Full length Research paper

Determinants of Household Food Security in Musanze District, Rwanda

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Despite significant economic growth and development in Rwanda over the past 20 years, twenty percent of Rwandan households remain food insecure. Interventions to address the wide variations in household food insecurity in Rwanda need to be data-driven. It is important to first characterize the household food security landscape within an intervention's proposed target area, so that stakeholders can design appropriate food security interventions. The food security status of households in Musanze District, northwest Rwanda, was measured using both an experience-based scale and a 24-hour dietary recall method, and calculated regression models to identify the significant determinants of household food security in Musanze District. Findings indicated that urban households which owned multiple assets, and had a household member with an education beyond primary school were most likely to be food secure in Musanze District. Amount of food purchased from the market was also identified as a significant determinant of household food security in the dietary recall model. Implications include the need to: 1) use multiple measures for food security characterization, 2) consider multiple educational pathways in food security interventions for long-term, sustainable impact, and, 3) base food security interventions on appropriate-scale data, including spatial context, to result in intended impacts.

Key words: dietary diversity; nutrition; Africa; education; appropriate-scale data.

Abbreviations

(ASAP) African Sustainable Agriculture Project Foundation, (CFSVA) Comprehensive Food Security and Vulnerability Analysis, (CHW) Community Health Workers, (FAO) Food and Agriculture Organization of the United Nations (FIES) Food Insecurity Experience Scale, (HDDS) Household Dietary Diversity Score, (MDD-W) Minimum Dietary Diversity for Women, (TI) USAID Feed the Future Tworore Inkoko, Twunguke, (USAID) United States Agency for International Development, (USG) United States Government, (UTIA) University of Tennessee Institute of Agriculture (WFP) World Food Programme of the United Nations.

INTRODUCTION

The Sustainable Development Goals of the United Nations have set an ambitious target of ending hunger globally by 2030 (United Nations, 2015). Central to achieving this goal is what transpires in sub-Saharan Africa, the region with the largest available acreage of underutilized land and fastest growing population (Tiwari et al., 2018). While questions remain as to how hunger can really be addressed in conflict-prone areas of the continent, countries that have enjoyed relative peace and stability over the Millennium Development Goal period (2000-2015) lend hope that a food secure Africa can be attained (Adenle et al., 2017).

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Rwanda has enjoyed a period of relative peace and stability since the genocide of 1994, and has shown remarkable progress toward abolishing hunger. Under its "Vision 2020", and driven by rapid population expansion and agricultural development, Rwanda has experienced an annual 15-year-average (2000-2015) economic growth rate of 7.8%, well above the sub-Saharan African average of 2.3% (World Bank, 2017). This has resulted in increased food availability from higher crop production volumes, resulting in Rwanda becoming self-sufficient in food supply in 2009 (World Bank, 2011). Despite this, much of this food availability trend has been accounted for by a move to calorie-dense roots and tubers, and away from grains and plant- and animal-based protein production (de Graaff et al., 2011). The most recent (2015) Comprehensive Food Security and Vulnerability Analysis (CFSVA), compiled by the Rwandan government, describes the task ahead: twenty percent of all Rwandan households remain food insecure (WFP, 2016). It is likely that the household food security landscape is multi-faceted, with food and nutritional concerns including sufficient per capita caloric, protein and/or micronutrient intake. The challenge to bring these households to food security is made markedly more complex by climate change, environmental degradation and a 2.8% annual population growth rate (Paul et al., 2017).

At the World Food Summit in 1996, the United Nations Food and Agriculture Organization (FAO) defined food security to exist when "all people, at all times, have physical, social and economic access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for an active and healthy life". This overarching and widely-accepted definition contains four dimensions of food security: availability, access, utilization and stability (FAO, 2009). At the household level, these four dimensions can be described as:

Availability

addresses the supply of food to a population, and includes productive resources needed to obtain food for the household, as well as a household's stocks and net trade of food;

Access

involves both economic purchasing power of a household, including income and other resources for buying or trading for food, as well as physical aspects of household food access, such as distance to markets and access to transport to reach markets to purchase or sell food.

Utilization

of food available and accessible to a household is dependent upon a household's level of knowledge about, and current practices related to food preparation, storage, intra-household distribution of food, and dietary/nutritional diversity.

Stability

refers to a household's ability to withstand shocks and stresses to its food security status, such as changes in political or economic climates, and environmental challenges such as climate change.

