	-1.38****(0.06)	-1.61****(0.09)	0.060(0.05)	-1.66****(0.07)
Northern region dummy (yes = 1)	0.52****(0.14)	-1.73****(0.21)	-2.58****(0.08)	-3.06****(0.12)	0.11***(0.05)	-2.77****(0.07)
Western region dummy (yes = 1)	-0.18(0.16)	0.058(0.13)	0.17****(0.06)	0.088(0.08)	-0.052(0.04)	0.15****(0.04)
Inverse Mills ratio	0.19****(0.07)	0.17****(0.06)	-3.25****(0.06)	-3.72****(0.05)		-3.39****(0.06)
<i>Year dummies (year 2010 is base = 0)</i>						
Year 2014 dummy (yes = 1)	1.51****(0.17)	0.54****(0.18)	0.21****(0.07)	0.42****(0.08)	0.11***(0.05)	0.37****(0.05)
Year 2016 dummy (yes = 1)	1.28****(0.17)	0.39***(0.19)	-0.016(0.07)	0.35****(0.08)	0.092*(0.05)	0.32****(0.04)
Constant	-2.18****(0.63)	-3.35****(0.64)	-3.62****(0.29)	-3.68****(0.26)	-0.11(0.21)	-4.85****(0.28)
var(e.lnmax)	4.64****(0.17)	5.14****(0.27)	0.79****(0.04)	0.76****(0.03)	0.47****(0.05)	0.48****(0.03)
No. of observations	2,066	2066	2066	2066	2066	2066
Left censored	586	750	550	902	43	539
Wald chi2(21)	2194.73	3087.66	7,638	10,899.03	7896.31	10013.35
Pro->Chi2	0.00	0.00	0.00	0.00	0.00	0.00
Pseudo R2	0.16	0.23	0.54	0.61	0.40	0.64
Log pseudolikelihood	-3750.25	-3430.41	-2056.89	-1567.85	-2179.90	-1686.89

Note: Values in parentheses are standard errors calculated based on the bootstrap method by replicating 100 times. *Significant at the 10% level. **Significant at the 5% level. ***Significant at the 1% level.

All monetary values are in real terms converted using the Consumer Price Index 2010=100.

Annexure E

Model validation

- Figure E1
- Figure E2
- Figure E3
- Figure E4
- Figure E5
- Figure E6

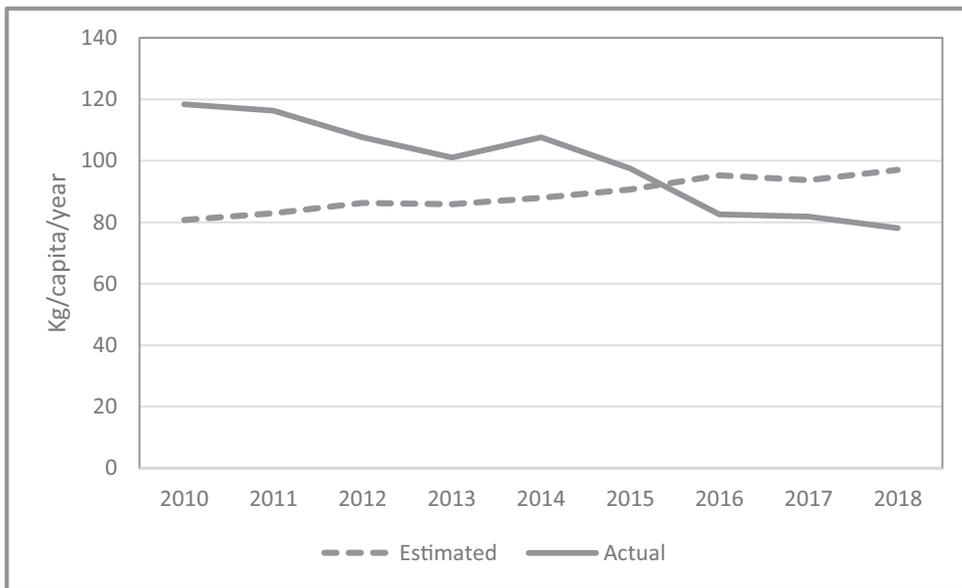


Fig. E1. Predicted and actual consumption of matooke in Uganda from 2010–18 (kg/capita/year). Sources: Authors' estimation and FAOSTAT (2021c).

