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ORIGINAL PAPER

Food availability and livelihood strategies among rural households across Uganda

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Abstract Despite continuing economic growth, Uganda faces persistent challenges to achieve food security. The effectiveness of policy and development strategies to help rural households achieve food security must improve. We present a novel approach to relate spatial patterns of food security to livelihood strategies, including the contribution of on- and off-farm activities to household food availability. Data from 1927 households from the World Bank Living Standards Measurement Study were used to estimate the calorific contribution of livelihood activities to food availability. Consumption of crops produced on-farm contributed most to food availability for households with limited food availability, yet the majority of these households were not food self-sufficient. Off-farm and market-oriented on-farm activities were more important for households with greater food availability. Overall, off-farm income was important in the north, while market-oriented on-farm activities were important in western and central Uganda. Food availability patterns largely matched patterns of agroecological conditions and market access, with households doing worst in Uganda's drier and remote northeast. Less food-secure households depended more on short-cycle food crops as compared with better-off households, who focused more on plantation (cash) crops, although this varied among regions. Targeting interventions to improve food security should consider such differences in enterprise choice and include options to improve household market access and off-farm income opportunities.

Keywords Smallholder farms · Household level · Food security · East Africa · District · Crop choice

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1 Introduction

The majority of rural households in East Africa derive much of their livelihood from agriculture. They face challenges related to declining soil fertility and stagnating crop yields, declining farm size as a result of population growth, poor market access, insecure land rights and climate change (Kristjanson et al. 2012; Jayne et al. 2006; Rufino et al. 2013). Household food security has decreased in East Africa (Kristjanson et al. 2012) with a steady decline in calorie availability per capita over the past 50 years (Leliveld et al. 2013). By contrast the poverty rate is reducing, particularly in Uganda, as a consequence of national economic growth (UBOS 2010a).[1] Yet, researchers disagree whether economic growth has contributed to poverty decline

[1] The Uganda Bureau of Statistics (UBOS) measures poverty as 'the cost of meeting caloric needs, given the food basket of the poorest half of the population and some allowance for non-food needs' (UBOS 2010a), which allows us to compare trends in poverty and food security.

across the whole population (Daniels and Minot 2015). For example, Daniels and Minot (2015) observed that the poverty decline from 1995 to 2010 was much greater in the eastern and western parts of the country, while UBOS (2013) identified northern Uganda as the most food insecure region. What remains clear is that both poverty and food insecurity are challenges in East Africa now and for the future. East Africa's rural households play an important role in agricultural production and make a major contribution to national food security and the economy. Poor agricultural performance has been related to a lack of supporting policies (e.g. Cooper and Coe 2011) to assist farmers to access knowledge, credit and functioning input-output markets. To identify suitable and effective policy interventions, the determinants of household food security need to be better understood.

Several studies have analysed the relationships between household food security and underlying (household level) drivers: larger cultivated land per capita, better education of the household head, a wider variety of crops, and access to market information are all positively related to food security (Fisher and Lewin 2013; Mango et al. 2014; Silvia et al. 2015). Yet our understanding of what affects household food security in East Africa remains rudimentary (Silvia et al. 2015) and strategies to achieve household food security vary widely across regions and among households. One challenge lies in the complexity of the food security concept itself, which consists of four pillars: Availability, access, utilisation, and stability (FAO 2009). No single indicator can capture all four dimensions of food security (Carletto et al. 2013). Frelat et al. (2016) developed a simple food availability indicator using information on household on- and off-farm activities of smallholders. This food availability indicator closely correlates to well-established indicators such as the Household Dietary Diversity Score (HDDS) and the Household Food Insecurity Access Scale (HFIAS) (Hammond et al. 2016). Frelat et al. (2016) observed that household food availability improved with increasing dependency on off-farm activities, suggesting diverse strategies among rural households. Frelat et al. (2016) analysed cross-sectional household data from more than 13,000 households across 97 locations in 17 countries across sub-Saharan Africa (SSA), yet their spatial coverage across the continent in general and Uganda in particular was poor; e.g. no data from northern and eastern Uganda were included. National policy makers need disaggregated regional analyses at more local levels, such as the district to target interventions on food security.

We aim to understand how spatial patterns in food availability and the related livelihood strategies vary within a single country. We chose Uganda because of its variety in agroecological conditions and farming systems ranging from perennial banana-coffee systems in the humid highlands and around Lake Victoria to dryland pastoral savanna systems in the northeast (Pender et al. 2004; Wortmann and Eledu 1999). Using household survey data, our analysis quantifies the contribution of diverse livelihood strategies to household food availability and reveals how these strategies differ in their importance across the country.

Country-wide assessments of food security for Uganda and other countries in SSA have been conducted before; for example the Comprehensive Food Security and Vulnerability Analyses of the World Food Programme (UBOS 2013) and the Famine Early Warning Systems Network (FEWS NET) (www.fews.net). FEWS NET uses livelihood zones as an aggregation level to project food insecurity across a country. Its main purpose is to provide early warning of acute risks of food insecurity and famine. FEWS NET stratifies countries into zones of similar livelihood activities and uses household information to identify wealth groups and related key sources of food and income per zone (Grillo and Holt 2009). Our study adds to the existing approaches by quantitatively linking food availability and contributing livelihood activities, using household level data thereby identifying the diversity and patterns of income and food sources using a 'bottom-up' approach. We investigated differences among regions and districts, aiming to make the targeting of interventions more location specific.

Our key objectives were: (i) to quantify and understand how on- and off-farm activities of Uganda's rural households contribute to their food availability, contrasting more food secure with food insecure households, and (ii) to assess how food availability and its relationship with different household activities vary across Uganda.

The following questions and related hypotheses were addressed:

1. What proportion of Ugandan households has insufficient food available and how does food availability differ across the country?

Hypothesis 1: The Northern region is characterised by less food availability compared to the Central, Western and Eastern region.

2. What livelihood strategies and household activities contribute to household food availability and how much, and how do these differ with food availability across the country?

Hypothesis 2: For the more food secure households, market-oriented on-farm activities and off-farm income, and not on-farm food production, are the major contributors to household food availability and this is similar across the country.

3. How do cropping patterns relate to household food availability and how do they differ across the country?

Hypothesis 3: Staple crops (particularly banana, cassava, maize and sorghum) are more important for food insecure households.

We used cross-sectional household survey data from the World Bank Living Standard Measurement Study – Integrated Surveys on Agriculture (LSMS-ISA) for the period 2010/11 (Kilic et al. 2015). The LSMS-ISA data of Uganda have been used in a wide range of livelihood studies both on food security, for example on effects of physical activities on food consumption and on the use of complementary indices for food security (Mathiassen and Hollema 2014; Hjelm et al. 2016) and on agriculture (e.g. Sheahan and Barrett 2017; Gilbert et al. 2017; Palacios-Lopez et al. 2017). The comprehensive cross-country coverage and the detailed agricultural survey of the LSMS provided an adequate dataset for the purpose of our study.

2 Material and methods

2.1 Background of Uganda

Uganda is one of the fastest growing economies in Africa (Kuteesa et al. 2010) with an annual GDP growth rate of 5% (World Bank 2016b). Agricultural value added ranges from 23 to 25% of the GDP and major agricultural commodities for export are coffee, cotton, sugar and tea (FAO 2015). More than 80% of Ugandans live in rural areas (FAO 2016b) and are involved in agriculture. Uganda's poverty rates reduced from 56% in the 1990s to 24% in 2010, but the standard of living did not improve uniformly across the country (Daniels and Minot 2015; Kakande 2010). Population densities are highest in the western, central and eastern parts of Uganda and most sparse in the northeast (WorldPop 2016). Similarly, the most dense road networks are found in the central and southwest of the country where the major towns and cities are located (Nelson 2008). The poorer infrastructure in the north of Uganda is partly related to the conflict that started in 1987 and lasted for more than 20 years. The conflict displaced millions of people and caused agricultural production and market structures to collapse (Tusiime et al. 2013). Today, roughly five years after the end of the conflict, the region is still recovering.

Temperatures in Uganda are in the range of 15 to 30 °C depending on elevation rather than on latitude with maximum temperatures in the range of 25 to 31 °C for most areas. Annual rainfall varies from 750 mm year^{-1} in the northeast to >1750 mm year^{-1} in the areas of high rainfall. The majority of the country receives annual rainfall between 1000 and 1750 mm year^{-1} (70% of the land area). Rainfall distribution is bimodal in the southern part of the country, while, towards the north (particularly the northeast), patterns gradually change to unimodal with an extended dry season (Mwebaze 1999). The diverse climatic patterns together with topographic and soil characteristics result in a large diversity of farming systems across Uganda.