These four dimensions are general guidelines to analyzing food security, however previous studies have identified a variety of determinants of household food security. Recent research shows that food secure households (versus food insecure households) in low-income countries are more likely to be urban (Smith et al., 2005), have more years of schooling (Maharjan and Joshi, 2011; Oluwatayo, 2009), have more assets (Guo, 2011; Harris-Fry et al., 2015), own livestock (Haile et al., 2005), and spend more on food in the market (Omotesho et al., 2010; Melgar-Quinonez et al., 2006). Food secure households are also less likely to be employed in the agriculture sector (Maharjan and Joshi, 2011; Beyene and Muche, 2010). Studies have also shown that other important determinants of household food security include variables such as household size (Babatunde et al., 2007; Sekhampu, 2013), number of females of reproductive age in a household (Harris-Fry et al., 2015), access to other productive resources (e.g. land, credit, other inputs) (Aidoo et al., 2013; Bogale and Genene, 2012; Bashir and Mehmood, 2010; Tefera, 2009), agricultural practices, technology adoption and farming systems (Beyene and Muche, 2010; Feleke et al., 2005), and distance to markets (Feleke et al., 2005).

The 2015 CFSVA national survey identified key determinants of Rwandan household food security as:i) urban/rural, ii) skilled labor, business owners and salaried work versus employment in agriculture, iii) available land acreage, iv) production of crops for household consumption, v) ownership of livestock and vi) market engagement for buying and selling food (WFP, 2016). This same survey describes Rwandan food insecure households as ones that are unable to meet essential food and non-food needs without engaging in atypical coping strategies, have an unacceptable diet, and/or, use a high share of their budget to cover food needs.

However, at sub-national levels, food security varies widely across Rwanda (Table 1). The percentage of food secure households by district varies from 98% in Nyarugenge District, Kigali Province, to 43% in Rutsiro District in Western Province (WFP, 2016). In order to appropriately design food security interventions and set attainable targets at the household level, it is important to

first characterize the household food security landscape within an intervention's proposed target area. Projects and programs to address food insecurity are frequently directed towards specific regions within a country; national level data are therefore insufficient to inform the design and successful implementation of such interventions. It is therefore paramount to identify which socio-economic characteristics are significant determinants of food security in a region in order to adequately design interventions that can account for, and hopefully overcome, any pre-existing barriers to household food security.

We present characterization and analysis of significant determinants of household food security in Musanze District, Rwanda. Data were collected as part of a baseline survey for an agricultural intensification project (smallholder broiler production) in Musanze District, Northern Province (Figure 1). This project targets the intervention toward smallholder households that are severely food insecure. Critical to the intervention's success is precision in the identification of the food insecure (Barrett, 2010). As we lacked access to disaggregated district-level data from published statistics databases, we conducted a baseline survey in Musanze at the start of the project, so that households experiencing severe food insecurity could be identified and targeted for recruitment into the intervention. Our objectives are to 1) measure the food security status of households in Musanze district using both an experience-based scale and a 24-hour dietary recall method, and 2) identify the significant determinants of household food security in Musanze District.

MATERIALS AND METHODS

This research aims to expand our understanding of determinants of household food security in Rwanda. While we recognize the importance of intra-household dynamics on food security of individuals within a household, we use the household as our unit of analysis, as households are the primary unit of production, consumption and exchange in low-income economies (Maxwell, 1996). Previous research indicates that household level is an appropriate unit of analysis for food security (Carletto et al., 2013).

Study site

Musanze district is located in northwestern Rwanda, (Figure 2) with a food system based around local production as well as regional trade from both within Rwanda and across international borders with the Democratic Republic of Congo and Uganda (WFP, 2016). According to the most recent statistics, 74% of Rwandan households are engaged in agricultural production, with the majority (58%) of agricultural production carried out by smallholders on landholdings of less than 0.5ha (WFP, 2016). With mean elevation of 1850m, favorable climate (average temperatures between 59 and 77°F) and rich volcanic soils, Musanze District's predominant agricultural system includes production of starchy food crops such as potatoes, maize, bananas and wheat, along with beans and a variety of fruits and vegetables (Uzamukunda, 2015). Although food security is generally worse in Northern and Western Provinces of Rwanda, average food security in Musanze district (Northern Province) is higher than the surrounding districts, primarily due to the existence of a significant urban area (Ruhengeri town) and a growing tourist industry, based around Volcanoes National Park and one of only two wild mountain gorilla populations in the world. However, the picture for Musanze District is representative of Rwanda as a whole, with 20% of households classified as food insecure, the same as the national average (Table 2). Thus, Musanze District is comparable to the national level food security statistics, and serves as an appropriate case to examine household food security at the district level.