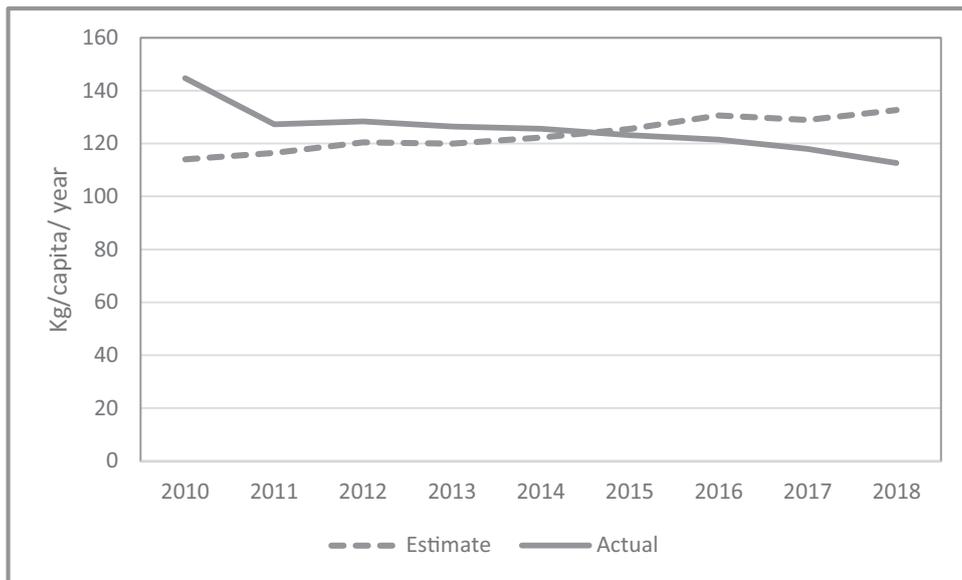


Fig. E2. Predicted and actual consumption of cassava, sweet potato, and potatoes in Uganda from 2010–18 (kg/capita/year). Sources: Authors' estimation and FAOSTAT (2021c).

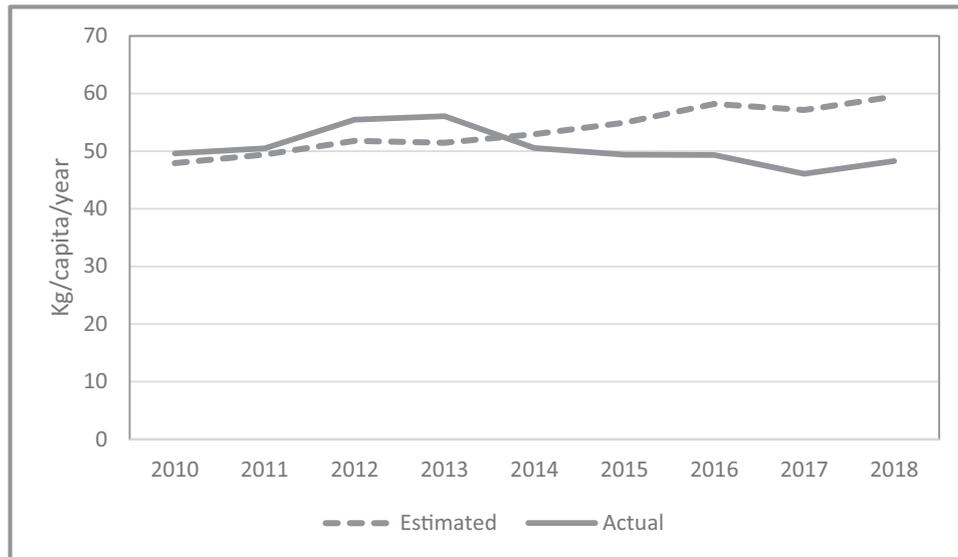


Fig. E3. Predicted and actual consumption of maize/coarse grains in Uganda from 2010–18 (kg/capita/year). Sources: Authors' estimation and FAOSTAT (2021c).