2.2 Data

We used cross-sectional household survey data sampled across Uganda in the period of 2010 to 2011 covering 2716 households (Fig. 1). The surveys were conducted as part of the World Bank Living Standard Measurement Study – Integrated Surveys on Agriculture (LSMS-ISA) (Kilic et al. 2015). Households were visited twice over a 12-month period to capture the two cropping seasons. The households were sampled from a former survey conducted in 2005 in which a stratification on urban/rural and regional levels was used (UBOS 2007). Details about the sampling method can be found in World Bank (2016c).

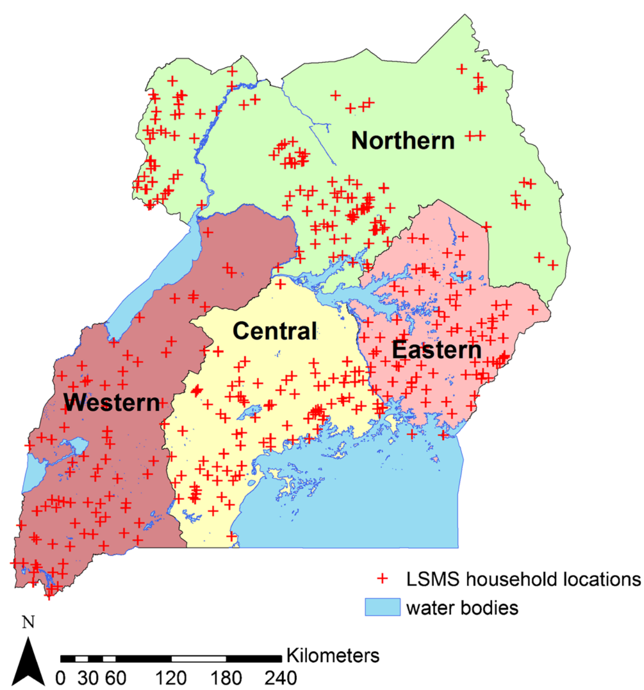


Fig. 1 Locations of the households that were included in the analysis (n = 1927) and administrative regions in Uganda (Sources: Thompson 2016, clipped from WRI (2009)). Each + represents a single household

We used survey data on household characteristics, farm size, crop and livestock production and off-farm income.

2.3 Household level food availability

For each household a simple food availability (FA) indicator was calculated following Frelat et al. (2016). The FA indicator (*FA*) estimates the average amount of potential food energy that is available to each male adult household member equivalent per day [kcal cap^{-1} day^{-1}]:

$$FA = \frac{(E_{consumed} + E_{income})}{365 \times n_{hh-mae}} \quad (1)$$

where $E_{consumed}$ is the annual direct consumption of potential food energy from on-farm products [kcal year^{-1}], E_{income} is the annual indirect consumption of potential food energy from on- and off-farm income [kcal year^{-1}], and $n_{hh\text{-}mae}$ is the household size in male adult equivalents. For the estimation we used annual data on agricultural and off-farm income generating activities and on the household composition. The contribution to FA was calculated for the following activities: Consumption of on-farm food crops and livestock products, sales of on-farm food crops and cash crops, sales of on-farm livestock products and off-farm income. The crop and livestock related activities were further differentiated into key crops and livestock groups (contributing to the crop part and livestock part of the food availability, respectively). A threshold of 2500 kcal cap^{-1} day^{-1}, representing the daily energy need of a male adult (FAO 2001), was chosen to distinguish households with sufficient and insufficient food available.

Kilo-caloric energy values for crops and livestock products were retrieved from the standard product list of the US Department of Agriculture (source: ndb.nal.usda.gov/ndb/search/list, accessed 02/07/16) and from the Food and Agricultural Organization of the United Nations (source: http://www.fao.org/docrep/x5557e/x5557e00.htm#Contents, accessed 02/07/16). We converted prices from local currency to US dollar (USD) using the currency-conversion rate of the first of January 2011.

We assumed that all money earned in a household was used to purchase a staple crop (in this case maize) for food consumption. With this assumption we overestimate the actual supply of energy to the household because no account is made of other household expenses (e.g. clothing, school fees, transport). The indicator thus shows the potential to obtain sufficient energy for the household, and not whether this actually occurs (Frelat et al. 2016). We also assumed that the amount of crops consumed by the household was the difference between the reported quantities harvested and sold. Hence, post-harvest losses, gifts, in-kind trading or saving of crop seeds were not considered. Cash crops were defined as crops of which more than 90% of the annual produce was sold (Frelat et al. 2016). Prices for crops and livestock products reported in the dataset varied substantially among the households. To reduce the possible effect of erroneous price reporting, we used the median of the reported prices per region per year to calculate income from sold crops and livestock products. We excluded all households from the analysis that reported both zero agricultural production and zero off-farm income in the year of sampling. We further excluded households that reported no area for cultivation. The final household sample for the analysis resulted in 1927 households out of a total of 2716 households.

2.4 Food availability classes and additional indicators

We aggregated the individual households into three food availability classes to understand how on− and off-farm activities differ according to the degree of food availability. Hammond et al. (2016) correlated the food availability indicator with other food security indicators, including the Household Dietary Diversity Score (HDDS) and the Household Food Insecurity Access Scale (HFIAS). These food security indicators improved up to a food availability indicator value of 5000 kcal cap^{-1} day^{-1}, but not beyond (Hammond et al. 2016). Hence, we split our dataset based on the following thresholds: Class 1 included households with food availability below 2500 kcal cap^{-1} day^{-1} (deficient food availability); Class 2 comprised households with food availability between 2500 and 5000 kcal cap^{-1} day^{-1} (adequate food availability); and Class 3 included households with food availability above 5000 kcal cap^{-1} day^{-1} (surplus food availability). Henceforth, we call Class 1 'food deficient households', Class 2 'food adequate households' and Class 3 'food surplus households'.

Besides the food availability indicator, we calculated five production and income-related indicators to provide information about households' performance and livelihood orientation. We calculated a food self-sufficiency indicator (*FSS*) to assess the importance of on-farm production for household food consumption:

$$FSS = \frac{E_{consumed}}{E_{needed}} \quad (2)$$

E_{needed} is the annual energy required for the household [kcal year^{-1}], calculated from 365 [days year^{-1}] × 2500 [kcal day^{-1}] × household size in male adult equivalents ($n_{hh\text{-}mae}$).

Gross daily income per capita (I_{gross}) [USD cap^{-1} day^{-1}] quantified the total income that a household generated per household member:

$$I_{gross} = \frac{I_{tot}}{365 \times n_{hh}} \quad (3)$$

I_{tot} is the total annual household income generated from sold on-farm products and off-farm activities [USD year^{-1}], n_{hh} is the household size.

Gross on-farm income per capita ($I_{gross,\ on\text{-}farm}$) [USD cap^{-1} day^{-1}] identified the income that a household generated per household member from the sold on-farm products:

$$I_{gross,on-farm} = \frac{I_{crops} + I_{livestock}}{365 \times n_{hh}} \quad (4)$$

I_{crops} [USD year^{-1}] is the annual income from sold cash and food crops, and $I_{livestock}$ [USD year^{-1}] is the annual income from sold livestock products.

While income indicators related to the real income generated from sold products and off-farm activities, cash value indicators related to the potential income that could be generated from produced goods. The cash value of production ($CV_{production}$) [USD cap^{-1} day^{-1}] identified the potential income that could have been generated if all on-farm products had been sold:

$$CV_{production} = \frac{CV_{crops} + CV_{livestock}}{356 \times n_{hh}} \quad (5)$$

CV_{crops} is the cash value of crops [USD year^{-1}], $CV_{livestock}$ is the cash value of livestock [USD year^{-1}].

Market orientation (MO) [%] identified the share of agricultural products that were sold relative to the cash value of crops and livestock:

$$MO = \frac{I_{crops} + I_{livestock}}{CV_{crops} + CV_{livestock}} \times 100 \quad (6)$$

2.5 Spatial aggregation levels

Results of the analyses are presented at regional level (four regions, Fig. 1), for the three food availability groups, as well as at district level for those districts for which the dataset included at least 8 households (87 districts). At regional level, we used simple mean values (i.e. the means were not weighted) to identify relative differences in contributing activities and crops per class. At district level, we used the simple (unweighted) median values because of the small sample sizes per district and the large skewness in the data.