Survey Instrument

The survey instrument was created in English and translated into Kinyarwanda by a bilingual native Kinyarwanda speaker. The survey was then back-translated by a different bilingual speaker. Edits were made to ensure the questions held the same meaning in both languages. Additionally, the survey instrument was fully reviewed and edited by all three bilingual enumerators. Training of enumerators was conducted in August, 2017. The survey was piloted 15 times, with nine females and six males.

To analyze different concepts of and pathways to household food security, we used two measures. First, we used the Food Insecurity Experience Scale (FIES) (Ballard et al., 2013). Experience-based food security scales have emerged in recent years as promising tools to elucidate household-level food security (Cafiero et al., 2014). Such scales can capture not only real experiences of food security that a household has faced, but also perceived food security related to uncertainty around the ability to procure enough food for the household. We modified the FIES tool piloted by the Food and Agriculture Organization of the United Nations from eight questions to a six-question tool, as part of the wider household survey. When piloting the questions for the Rwandan context, we eliminated questions 7 and 8 from the FIES tool, as these were too similar in translation and meaning to questions 4 and 6 respectively (Figure 3). Questions were coded with yes/no (yes=1; no=0)

Table 1. Rwanda Food Security by Province (Adapted from WFP (2016)

Province	Percent Food Secure
Kigali City	97.0%
Southern	76.8%
Western	64.8%
Northern	82.6%
Eastern	85.8%
Total	80.6%

USAID Feed the Future *Tworore Inkoko, Twunguke* (TI), or "Let's raise chickens and make a profit" in Kinyarwanda, the primary language spoken in Rwanda, is a three-year pilot project (2016-2019) that aims to increase the capacity of smallholder farmers in Musanze District, Rwanda, to produce broiler chickens. TI has two main objectives: (1) improve household incomes and (2) improve nutrition objectives for smallholder farmers, particularly through the consumption of chicken meat. TI uses a private extension model to train, supply resources for, and support 750 smallholder farmers to grow 100 birds at a time. Through the provision of micro-loans for capital and recurring expenses and guaranteed broiler chicken buyback at the end of each grow-out cycle, the goal is to create a sustainable model for small-scale broiler production, which can be scaled up throughout Rwanda and the surrounding region. University of Tennessee Institute of Agriculture (UTIA) implements the activities in partnership with a private feed mill based in Rwanda, Zamura Feeds. TI is funded by USAID/Rwanda and a private, US-based foundation, African Sustainable Agriculture Project (ASAP) Foundation.

Figure 1. **Tworore Inkoko, Twunguke**

Table 2. Comparison of household food security at district, provincial and national levels for target area (Adapted from WFP (2016)

	Food secure		Marginally food secure		Moderately food insecure		Severely food insecure		TOTAL
	%	HH	%	HH	%	HH	%	HH	
Musanze District	44	37,251	36	30,648	15	12,840	5	4,017	**84,756**
Northern Province	40	158,338	42	165,438	14	56,079	3	11,813	**391,668**
Rwanda	40	979,707	40	973,855	17	407,978	3	63,358	**2,424,898**
FOOD SECURITY CLASSIFICATION	Food secure				Food insecure				

responses and then household responses to all six questions were aggregated to give a household food security score between zero (food secure) and six (food insecure).

Secondly, we used the Minimum Dietary Diversity for Women (MDD-W) Score (FAO and FHI 360, 2016). This measure allowed us to analyze diversity in consumption patterns within a household, which provides valuable insight on diet quality. The larger USAID-funded project with which this study is associated reports on this annual indicator, specifically in the context of women of child-bearing age; however, for this study we focused on the
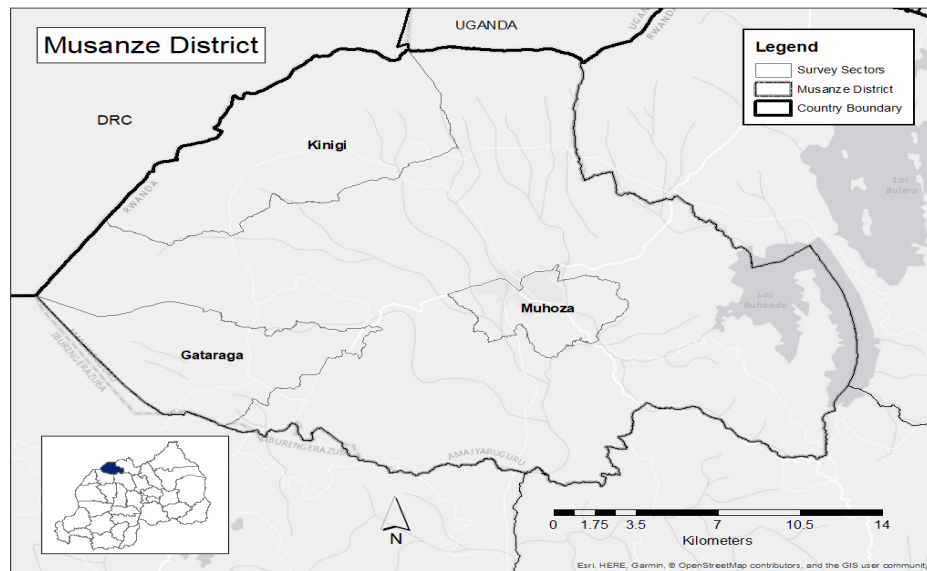
Figure 2. Map of Musanze District and sectors surveyed