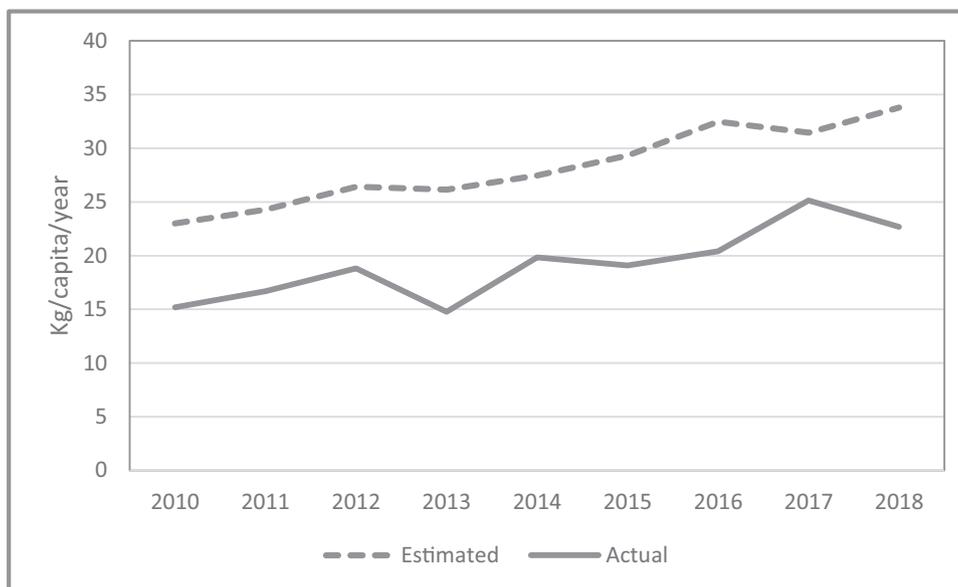


Fig. E4. Predicted and actual consumption of wheat and rice in Uganda from 2010–18 (kg/capita/year). Sources: Authors' estimation and FAOSTAT (2021c).

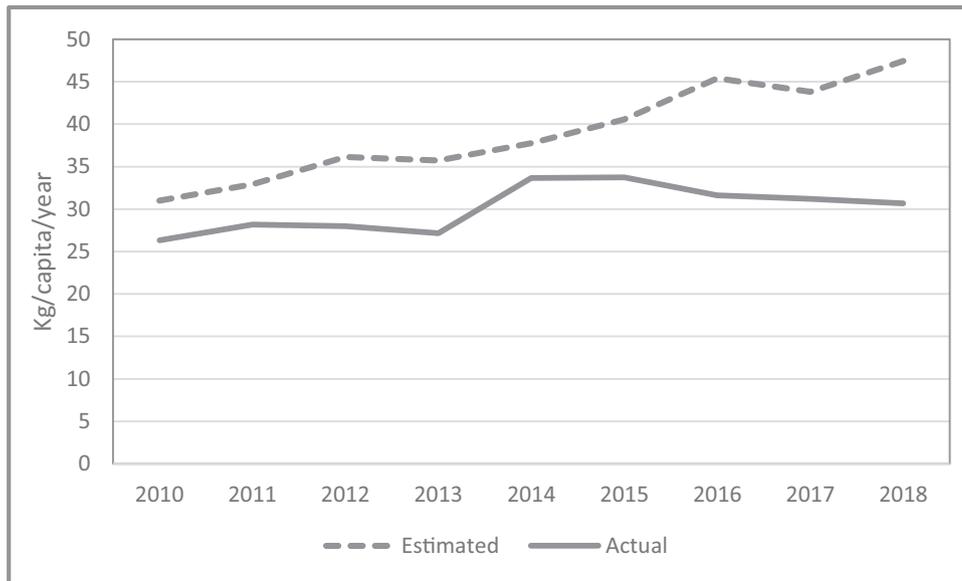


Fig. E5. Predicted and actual consumption of vegetables in Uganda 2010–18 (kg/capita/year).
Sources: Authors' estimation and FAOSTAT (2021c).