LSMS data for Uganda are representative at the national and regional levels (World Bank 2016a). However, we use a more fine-grained aggregation of data to allow analysis at the district level, so as to visualise spatial trends in household characteristics as a function of strong socio-economic and environmental gradients within regions, agricultural production zones (MAAIF 2010) and livelihood zones (FEWS NET 2013). In addition, if insights from this analysis are to provide support to sub-national policy processes, then districts are the highest aggregation level at which policy decisions are taken, as neither policy engagement nor policy decisions take place at a zonal/ regional level (an exception are the zonal agricultural research and development institutes that manage and apply agricultural research for specific agro-ecological zones, The National Agricultural Research Act, 2005). Consequently, several ongoing agricultural research programmes for policy advice engage with policy stakeholders at the district and not zonal/ regional level (e.g. CCAFS-PACCA – www.ccafs.cgiar.org/policy-action-climate-change-adaptation-east-africa, PASIC – www.pasic.ug).

However, our approach of aggregating the data to district levels may introduce statistical bias (i.e. Modifiable Areal Unit Problem, MAUP) (Openshaw and Taylor 1979). In addition, sample numbers of households per district were small (n = 8 to 64 households for the districts included in the aggregation) as compared with the district populations (ranging from 50,000 to 2 million inhabitants) to generate accurate and representative data at the district level (UBOS 2016). To improve our understanding of, and confidence in (i.e. subject to spatial bias), spatial patterns across districts, we compared results of district level to livelihood zone level aggregation (FEWS NET 2013). If patterns observed were similar at both aggregation levels, then we considered results to be robust. All analyses were performed in R, version 3.2.3 (R Development Core R Development Core Team 2008) and maps were created in ArcMap, version 10.2.1 (ESRI 2011).

2.6 Scope of the study

The food availability indicator addresses part of what FAO (2009) defined as 'food security'. Nutritional food security, for example, is not included. Yet, Hammond et al. (2016) observed that the food availability indicator correlates with indicators of dietary diversity. Because the majority of Uganda's households depend on own farm products (UBOS 2013), food availability plays an important role for their food security. For that reason, the food availability indicator was considered suitable to answer our research questions. Still, areas that we identify as having large food availability can be areas having small dietary diversity. The food availability and food self-sufficiency indicators were sensitive to the threshold of minimum energy requirements, which we set at 2500 kcal cap^{-1} day^{-1}. In our food availability analysis we compared only the proportional contribution of on- and off-farm activities, potentially obscuring differences in absolute energy values among the regions. However, as an analysis of the absolute values of the on- and off-farm activities did not provide additional insight, they were not included in the further analysis. When interpreting the results of the aggregated household data, we need to consider the MAUP and the loss of information on variability among households within an aggregation unit. In the interpretation of district level data, focus should be given to trends across districts rather than outcomes for individual districts. Household locations (in latitude/ longitude) were randomly off-set by the publisher (UBOS 2010b). When interpreting the aggregated household data to small districts or livelihood zones, the risk of allocation of households to wrong livelihood zones must be considered. However, large-scale patterns are not affected.

3 Results

3.1 Household food availability patterns across Uganda

Food availability varied strongly among the rural households with values ranging from well below 2500 kcal cap^{-1} day^{-1} to values beyond 40,000 kcal cap^{-1} day^{-1} (Fig. 2a). Households with insufficient food availability constituted 23% of the overall dataset. Also, at the regional level, food availability varied strongly: Mean food availability ranged from 10,000 kcal cap^{-1} day^{-1} for eastern Uganda to 49,000 kcal cap^{-1} day^{-1} for central Uganda (Table 1), but the variability of households within the regions was large (standard deviations from 20,000 kcal cap^{-1} day^{-1} in eastern Uganda to 491,000 kcal cap^{-1} day^{-1} in central Uganda). Because of the large variability we used the percentage of households per class to determine regional differences in food availability. Food surplus households (Class 3, > 5000 kcal cap^{-1} day^{-1} available) constituted the majority of households (66 and 72%) in the Central and

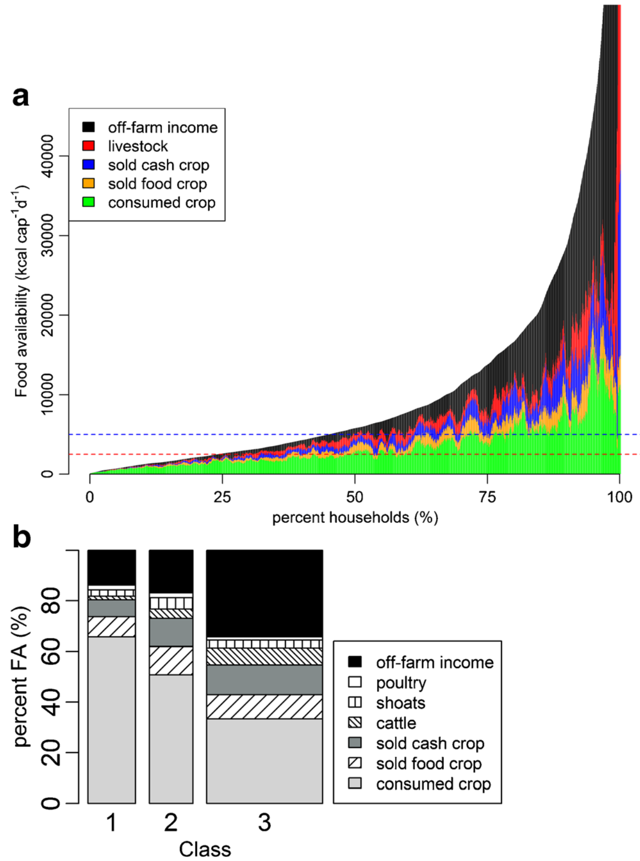


Fig. 2 **a** Household level food availability for 1927 households across Uganda. Households are ordered by increasing food availability (FA) along the x-axis where each bar represents one household. The red dashed line represents a food availability value of 2500 kcal cap^{-1} day^{-1}, the daily energy need of a male adult (Holden et al. 2001) and the blue dashed line represents 5000 kcal cap^{-1} day^{-1}, the lower boundary of 'food surplus households'. A moving average was applied with a window length of 10 households. The large values of consumed crop on the right side are a result of a few households that reported high amounts of consumed crops, which are expected to result from a bias in the survey rather than to reflect real consumption figures. **b** Contribution of on- and off-farm activities to FA per class (Class 1, deficient FA <2500 kcal cap^{-1} day^{-1}; Class 2, adequate FA between 2500 and 5000 kcal cap^{-1} day^{-1}; Class 3, surplus FA >5000 kcal cap^{-1} day^{-1}) for n = 1927 households. The thickness of bars represents the number of households per class. Livestock is divided into poultry, shoats (sheep and goats), and cattle

Western regions, respectively, while food deficient households (Class 1, < 2500 kcal cap^{-1} day^{-1} available) constituted the minority of households (15 and 10%) respectively. In contrast, in the Eastern and Northern regions, only 48 and 40% were food surplus households, respectively, while 27 and 34% were food deficient households, respectively. The patterns observed at district level resembled the observations at the regional level. Median food availability was largest in the western and central districts and smallest in the northeastern districts (part of the Northern region), where food insufficiency (< 2500 kcal cap^{-1} day^{-1}) prevailed (Fig. 3a)

Table 1 Median, mean and standard deviation of farm and food availability characteristics per region and for the overall dataset

Characteristics	Total Uganda			Central region			Western region			Eastern region			Northern region		
Number of households	1927*			397			458			511			554		
Food self-sufficient households [%]	38			52			66			29			14		
Households per class [%]															
Class 1, food deficient households	23			15			10			27			34		
Class 2, food adequate households	21			18			18			24			21		
Class 3, food surplus households	55			66			72			48			40		
	median	mean	st. dev	median	mean	st. dev	median	mean	st. dev	median	mean	st. dev	median	mean	st. dev
Farm size [ha]	0.8	1.8	6.4	0.8	1.8	5.2	0.8	1.4	1.9	0.8	1.4	2.1	1.2	2.4	10.8
herd size (TLU)	0.4	1.8	4.9	0.3	1.9	7.2	0.3	1.8	4.5	0.7	1.7	3.3	0.5	1.8	4.3
Food availability [10^3 kcal cap^{-1} d^{-1}]	6	20	225	8	49	491	10	17	22	5	10	20	4	12	47
Gross daily income [USD cap^{-1} d^{-1}]	0.2	0.5	5.1	0.2	1.2	11.2	0.3	0.5	0.6	0.1	0.3	0.5	0.1	0.3	1.1
Gross daily income on-farm [USD cap^{-1} d^{-1}]	0.03	0.09	0.27	0.04	0.13	0.37	0.04	0.11	0.17	0.02	0.08	0.32	0.01	0.06	0.17
Cash value of production [USD cap^{-1} d^{-1}]	0.1	0.2	0.4	0.2	0.3	0.5	0.2	0.3	0.3	0.1	0.2	0.4	0.1	0.1	0.3
Market orientation [%]	24	29	25	26	31	24	22	25	21	27	20	26	21	29	29

*7 households located in Kampala region were not included in regional analysis, but in national and district level analysis

and the proportion of food deficient households was largest.