In the last 12 months because of a lack of money or other resources, was there a time when:
1.   you or others in your household were worried about not having enough food to eat?
2.   you or others in your household were unable to eat healthy and nutritious food?
3.   you or others in your household ate only a few kinds of foods?
4.   you or others in your household had to skip a meal? (*similar to question 7 in FIES*)
5.   you or others in your household ate less than you thought you should?
6.   your household ran out of food? (*similar to question 8 in FIES*)

Figure 3. Tool used for measuring household food security experience

household unit. Through the MDD-W measurement, we asked respondents to report whether or not their household had eaten each of ten (10) food groups over the last 24 hours. The ten food groups are: (1) Grains, white roots and tubers, and plantains; (2) Pulses; (3) Nuts and seeds; (4) Dairy; (5) Meat, poultry and fish; (6) Eggs; (7) Dark green leafy vegetables; (8) Vitamin A-rich fruits and vegetables; (9) Other vegetables; (10) Other fruits. While reliability of food security measures can be increased by adapting food groups to those locally available if certain foods are not available (FAO and FHI 360, 2016), we did not need to make any modifications to the groups because the corresponding foods were available in Musanze District. To reduce food group categorization error, small, hand-held flip charts were created with 5-10 color pictures of foods, commonly found in the district, for each food group. Enumerators provided the charts to the respondents as a reference during the survey.

Additional survey questions included general household demographics, including age and sex of all household members, and weekly food group expenditures, as well as questions relating to income and other household expenditures and assets.

Survey Methods

Musanze District contains three sub-levels of administrative units, in order of largest to smallest: Sectors, Cells, and Villages. For this research, we conducted surveys in three of the 15 sectors, Muhoza, Gataraga, and Kinigi. These sectors were selected purposively based on the design of the broiler chicken project for which this survey was conducted providing data on two rural (Gataraga and Kinigi) and one urban (Muhoza) sector from which we would be recruiting farmers for training in broiler production. A target of 300 surveys per sector was determined based on total collection time. We used a three stage random sampling approach by administrative unit (cell, village, household). The number of surveys was chosen to be proportional to the larger administrative unit's population. Therefore, our survey responses are proportional to the actual populations within each administrative unit to allow for greatest

possibility of accurate representation.

In all, 951 households were randomly surveyed across the three selected sectors. Surveys were completed throughout September and October 2017, given the evidence from the most recent Rwandan government analysis on household food security indicating that September exhibits peak levels of food insecurity across Rwanda (WFP, 2016).

A head of household, male or female, was requested to respond to the survey questions and the respondent was directed to answer questions for the household as a whole. At the onset of the diet-related questions, the main food preparer for the household was asked to join the survey and respond, a common method to ensure validity of responses to such questions (e.g. Ochieng et al., 2018). Survey questions were read to the respondents, and the responses were recorded on tablet devices. This method helped reduce administration time and respondent fatigue, and allowed the enumerator to address any confusion. Resulting data were uploaded via wireless networks at the end of each day so that data could be synced into an online database for Rwandan and American project collaborators to view.

Analysis methods and hypotheses

All data were analyzed in SPSS (version 24) and descriptive results (means and percentages) were calculated and are reported in Table 3. Bivariate correlations were calculated to identify statistically significant relationships between variables selected.