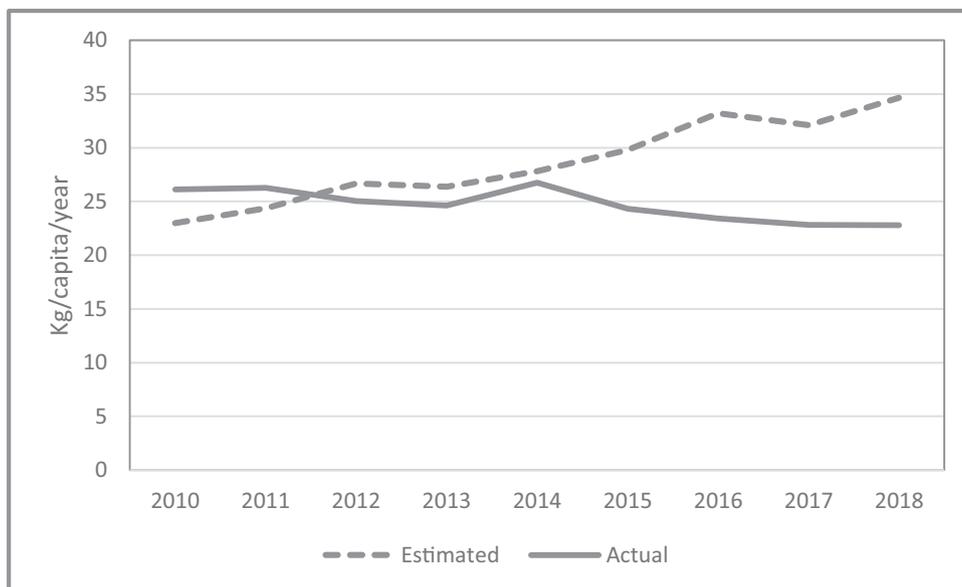


Fig. E6. Predicted and actual consumption of fish and meat in Uganda from 2010–18 (kg/capita/year).
Sources: Authors' estimation and FAOSTAT (2021c).