Similarly, at the livelihood zone level median food availability was smallest in the Northeast and North/Northwest and largest in the southwest and central areas (Fig. 3b). Yet, differences between the two aggregation levels were also apparent revealing aggregation bias. For example, two districts in the northwest and two districts in the Eastern region had small median food availability, while these trends were not observed at the level of the livelihood zone level. In contrast, at livelihood zone level the area in the north indicating smallest median food availability was not identified at the district level. Overall, patterns at the district level were more variable than at the livelihood zone level.

3.2 Household activities and strategies

3.2.1 Household activities contributing to food availability

Contributions of activities differed strongly across households with similar food availability (Online Resource A1) demonstrating a large diversity in how households across Uganda acquired food. Further, the role of contributing activities changed along the FA gradient as revealed by the moving average (Fig. 2a). Consumption of food crops produced on-farm contributed to a basic level of food availability for almost all households. However, beyond this basic level, the contribution of the other activities to food availability increased. Cash income from sale of on-farm products (food crops, cash crops and livestock products) first became more important with increasing food availability (moving to the right along the *x*-axis in Fig. 2a), followed by an increase in off-farm income. Similarly, in food deficient households (Class 1, < 2500 kcal cap^{-1} day^{-1} available) off-farm income contributed least to food availability (14%), while in food surplus households (Class 3, > 5000 kcal cap^{-1} day^{-1} available) this contribution was largest (34%) (Fig. 2b). In contrast, food deficient households had the largest contribution to food availability of consumed crops produced on-farm (66%) and food surplus households had the smallest (33%). While the contribution to food availability of small livestock including poultry, goats and sheep ('shoats') did not show clear differences among classes, the contribution of cattle increased from deficient to food surplus households. However, the variability around the mean per contributing activity was large (Table 2), pointing again to diverse strategies of rural households within the classes.

Between regions, the contribution of on- and off-farm activities to food availability was similar with only a smaller mean contribution of consumed crops produced on-farm and an equivalent larger mean contribution of off-farm income in the Northern region (Fig. 4). At district level, the median contribution of sold food crops to food availability amounted to less than 10% for the majority of the districts (Fig. 5a). For some 13 districts scattered across all regions median contributions

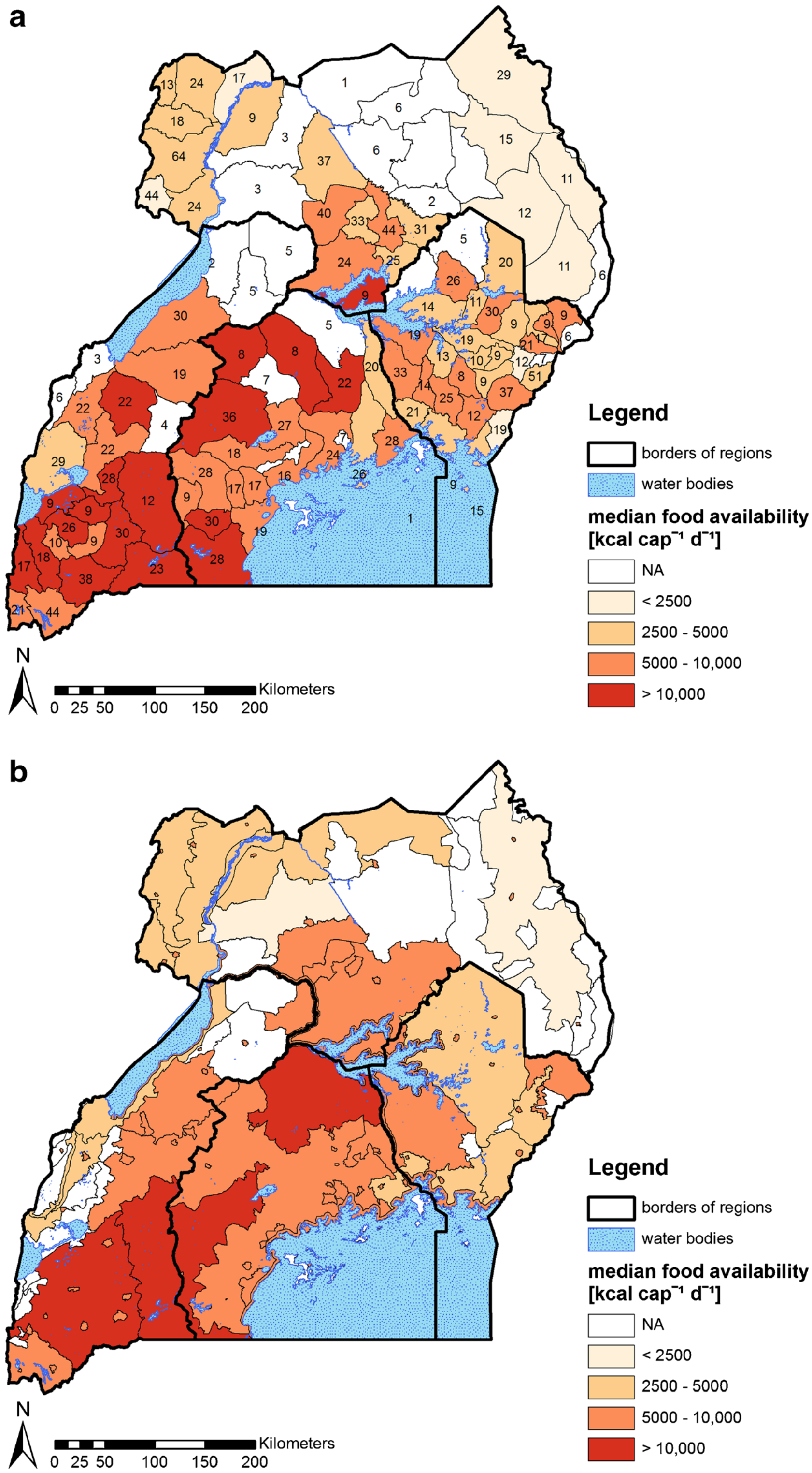


Fig. 3 **a** Median food availability at district level. All districts with at least eight households taken into account. The numbers in the figure represent the number of observations (households) per district. **b** Median food availability at livelihood zone level. All zones with at least eight households taken into account. The maps reveal patterns, while individual district/ livelihood zone values must be interpreted with care as LSMS data is not representative at the district/ livelihood zone level and their location (in latitude/longitude) was randomly off-set adding uncertainty to the exact location (Sources: UBOS 2012; WRI 2009; FEWS NET 2013; Thompson 2016)

amounted to 10–20% or above. The median contribution of cash crops was zero for many districts in the Northern and the Eastern regions (Fig. 5b). Median off-farm income contribution was large (> 20%) in four large districts in the northeast, in five districts in the northwest (Fig. 5c), around Kampala and in a few districts in the Eastern, Central and Western regions.

Observations of the contribution of these livelihood activities to food availability were similar at livelihood zone levels. For example, the large median off-farm

Table 2 Contribution of on- and off-farm activities to food availability per class and region [%]

		Total Uganda			Central region			Western region			Eastern region			Northern region		
Class		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Off-farm income	Median	0.0	0.0	17.7	0.0	0.0	23.5	0.0	0.0	5.6	0.0	0.0	11.5	0.0	0.0	0.0
	Mean	14.0	17.0	34.0	6.5	14.9	35.6	7.0	10.3	27.3	6.4	12.7	33.0	23.0	14.0	17.0
	St. dev	27.4	27.7	37.1	19.6	27.9	36.3	21.1	21.4	33.4	17.8	21.7	37.3	33.4	27.4	27.7
Poultry	Median	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Mean	1.9	1.9	1.3	0.5	0.4	1.5	0.0	0.8	0.2	1.2	3.0	2.1	3.2	1.9	1.9
	St. dev	9.5	7.6	6.1	3.3	1.8	8.2	0.0	3.9	1.8	6.8	8.3	6.9	12.8	9.5	7.6
Shoats	Median	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Mean	2.0	4.0	3.0	3.1	4.7	3.3	1.3	2.5	1.9	1.5	4.5	3.7	3.2	2.0	4.0
	St. dev	10.9	12.8	8.9	14.3	13.3	9.8	4.7	10.9	5.8	6.6	12.1	9.7	12.9	10.9	12.8
Cattle	Median	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Mean	1.4	4.0	7.0	1.8	1.8	6.7	1.3	1.1	5.4	1.8	5.5	8.4	1.0	1.4	4.0
	St. dev	7.6	14.1	16.9	9.2	8.9	17.5	5.2	6.8	15.5	8.1	16.9	17.1	7.3	7.6	14.1
Cash crops	Median	0.0	0.0	1.9	0.0	8.1	3.3	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0
	Mean	7.0	11.1	11.7	13.0	15.1	11.1	5.4	11.6	11.7	7.4	8.8	9.2	4.6	7.0	11.1
	St. dev	15.9	19.8	19.0	21.9	18.8	15.8	9.9	22.1	18.2	15.0	16.8	16.5	15.0	15.9	19.8
Food crops sold	Median	0.0	4.7	3.6	0.0	0.0	3.6	0.0	7.6	4.1	0.0	5.1	3.7	0.0	0.0	4.7
	Mean	8.0	11.2	9.6	6.9	8.3	8.5	9.6	14.3	8.7	6.9	12.2	11.7	8.7	8.0	11.2
	St. dev	14.0	15.0	13.8	12.5	13.5	11.4	15.3	16.5	11.7	13.3	15.8	17.4	14.7	14.0	15.0
Food crops consumed	Median	70.3	50.5	27.1	74.5	55.7	28.2	75.7	59.9	43.0	81.0	49.8	22.9	56.1	70.3	50.5
	Mean	65.7	50.8	33.4	68.1	54.9	33.3	75.5	59.4	44.7	74.8	53.2	31.8	56.0	65.7	50.8
	St. dev	30.5	27.0	27.1	27.8	26.5	25.3	24.1	25.0	28.0	25.8	25.1	27.7	33.2	30.5	27.0

Class 1: Food deficient households, Class 2: Food adequate households, Class 3: Food surplus households

income contribution in the north was confirmed at livelihood zone level. Yet, particularly in areas where districts were small, district level maps showed variation at short distance while livelihood zone maps indicated larger patterns (Online Resources A2-4).

3.2.2 Household production, income and food self-sufficiency

Food self-sufficiency is the ratio of the household's annual direct consumption of potential food energy from on-farm products ($E_{consumed}$) to the annual food energy required for the household

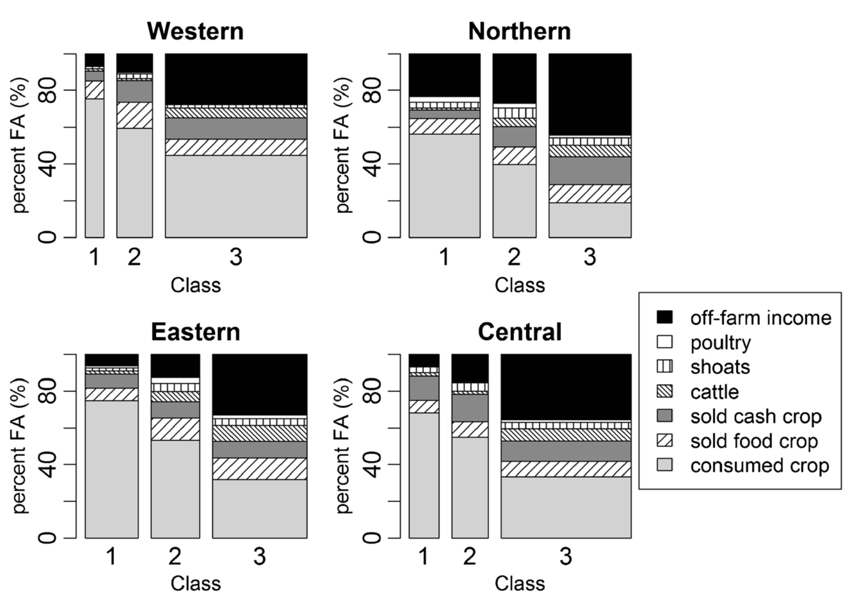
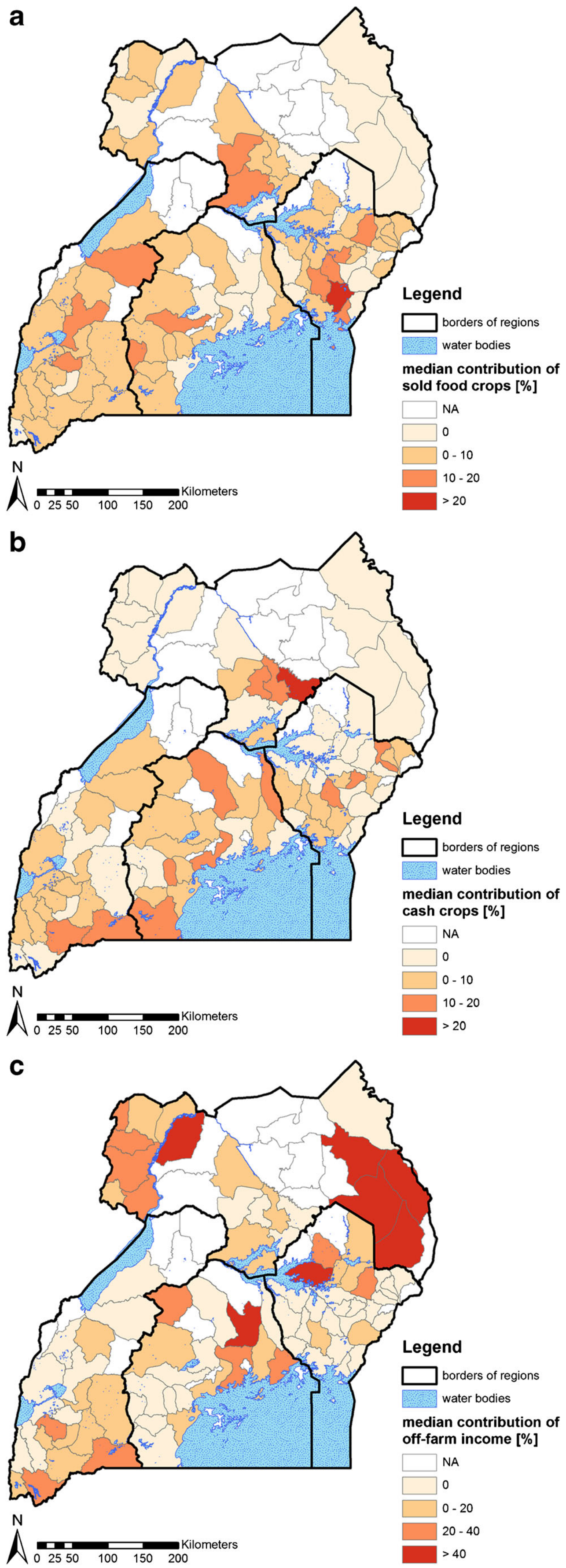


Fig. 4 Contribution of on- and off-farm activities to rural household food availability (FA) per class (Class 1, deficient food availability <2500 kcal cap^{-1} day^{-1}; Class 2, adequate food availability between 2500 and 5000 kcal cap^{-1} day^{-1}; Class 3, surplus food availability >5000 kcal cap^{-1} day^{-1}) and per region. Number of households: $n_{Western}$ = 458, $n_{Northern}$ = 554, $n_{Central}$ = 397, $n_{Eastern}$ = 511 (7 households from Kampala not included in analysis). The thickness of bars represents the number of households within the class. Livestock is divided into poultry, shoats (sheep and goats), and cattle



◀ **Fig. 5** **a** Median contribution of sold food crops to household food availability per district. **b** Median contribution of cash crops to household food availability per district. **c)** Median contribution of off-farm income to household food availability per district. All districts with at least eight households were taken into account. The maps reveal patterns, while individual district values must be interpreted with care as LSMS data is not representative at the district level and their location (in latitude/longitude) was randomly off-set adding uncertainty to the exact location (Sources: UBOS 2012; WRI 2009; Thompson 2016)

(E_{need}). E_{need} was calculated from 365 [days year^{-1}] × 2500 [kcal day^{-1}] × household size in male adult equivalents.