References

- Alexandratos, N., 2005. Countries with rapid population growth and resource constraints: Issues of food, agriculture, and development. *Popul. Dev. Rev.* 31, 237–258. doi:10.1111/j.1728-4457.2005.00064.x.
- Banks, J., Blundell, R., Lewbel, A., 1997. Quadratic Engel curves and consumer demand. *Rev. Econ. Stat.* 79, 527–539.
- Béné, C., Prager, S.D., Achicanoy, H.A.E., Toro, P.A., Lamotte, L., Cedrez, C.B., Mapes, B.R., 2019. Understanding food systems drivers: A critical review of the literature. *Glob. Food Sec.* 23, 149–159. doi:10.1016/j.gfs.2019.04.009.
- Boysen, O., 2016. Food Demand Characteristics in Uganda: Estimation and Policy Relevance. *South African J. Econ.* 84, 260–293. doi:10.1111/saje.12093.
- Call, M., Gray, C., 2020. Climate anomalies, land degradation, and rural out-migration in Uganda. *Popul. Environ.* 41, 507–528. doi:10.1007/s11111-020-00349-3.
- Call, M., Gray, C., Jagger, P., 2019. Smallholder responses to climate anomalies in rural Uganda. *World Dev.* 115, 132–144. doi:10.1016/j.worlddev.2018.11.009.
- Cockx, L., Colen, L., De Weerd, J., 2018. From corn to popcorn? Urbanization and dietary change: Evidence from rural-urban migrants in Tanzania. *World Dev.* 110, 140–159. doi:10.1016/j.worlddev.2018.04.018.
- Deaton, A., 2018. The analysis of household surveys: A microeconomic approach to development policy. World Bank, Washington D.C doi:10.1596/978-1-4648-1331-3, Reissue ed. ed..
- Deaton, A., 1990. Price elasticities from survey data. *J. Econom.* 44, 281–309. doi:10.1016/0304-4076(90)90060-7.
- Deaton, A., 1988. Quality, Quantity, and Spatial Variation of Price. *Am. Econ. Rev.* 78, 418–430 <http://www.jstor.org/stable/1809142>.
- Deaton, A., Muellbauer, J., 1980. An Almost Ideal Demand System. *Am. Econ. Rev.* 70, 312–326 <https://www.jstor.org/stable/1805222>.
- Drewnowski, A., Popkin, B.M., 2009. The Nutrition Transition: New Trends in the Global Diet. *Nutr. Rev.* 55, 31–43. doi:10.1111/j.1753-4887.1997.tb01593.x.
- FAO, 2018. Africa Sustainable Livestock 2050: Transforming livestock sector Uganda, What do long-term projection say?. Food and Agriculture Organization of the United Nations (FAO), Kampala.
- FAO, 2009. How to Feed the World 2050: Global agriculture towards 2050. In: High-Level Expert Forum: How to Feed World in 2050. Food and Agriculture Organization of the United Nations (FAO), Rome, pp. 1–4 Rome 12-13 October, 2009.
- FAO, 2006. Food Security Policy Brief 2. Food and Agriculture Organization of the United Nations (FAO), Rome.
- FAO, IFAD, UNICEF, WFP, WHO, 2019. The State of Food Security and Nutrition in the World 2019. Safeguarding against economic slowdowns and downturns. Food and Agriculture Organization of the United Nations (FAO), Rome doi:10.1109/JSTARS.2014.2300145.
- FAO, IFAD, UNICEF, WFP, WHO, 2018. The State of Food Security and Nutrition in the World 2018. Building climate resilience for food security and nutrition. Food and Agriculture Organization of the United Nations (FAO), Rome.
- FAO, IFAD, UNICEF, WFP, WHO, 2017. The State of Food Security and Nutrition in the World 2017 : Building Resilience for Peace and Food Security. Food and Agriculture Organization of the United Nations (FAO), Rome.
- FAOSTAT, 2021a. Food Balance Sheets (database) [WWW Document]. Food Agric. Organ. United Nations URL <http://www.fao.org/faostat/en/#data/FBS>.
- FAOSTAT, 2021b. Data: Production [WWW Document]. Online database Crop Prod. Harvest. area URL <http://www.fao.org/faostat/en/#data/QC>.
- FAOSTAT, 2021c. New Food Balances [WWW Document]. Food Agric. Organ. United Nations, Online database food Balanc. URL <http://www.fao.org/faostat/en/#data/FBS> (accessed 3.3.21).
- FEWSN, 2021. COVID-19 control measures expected to lead to atypical food insecurity in urban areas, FUGanda - Food Security Outlook Update Thu, 2020-04-30. Famine Early Warning Systems Network (FEWSN).