Overall, 38% of the rural households were food self-sufficient, but patterns differed among the regions. In the Central and Western regions, 52 and 66%, respectively, of the households were food self-sufficient as compared to 29 and 14%, respectively, in the Eastern and Northern regions (Table 1). Per class, the proportions of food self-sufficient households were largest in the Western region with 83% of the food surplus households and 35% of the food adequate households. By contrast, in the Northern region, only 27% of the food surplus households and 15% of the food adequate households were food self-sufficient (Online Resource A5). Household income, production and production resources differed among the regions. Mean gross daily income was smallest in northern and eastern Uganda (0.3 USD cap^{-1} day^{-1}) and largest in central Uganda (1.2 USD cap^{-1} day^{-1}) (Table 1). However, mean gross daily income in central Uganda also had the largest variability around the mean. The mean cash value of production was smallest in the Northern region (0.1 USD cap^{-1} day^{-1}) and largest in the Western and Central regions (0.3 USD cap^{-1} day^{-1}), but also here variability around the mean was large. Mean farm size was similar (1.4 ha) for the Western and Eastern regions, but 20% larger for the Central region and more than 40% larger in the Northern region compared with the Western and Eastern regions. For all regions except the Central region, mean farm size increased from food deficient households to food surplus households (Online Resource A5).

Also, at the district level, the median cash value of production was larger in the west than in the northeast and the northwest (Fig. 6a). Median farm size was not correlated with median cash values of production (linear model, $R^2 = 1 \times 10^{-5}$, $p = 0.98$). For example, the median cash value of production was small in the northeast and northwest, despite the larger median farm sizes (Fig. 6b). Some districts in the west had smaller median farm sizes, yet their median cash value of production was larger than in areas with larger farm sizes. Median food availability and median farm size were not correlated at the district level (linear model, $R^2 = 0.006$, $p = 0.44$).

Similar to the district level, the median cash value of production at the livelihood zone level was largest in the southwest and smallest in the north and east. Median

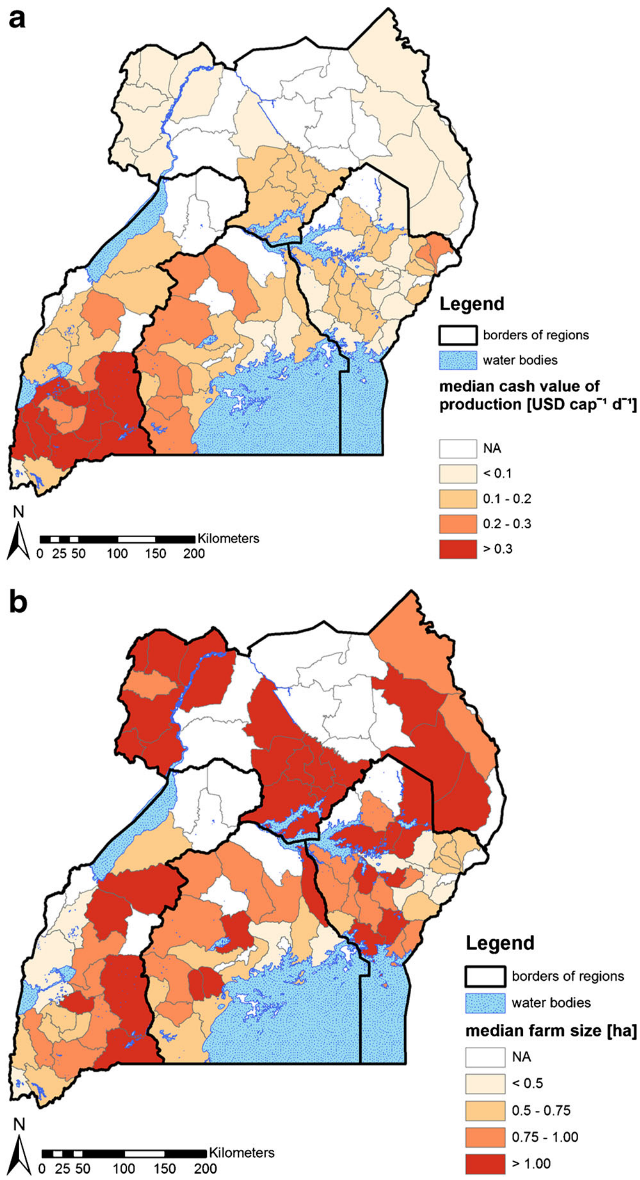


Fig. 6 **a** Median cash value of production [USD cap^{-1} year^{-1}]. **b** Median farm size [ha] of the households. All districts with at least eight households taken into account. The maps reveal patterns, while individual district values must be interpreted with care as LSMS data are not representative at the district level and their location (in latitude/longitude) was randomly off-set adding uncertainty to the exact location (Sources: UBOS 2012; WRI 2009; Thompson 2016)

farm size aggregated per livelihood zone revealed more distinct patterns than at the district level: At livelihood zone level, an area of median farm sizes >1 ha stretched from the northwest (West Nile) to the Eastern region, while median farm sizes <1 ha covered most of the Central and Western regions, parts of the Eastern region and Karamoja (northeast). Median farm sizes <0.5 ha were apparent in the mountain areas (Online Resources A6-7).

3.3 Cropping patterns related to food availability

The contribution of individual crops to the household food availability differed per food availability class (Fig. 7). The mean contribution of banana, one of the important food crops in Uganda, was largest for food surplus households (33%) and smallest for food deficient households (14%). In contrast, the mean contribution of the other important food crops (maize, cassava and sorghum) was least for food surplus households (14%, 9% and 2%, respectively) and most for food deficient households (19%, 15% and 10%, respectively). The mean contribution of coffee was relatively similar (3–5%) for all classes, though the lowest contribution was consistently observed for the food deficient households across all regions.

At the regional level, we observed differences in the importance and type of crops contributing to food availability in terms of consumption and cash generation. While banana was the most important food crop in the Western and Central regions, cassava, maize and sorghum were the most important in the Northern and Eastern regions (Fig. 8). Coffee was an important cash crop in the Central region (and to a lesser extent in the Eastern region), while there was no single dominant cash crop in the other regions. In the Western region, banana was most important for food surplus households showing that banana was an important crop for income generation as well as food. Most of the food deficient households consumed all their produced bananas (almost 90% of the food deficient households), while 66% of the food surplus households (comprising more than 70% of all households in the Western region) sold on average 19% of their banana production. In the Northern region, 'other crops', including rice and tobacco, contributed most for the food surplus

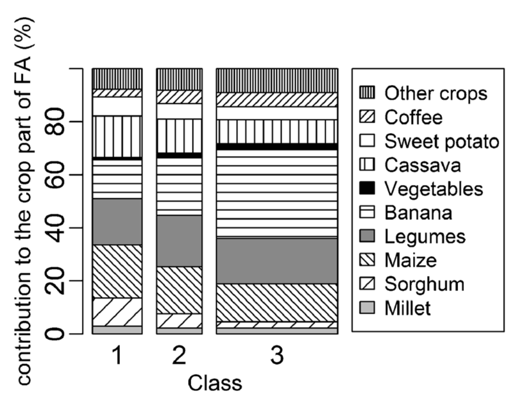


Fig. 7 Contribution of crops to the crop part of household food availability per class (Class 1, deficient food availability <2500 kcal cap^{-1} day^{-1}; Class 2, adequate food availability between 2500 and 5000 kcal cap^{-1} day^{-1}; Class 3, surplus food availability >5000 kcal cap^{-1} day^{-1}). The crop part includes energy from food crops consumed and energy equivalent from income from food and cash crops sold (N.B. coffee). Number of households: n = 1927. The thickness of bars represents the number of households within the class