- FSIN, 2020. 2020 Global Report on Food Crises: Joint Analysis for Better Decisions. Rome, Food Security Information Network (FSIN). World Food Program (WFP).
- Fukase, E., Martin, W., 2017. Economic Growth, Convergence, and World Food Demand and Supply (No. 8257), Policy Research Working Paper. World Bank, Washington D.C..
- Gerbens-Leenes, P.W., Nonhebel, S., Krol, M.S., 2010. Food consumption patterns and economic growth. Increasing affluence and the use of natural resources. *Appetite* 55, 597–608. doi:10.1016/j.appet.2010.09.013.
- Gibson, J., Kim, B., 2013. Quality, Quantity, and Nutritional Impacts of Rice Price Changes in Vietnam. *World Dev.* 43, 329–340. doi:10.1016/j.worlddev.2012.11.008.
- Godfray, H.C.J., Beddington, J.R., Crute, I.R., Haddad, L., Lawrence, D., Muir, J.F., Pretty, J., Robinson, S., Thomas, S.M., Toulmin, C., 2010. Food Security: The Challenge of Feeding 9 Billion People. *Science* (80-). 327, 812–818. doi:10.1126/science.1185383.
- Government of Uganda, 2015. The Uganda Food and Nutrition Policy, 2003. Ministry of Agriculture, Animal Industry and Fisheries (MAAIF) and Ministry of Health (MOH), Kampala.
- Government of Uganda, 2011. Uganda Nutrition Action Plan 2011–2016. Scaling up multi-sectoral efforts to establish a strong nutrition foundation for Uganda's development. Office of the President of the Republic of Uganda, Kampala.
- Grebmer, K., von, Bernstein, J., Alders, O., Mukerji, R., Patterson, F., Wiemers, M., Chéilleachair, R.N., Foley, C., Gitter, S., Ekstrom, K., Fritschel, H., 2020. 2020 Global hunger index: One decade to zero hunger, linking health and sustainable food systems. Welthungerhilfe and Concern Worldwide, Bonn and Dublin.
- Hirvonen, K., Bai, Y., Headey, D., Masters, W.A., 2020. Affordability of the EAT–Lancet reference diet: a global analysis. *Lancet Glob. Heal.* 8, e59–e66. doi:10.1016/S2214-109X(19)30447-4.
- Huang, J., Bouis, H., 2001. Structural changes in the demand for food in Asia: empirical evidence from Taiwan. *Agric. Econ.* 26, 57–69. doi:10.1016/S0169-5150(00)00100-6.
- Huang, J., David, C.C., 1993. Demand for cereal grains in Asia: The effect of urbanization. *Agric. Econ.* 8, 107–124. doi:10.1016/0169-5150(92)90025-T.
- Jakicic, J.M., Davis, K.K., 2011. Obesity and Physical Activity. *Psychiatr. Clin. North Am.* 34, 829–840. doi:10.1016/j.psc.2011.08.009.
- Kamara, J.K., Renzaho, A., 2014. The politics of food and the fight against hunger: Reflections and lessons from Uganda. *African J. Food, Agric. Nutr. Dev.* 14, 9016–9038.
- Kearney, J., 2010. Food consumption trends and drivers. *Philos. Trans. R. Soc. B Biol. Sci.* 365, 2793–2807. doi:10.1098/rstb.2010.0149.
- Khanal, A.R., Mishra, A.K., Keithly, W., 2016. Heterogeneity in Food Demand among Rural Indian Households: The Role of Demographics. *Can. J. Agric. Econ. Can. d'agroeconomie* 64, 517–544. doi:10.1111/cjag.12094.
- Kron, J., 2011. Protests in Uganda Over Rising Prices Grow Violent. *New York Times* April 21, 2011.
- Mason, N.M., Jayne, T.S., Shiferaw, B., 2015. Africa's Rising Demand for Wheat : Trends, Drivers, and Policy Implications. *Dev. Policy Rev.* 33, 581–613.
- McKelvey, C., 2011. Price, unit value, and quality demanded. *J. Dev. Econ.* 95, 157–169. doi:10.1016/j.jdeveco.2010.05.004.
- Mittal, S., 2007. What Affects Changes in Cereal Consumption? *Econ. Polit. Wkly.* 42, 444–447 <http://www.jstor.org/stable/4419216>.
- Mottaleb, K.A., Rahut, D.B., Kruseman, G., Erenstein, O., 2018a. Evolving food consumption patterns of rural and urban households in developing countries. *Br. Food J.* 120, 392–408. doi:10.1108/BFJ-12-2016-0620.
- Mottaleb, K.A., Rahut, D.B., Kruseman, G., Erenstein, O., 2018b. Changing Food Consumption of Households in Developing Countries: A Bangladesh Case. *J. Int. Food Agribus. Mark.* 30, 156–174. doi:10.1080/08974438.2017.1402727.
- Mubiru, D., Namakula, J., Lwasa, J., Otim, G., Kashagama, J., Nakafeero, M., Nanyenya, W., Coyne, M., 2017. Conservation Farming and Changing Climate: More Beneficial than Conventional Methods for Degraded Ugandan Soils. *Sustainability* 9, 1084. doi:10.3390/su9071084.
- Nkonya, E., Pender, J., Kaizzi, K.C., Kato, E., Mugarura, S., Ssali, H., Muwonge, J., 2008. Linkages between land management, land degradation, and poverty in Sub-Saharan Africa: The Case of Uganda (No. 159). Washington D.C.
- Pingali, P., 2006. Westernization of Asian diets and the transformation of food systems: Implications for research and policy. *Food Policy* 32, 281–298. doi:10.1016/j.foodpol.2006.08.001.
- Pingali, P., Aiyar, A., Abraham, M., Rahman, A., 2019. Transforming Food Systems for a Rising India. In: Palgrave, S (Ed.), *Palgrave Studies in Agricultural Economics and Food Policy*. Springer International Publishing, Ithaca, New York doi:10.1007/978-3-030-14409-8.
- Pinstrup-Andersen, P., Pandya-Lorch, R., Rosegrant, M.W., 1999. World food prospects: Critical issues for the early twenty-first century, 2020 Vision. International Food Policy Research Institute (IFPRI), Washington D.C.
- Poole, N., Donovan, J., Erenstein, O., 2021. Viewpoint: Agri-nutrition research: Revisiting the contribution of maize and wheat to human nutrition and health. *Food Policy* 100, 101976. doi:10.1016/j.foodpol.2020.101976.
- Popkin, B.M., 2008. The Nutrition Transition and Its Relationship to Demographic Change, in: *Nutrition and Health in Developing Countries*. Humana Press, Totowa, NJ, pp. 601–616. doi:10.1007/978-1-59745-464-3_20.
- Popkin, B.M., 2003. The Nutrition Transition in the Developing World. *Dev. Policy Rev.* 21, 581–597. doi:10.1111/j.1467-8659.2003.00225.x.
- Popkin, B.M., 1999. Urbanization, lifestyle changes and the nutrition transition. *World Dev.* 27. doi:10.1016/S0305-750X(99)00094-7, 1905–1916.
- Ray, D.K., Mueller, N.D., West, P.C., Foley, J.A., 2013. Yield Trends Are Insufficient to Double Global Crop Production by 2050. *PLoS One* 8, e66428. doi:10.1371/journal.pone.0066428.
- Reardon, T., Chen, K., Minten, B., Adriano, L., 2012. The Quiet Revolution in Staple Food Value Chains: Enter the Dragon, the Elephant and the Tiger. Asian Development Bank and International Food Policy Research Institute, Manila <https://doi.org/10.1016/j.agsy.2018.01.022> (PDF).
- Reardon, T., Echeverria, R., Berdegue, J., Minten, B., Liverpool-Tasie, S., Tschirley, D., Zilberman, D., 2019. Rapid transformation of food systems in developing regions: Highlighting the role of agricultural research & innovations. *Agric. Syst.* 172, 47–59. doi:10.1016/j.agsy.2018.01.022.
- Reardon, T., Tschirley, D., Dolislager, M., Snyder, J., Hu, C., White, S., 2014. Urbanization, Diet Change, and Transformation of Food Supply Chains in Asia. East Lansing, Michigan.
- Regmi, A., 2001. Changing structure of global food Consumption and Trade. U.S. Department of Agriculture, Agriculture and Trade Report. WRS-01-1. Abstract, Washington D.C.
- Regmi, A., Dyck, J., 2001. Effects of urbanization on global food demand. In: Regmi, A. (Ed.), *Changing Structure of Global Food Consumption and Trade*. Economic Research Service. United States Department of Agriculture (USDA), Washington D.C., pp. 23–30.
- Semba, R.D., Bloem, M.W., Piot, P., 2008. Nutrition and Health in Developing Countries, 2nd ed, Nutrition and Health Series. Humana Press, Springer, Totowa, NJ doi:10.1016/j.jneb.2009.07.007.
- Sneyd, L.Q., Legwegoh, A., Fraser, E.D.G., 2013. Food riots: Media perspectives on the causes of food protest in Africa. *Food Secur.* 5, 485–497. doi:10.1007/s12571-013-0272-x.