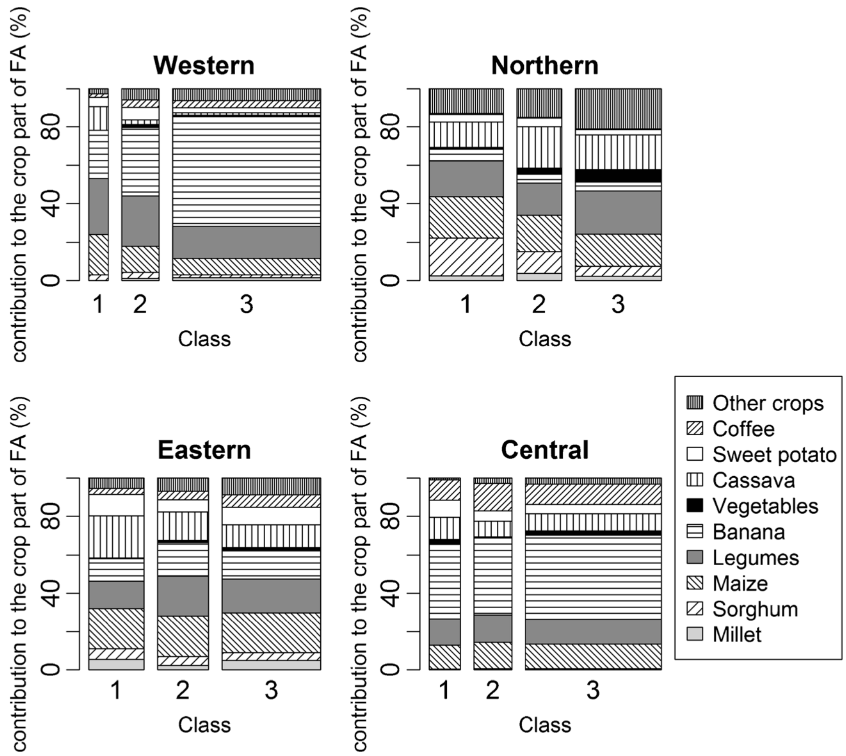


Fig. 8 Contribution of crops to the crop part of household FA per class (Class 1, deficient food availability <2500 kcal cap^{-1} day^{-1}; Class 2, adequate food availability between 2500 and 5000 kcal cap^{-1} day^{-1}; Class 3, surplus food availability >5000 kcal cap^{-1} day^{-1}) and region. The crop part includes energy from food crops consumed and energy equivalent from income from food and cash crops sold (N.B. coffee). Number of households: $n_{Western}$ = 458, $n_{Northern}$ = 554, $n_{Central}$ = 397, $n_{Eastern}$ = 511 (7 households from Kampala not included in analysis). The thickness of bars represents the amount of households within the class

households. Legumes contributed similarly to the crop part of food availability across all regions and classes with a mean of 14 to 20%.

4 Discussion

We structure the discussion around our research questions and hypotheses on how food availability differed across Uganda, how activities contributing to food availability and cropping patterns differed with food availability and how our findings could guide intervention strategies of policy and development actors.

4.1 What proportion of Ugandan households is food deficient and how does food availability differ across the country?

Overall 23% of the households across Uganda were food deficient. Similarly, the national poverty rate was observed to be around 24% in 2010 (Daniels and Minot 2015) and the FAO Hunger map identified 24.8% of the total population to be unable to meet their minimum dietary energy requirements over one year in the period from 2010 to 2012 (FAO 2016a). Because our food availability indicator did not consider non-food expenses, our figures may underestimate the country's food insecurity status.

In the northern region more households are food deficient Household food availability varied greatly across Uganda with generally smaller food availability in the north, which corresponds to less optimal agroecological conditions (e.g. rainfall quantity and distribution) and poorer market access due to weaker road infrastructure and absence of large urban markets. The low food availability in the north matched with a smaller mean cash value of production and a smaller mean daily income.

Agroecological conditions are known to affect food security (Hyman et al. 2005). For example, in Malawi Fisher and Lewin (2013) observed that relatively high annual rainfall corresponds to a greater likelihood of households being food secure. Rural households in the Northeast experience low annual rainfall and a prolonged dry season (UBOS 2013), which can affect agricultural production and subsequently household food availability. However, while parts in the Southwest receive similar amounts of annual rainfall as in the Northeast, food availability in the Southwest was generally greater, indicating that regional differences in food security are subject to multiple factors that go beyond rainfall distribution.

Differences in infrastructure and market access may be one reason for the regional differences in food availability. Frelat et al. (2016) observed a positive relation between market access and food availability. The long-lasting conflicts in northern Uganda prior to 2009/2010 (Tusiime et al. 2013) caused insecurity and destroyed infrastructure, including food production and distribution systems in the north (FANTA-2 2010; Martiniello 2013). In addition, most larger urban centres in Uganda with a high demand for food are located in the Central and Western regions. Mean values of farm production resources (farm size and tropical livestock units) could not explain the lesser food availability in the Northern region compared to the other regions.

Households in the Eastern region were more food deficient than in central and western Uganda Regional mean household food availability was less in the east than in the Central and Western regions, although aggregations at district level showed a more diverse picture. Also regional mean gross daily income and mean cash value of production were lower in the Eastern region. Similar to the north, farming systems in the east (except for the Mount Elgon region) are more based on annual crops and less on major cash crops such as coffee.

4.2 How do contributing activities differ with food availability and across Uganda?

The activities contributing to food availability varied strongly between households and regions and with household food availability. Consumption of crops produced on-farm was the major contributor to food availability across all households, matching observations by Frelat et al. (2016). However, while consumption of crops produced on-farm was particularly important for households with low food availability, off-farm income and market-oriented on-farm activities increased in their importance with greater household food availability, thereby partly supporting Hypothesis 2. The changes in the activities along a food availability gradient suggest that rural households follow different livelihood strategies, related to their food availability. Three major strategies for food availability are discussed: Food self-sufficiency (1), cash crop production (2), and off-farm income generation (3).

Food self-sufficiency as a strategy for rural households Although consumption of crops produced on-farm was generally important for food availability, the majority of the households were not food self-sufficient. Instead, the sale of food crops played an important role also for the food deficient households. Two factors may be at play: First, many households choose to diversify their livelihoods towards income-generating activities before they are food self-sufficient (Frelat et al. 2016; Ritzema et al. 2017). Second, particularly the food deficient households are often unable to achieve food self-sufficiency, because they need to sell some of their food crop harvest to pay for non-food expenses (Leonardo et al. 2015). In the Northern region, food self-sufficiency was less than in the other regions both overall and per class. Food self-sufficiency was thus not a strategy towards food security for households in the north despite poor market access and infrastructure. This is perhaps partly due to low productivity resulting from the low and variable rainfall. Harris and Orr (2014) identified three potential pathways out of poverty: Extensification by increasing land area, diversification and commercialisation of crop production, and diversification of income. The smaller proportion of food self-sufficient households on relatively large farms in the north suggests that extensification seemed not to be a strategy towards food security and poverty reduction in that area. Instead, households focus on income-generating activities, particularly off-farm income.

Cash crops as a strategy for rural households Crop commercialisation can lift households out of poverty (Harris and Orr 2014) and has positive effects on food security (Kristjanson et al. 2010). In addition, cash crops have beneficial effects on the overall farm, as they generate money for households to reinvest in their food crops. This reinvestment can increase the productivity of the food crops and thereby benefit household food security (Govereh and Jayne 2003). Indeed, the contribution of cash crops (e.g. coffee) increased from deficient to food surplus households. Yet, the contribution strongly depended on the region. At district and livelihood zone levels, the median cash crop contribution was zero for most of the north and the northeast of Uganda and between zero and 10% in most districts in the west. These patterns match the differences in infrastructure across Uganda and highlight that market access is paramount for venturing into cash crops.

Off-farm income as a strategy for rural households Overall, the contribution of off-farm income to food availability increased with the household food availability status. This observation contrasts with other studies that identified off-farm income to be particularly important for the poorest (e.g. Jayne et al. 2014). However, Haggblade et al. (2010) observed that poorer households have no access to high quality sources of off-farm income. Instead, they remain in low-pay market segments (e.g. unskilled casual labour) with few opportunities to step out of poverty. For these poorer households, off-farm income is rather a means of survival. Yet, off-farm income activities can serve as an important safety net for food insecure or poor households during periods of stress. For example, during drought years off-farm income activities stabilise household income (Haggblade et al. 2010). The north of Uganda is particularly vulnerable to droughts and weather-related impacts because of its unimodal rainfall and variability of rainfall (UBOS 2013). Indeed, at all spatial aggregation levels, off-farm income contribution was largest in these low-potential agricultural areas in the north. This is in line with Matsumoto et al. (2006) who observe that the likelihood of households participating in off-farm activities is greater in low-potential areas.

4.3 How do cropping patterns differ with food availability and across Uganda?

The contribution of major crops (banana, maize, cassava and sorghum) to the crop part of food availability varied along a food availability gradient and across regions. While the contribution of sorghum and maize as major staple crops decreased from deficient to food surplus households, the contribution of banana increased, thereby only partly supporting Hypothesis 3 that staple crops are more important for food insecure households. Banana was a predominant crop in western and central Uganda with increasing importance from deficient to food surplus households, while cropping systems in northern and eastern Uganda had greater crop diversity. Such regional diversity patterns are expected to reflect the crop diversity at farm level. What remains hypothetical is to what extent such differences in crop diversity on the farm level result in differences in household dietary diversity (e.g. Carletto et al. 2015; Dillon et al. 2015). In fact, the Western region of Uganda has poor nutritional diversity (FANTA-2 2010; UBOS 2013), which matches our observations of low crop diversity in western Uganda.