- Sumner, A., Hoy, C., Ortiz-juarez, E., 2020. Estimates of the impact of COVID-19 on global poverty (No. WIDER Working Paper 2020 /43). Helsinki.
- Tilman, D., Balzer, C., Hill, J., Befort, B.L., 2011. Global food demand and the sustainable intensification of agriculture. *Proc. Natl. Acad. Sci.* 108, 20260–20264. doi:10.1073/pnas.1116437108.
- United Nations, 2019. *World population prospects 2019, World Population Prospects 2019, Total population (both sexes combined) by region, subregion and country, annually for 1950-2100 (thousands) Estimates, 1950-2020*. Department of Economic and Social Affairs, Population Division, United Nations (UN), New York.
- USDA, 2021. Projected Gross Domestic Product (GDP) Per Capita for Baseline Countries/Regions (in 2010 dollars) [WWW Document]. *Int. Macroecon. Data Set*. URL <https://www.ers.usda.gov/data-products/international-macroeconomic-data-set.aspx> (accessed 8.3.20).
- USDA, 2020. Projected Real Gross Domestic Product (GDP) and Growth Rates of GDP for Baseline Countries/Regions (in billions of 2010 dollars) 2011-2031 [WWW Document]. *Int. Macroecon. Data Set, United States Dep. Agric.* URL www.ers.usda.gov/data-products/international-macroeconomic-data-set.aspx (accessed 6.3.20).
- USDA, 2015. Projected Real Gross Domestic Product (GDP) and Growth Rates of GDP for Baseline Countries/Regions (in billions of 2010 dollars) 2010-2030 [WWW Document]. *United States Dep. Agric.* URL <https://www.ers.usda.gov/webdocs/DataFiles/51832/ProjectedRealGDPValues.xls> (accessed 8.18.19).
- Vella, F., 1998. Estimating Models with Sample Selection Bias: A Survey. *J. Hum. Resour.* 33, 127. doi:10.2307/146317.
- WFP, 2020. COVID-19 will double number of people facing food crises unless swift action is taken [WWW Document]. *World Food Program*. URL <https://www.wfp.org/news/covid-19-will-double-number-people-facing-food-crises-unless-swift-action-taken> (accessed 5.11.20).
- WHO, 2018. Global hunger continues to rise, UN report says [WWW Document]. *World Heal. Organ.* URL <https://www.who.int/news-room/detail/11-09-2018-global-hunger-continues-to-rise-new-un-report-says> (accessed 10.21.19).
- Wilde, P., 1989. *Changing Food Consumption Patterns in Sub-Saharan Africa (No. 64705)*, USAID FVA/PPM. *United States Agency for International Development (USAID)*, Washington D.C.
- Willett, W., Rockström, J., Loken, B., Springmann, M., Lang, T., Vermeulen, S., Garnett, T., Tilman, D., DeClerck, F., Wood, A., Jonell, M., Clark, M., Gordon, L.J., Fanzo, J., Hawkes, C., Zurayk, R., Rivera, J.A., De Vries, W., Majele Sibanda, L., Afshin, A., Chaudhary, A., Herrero, M., Agustina, R., Branca, F., Lartey, A., Fan, S., Crona, B., Fox, E., Bignet, V., Troell, M., Lindahl, T., Singh, S., Cornell, S.E., Srinath Reddy, K., Narain, S., Nishtar, S., Murray, C.J.L., 2019. Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems. *Lancet* 393, 447–492. doi:10.1016/S0140-6736(18)31788-4.
- World Bank, 2021. *Data Bank: Population estimates and projections [WWW Document]*. *Popul. Estim. Proj. Resour. Type Query Tool*. URL <https://databank.worldbank.org/reports.aspx?source=Health+Nutrition+and+Population+Statistics:Population+estimates+and+projections> (accessed 6.26.10).
- World Bank, 2020a. *World Development Indicators [WWW Document]*. *Data Bank, World Dev. Indic.* URL <https://databank.worldbank.org/data/reports.aspx?source=world-development-indicators#> (accessed 2.7.19).
- World Bank, 2020b. *The World Bank in Uganda [WWW Document]*. *Overv. #Africa can.* URL <https://www.worldbank.org/en/country/uganda/overview> (accessed 11.14.20).
- World Bank, 2019a. *Decline of global extreme poverty continues but has slowed [WWW Document]*. *Press release No. 2019/030/Dec-GPV.* URL <https://www.worldbank.org/en/news/press-release/2018/09/19/decline-of-global-extreme-poverty-continues-but-has-slowed-world-bank> (accessed 9.24.19).
- World Bank, 2019b. *Uganda National panel survey 2015-16 [WWW Document]*. *Uganda Bur. Stat. World Bank, Microdata Libr. Living Stand. Meas. Study*. URL <https://microdata.worldbank.org/index.php/catalog/3460> (accessed 11.11.20).
- World Bank, 2016a. *The Uganda Poverty Assessment Report 2016 Farms, cities and good fortune: assessing poverty reduction in Uganda from 2006 to 2013 (No. ACS18391)*. Washington D.C. <https://doi.org/10.1002/adma.201102804>
- World Bank, 2016b. *Uganda National panel survey 2013-14 [WWW Document]*. *Uganda Bur. Stat. World Bank, Microdata Libr. Living Stand. Meas. Study*. URL <https://microdata.worldbank.org/index.php/catalog/2663> (accessed 11.11.20).
- World Bank, 2014. *Uganda National Panel Survey 2010-2011 [WWW Document]*. *Uganda Bur. Stat. World Bank, Microdata Libr. Living Stand. Meas. Study*. URL <https://microdata.worldbank.org/index.php/catalog/2166> (accessed 11.11.20).