East African highland banana is an important food and cash crop East African highland banana is one of the most important food crops in Uganda (Komarek and Ahmadi-Esfahani 2011) and contributes considerably to household food availability. At national level, the contribution of highland banana was largest for food surplus households. Banana is both an important food crop and cash crop in Uganda, particularly in western Uganda (Komarek and Ahmadi-Esfahani 2011; Jassogne et al. 2013). The larger banana contribution for food surplus households can be explained in two ways. On the one hand, most food surplus households are located in western and central Uganda, two regions that are important for banana production as a cash crop. However, this coincidence results in a large banana contribution to the crop part of food availability for the overall dataset, but does not reflect causal relations between banana contribution and food availability. On the other hand, the larger banana contribution to the food availability of food surplus households may also be related to the properties of banana as a perennial crop. Perennial crops show potential benefits for food security over annual crops (e.g. maize, sorghum). These benefits include reduced expenditures on seeds, fertilizers and other inputs, reduced labour for planting and weeding (thereby saving labour to invest in off-farm activities), and extended growing seasons that enable farmers to harvest over longer periods of time (Batello et al. 2013). The second reason can also explain the greater food self-sufficiency in western and central as compared with northern and eastern Uganda. Finally, as one of the most important staple crops in central and western Uganda, demand for highland banana is high in the urban areas generating an attractive market.

Crop contributions to FA were quantified assuming that all harvest that was not reported as sold, was consumed. In reality, farmers use part of the harvest as seed for the following season and part is lost during handling or storage. Because of this simplification, the FA approach quantifies the *potential* FA rather than the *actual* FA. Differences in on-farm post-harvest losses (PHL) between crops could affect the contribution of crops to household FA. For example, while maize grains can be easily stored, harvested banana must be sold and consumed soon after harvest. This difference in storage characteristics of crops can result in differences in on-farm PHL between crops.

At the national level in Uganda PHL for banana are larger than for maize (approximately 12% for banana as compared to 6% for maize), while on-farm PHL are similar (less than 3% for banana as compared to about 4% for maize) (Enoch Kikulwe, personal communication, 31 March 2017; Kaminski and Christiaensen 2014). On-farm, banana is harvested for each meal thereby reducing food wastage (Enoch Kikulwe, personal communication, 31 Mar 2017). By contrast, crops like maize are stored for longer, increasing the risk of damage (Affognon et al. 2015). Estimating the effect of PHL on FA remains challenging, because data are scanty (Affognon et al. 2015), and PHL vary depending on crops, post-harvest management and location (Affognon et al. 2015; Kaminski and Christiaensen 2014). Yet, the figures mentioned above suggest that differences in on-farm PHL between major crops are small.

4.4 Targeting interventions: Intensifying food production, increasing market access or generating off-farm income sources – What makes households food secure?

Our results show that agricultural interventions alone will not achieve household food security in Uganda's north, where market access is poor and agroecological conditions are unfavourable. Instead, holistic livelihood interventions are needed that promote opportunities for off-farm income generation, such as improved access to education and urban employment (Haggblade et al. 2010). Yet, interventions must also support agriculture (particularly through food markets and security of land tenure). Given that northern Uganda is still recovering after a period of insecurity this may explain the smaller role of agricultural activities for household food availability as compared with the other regions (FANTA-2 2010).

Cash crops were important for food availability while the contribution of food crops remained limited. Improving access to (cash crop) markets and to urban centres will probably contribute more to improving household food security than focusing solely on closing the yield gap of food crops. This observation is confirmed by the small proportion of food self-sufficient households and the fact that sale of food crops, particularly short-cycle crops such as maize, was not related to increasing food availability. Barrett (2008) observed that smallholder participation in food crop markets only benefits the households with sufficient available assets (land, livestock, capital and technology similar to the sustainable livelihood framework capital assets). The poor households, in contrast, do not manage to produce marketable surpluses from which to derive income that could be used to borrow or buy assets and thus to step out of poverty (Barrett 2008). Also the often low prices for food crops (Harris and Orr 2014) and large investment barriers for closing the yield gap (e.g. Tittonell and Giller 2013) may be reasons why commercialisation of most food crops was not observed as a key strategy for food availability in our data. For that reason, current programmes that focus on the promotion of maize for poverty reduction (e.g. the USAID Feed the Future programme in Uganda) need to be evaluated on their success in increasing household food security.

East African highland banana is an exception to our observations on the role of food crops for household food availability in western and central Uganda, as banana is an important cash crop but also important in supporting household food security. Potential interventions include breaking down the barriers for access to cash crop markets along with facilitating the uptake of yield-improving technologies and establishing access to productive assets (Barrett 2008). However, simply establishing cash crop markets is not enough to improve household food security. While the cultivation of cash crops increases the frequency and amount of household income, they also increase the dependency on local markets and on highly unstable food prices (Anderman et al. 2014). Therefore, for a positive effect of cash crop cultivation on food security, interventions (e.g. cross-border trade, grain storage, no export bans in drought period) also need to promote access and price stability of food crop markets (Anderman et al. 2014).

4.5 Zooming in and zooming out – Contributions of the FA framework

District aggregation is strictly administrative and can be questionable when contrasting livelihood systems are found within districts. Averaging indicators across these systems introduces bias. Therefore, FEWS NET developed livelihood zones to represent core livelihood activities (Boudreau 1998). For some areas in Uganda these livelihood zones are defined at a coarser level than the districts, for others in finer detail. Our approach, based on individual household data, showed that aggregation to livelihood zones did not capture small-scale variation within zones, suggesting bias also at livelihood zone level. This said, aggregation at both district and livelihood zone levels must be interpreted with caution. For any policy decision, further zooming in using representative datasets is needed.

A major contribution of our FA approach is the use of household data to provide quantitative information on livelihood strategies in relation to food availability. The approach enables us to describe countrywide patterns while preserving the original household level variability, thus capturing a large diversity of household strategies at the smallest scale. In this way it is a useful addition to frameworks on vulnerability and risk assessments (such as the sustainable livelihood framework linking assets, vulnerability, livelihood strategies and outcomes). The FA approach can further be used to validate aggregation zones, for example by comparing livelihood zone descriptions on major crops with the household information from the FA approach (Browne and Glaeser 2010). Such a comparison on crop level among the livelihood zone descriptions and our LSMS household information revealed that in some zones where cassava was described as an important crop, it contributed little to households' food availability (e.g. in the northwest and in central and southern parts of Uganda). In contrast, in livelihood zones where banana was not described as an important crop, the household data revealed that banana was important for household food availability (in central and southern areas) (Browne and Glaeser 2010).

5 Conclusions

Uganda's rural households follow diverse livelihood strategies, which differ across the regions and with their degree of food availability. Households with greater food availability tend to diversify their on-farm and off-farm activities in order to spread the risk. Those households with surplus food availability have more income from on-farm and off-farm activities as compared to households with insufficient food availability. In areas with good market access and infrastructure, cash crops can be an important strategy contributing to household food availability, while in areas with poor infrastructure and less favourable agroecological conditions, off-farm income, probably of low quality, plays a more important role. Most staple crops are more important for the households with insufficient food availability, while East African highland banana was identified to be one of the key crops for income generation in western and central Uganda and most important for households with surplus food availability.

The diversity of livelihood strategies must be considered when targeting interventions. Holistic livelihood interventions, including access to off-farm activities, are needed to improve household food availability in Uganda's north. Instead of focusing on food self-sufficiency, households with low food availability already diversify towards income-generating activities. Interventions need to facilitate these diversification strategies by improving access to food and cash crop markets and to off-farm activities. Current programmes often focus on promoting maize as a cash crop for food security, but our results show that maize is important for households with insufficient food availability, but not as a cash crop for the households with a food surplus. In contrast, we show East African highland banana to be both an important food and cash crop. However, this crop has so far received scant attention in investment programmes.

Our analytical framework provides a basis to account for diverse household strategies in decision-making on interventions. The food availability analysis quantifies where and which activities are important for which group of farmers and can help to identify suitable interventions for rural households. We identify differences in livelihood strategies across a food availability gradient and across the country. Both dimensions are necessary for targeting interventions.

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Compliance with ethical standards

Conflict of interest We declare no conflict of interest.

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