We calculated multiple linear regressions to establish the determinants of household food security. The data passed all assumptions for the use of multiple regressions without any violations. To assess the determinants of household food security we initially included eight variables in our linear regression models. We calculated the regressions against both measures: first with the FIES score as the dependent variable, and then with the MDD-W score as the dependent variable.
We hypothesized that these variables would have the following relationships with household food security:

Positive (+) expected relationship:

● Education - Households that have a household member who has completed any schooling beyond primary level are likely more food secure. Our measure of education level was slightly different than the level of education or literacy of the head of household that is typically used (Sekhampu, 2013; Maharjan and Joshi, 2011; Babatunde, et al., 2007). We used the highest educational attainment of anyone living in the house, with the assumption that any knowledge attained is available to other members of the household and would therefore

assist the household in being more food secure. A dummy variable was used (0=completed primary or less, 1=completed more than primary).
● Assets - Households that own a greater number of assets are likely more food secure. To categorize household wealth, we used asset tertiles. Those with more assets should have more resources to obtain food. These were determined by grouping the respondents into three tertiles according to the number of items owned by a household. Assets included general household items and furniture, agriculture implements, modes of transport, and entertainment items, such as TV or radio. Those with the least number of assets received a 1 and those with the most received a 3. A total of 25 items were asked in the survey, but no household reported having more than 14 items, therefore tertiles contain groups of 5 items.
● Urban - Households that are located in an urban area are likely more food secure than those located in rural areas. Food markets are located in urban centers and are therefore more accessible to urban residents. A dummy variable was used (0=lives in a rural area, 1=lives in an urban area).
● Purchases food from market - Households whose primary source of food comes from market purchases are likely more food secure, due to them having increased access to a wider variety of foods. This was determined by asking respondents to rank how their food was obtained, purchased from the market and produce their own food were mentioned most often. (0=purchasing from the market was not their primary way to obtain food, 1=purchasing from the marker was their primary way of obtaining food)
● Owns livestock - Households that own livestock are likely to be more food secure. Similar to assets, owning livestock can be a proxy for wealth, signaling more resources available for the household to obtain food. (0=does not own livestock, 1=owns livestock)

Unknown direction of relationship:

● Household size - More mouths to feed in a household may be offset by more available labor to the household or may result in a decrease in available resources per person.
● Number of females of reproductive age - Households that have more females of reproductive age are more likely to have more children in the house and therefore more mouths to feed. Conversely, households with children under five are targeted by Community Health Workers (CHW) for malnutrition screenings and more likely to receive nutrition interventions (Rwanda Ministry of Health, 2013). Thus, these interventions could positively impact household utilization of food.
● Work in agriculture sector - We hypothesize the incomes from agricultural work are lower than other types

Table 3. Descriptive statistics for Musanze District, Rwanda

Sectors surveyed *Muhoza (N=319), Gataraga (N=325), Kinigi (N=307)*	N=951
Rural (%)	66.5
Asset tertile *Mean; 1=least number of assets, 3=highest number of assets*	1.18
Buys primarily from market (%)	40.1
Primarily produces own food (%)	49.7
Household size (mean)	4.33
Highest education level in household (% beyond primary)	40.3
Females of reproductive age (mean)	1.28
Work in the agricultural sector (%)	59.8
Food expenditure (Mean RWF/week)	6,150
Reported household income (Mean RWF/month)	36,616
Modified-FIES score *Scale 0-6*	4.94
Food groups consumed (Mean) *Out of 10 food groups*	2.95

of work as agricultural work is frequently unskilled or lower skilled and with seasonality of production, can be a less secure form of income generation. This would result in these households being less food secure. However, these households are also the ones working directly in agriculture and so may have more direct access to food and/or more food available to them, making them more food secure. (0=no-one in the house works in the agriculture sector, 1=someone in the house works in the agriculture sector)

Based on the literature, including the WFP (2016) CFSVA, that indicate land size and distance to market as significant variables for food security, we initially included these in our analysis.

However, they were removed following pilot testing of the survey instrument. Land size was a difficult to measure, as households were either unsure of their land acreage and/or unclear as to how to define land acreages held under different tenure statuses. For "distance to market", it became clear that there were too many ways for households to define this, including physical distance vs timed distance; timed distance using different vehicles; access to different modes of transport at different times of the year, season or week; different route-to-market accessibility dependent upon the nature of the season

(rainy vs dry) (WFP, 2016).

RESULTS

Descriptives

Survey respondents were predominantly rural (66.5%). Only 40 percent of households have someone in the house with education beyond primary school and about 60 percent of households work in the agricultural sector. In terms of food security, about 40 percent of households report that they buy the majority of their food from the market whereas about 50 percent of households report primarily producing their own food. From the results, we calculated that 67.2 percent of household income is spent on food.

Food Insecurity Experience Score

Descriptives
Households, on average, answered yes to 4.9 of the of the six FIES questions, exhibiting a low rate of food security. Table 4 presents a breakdown of responses by questions, with question 1 (you or others in your

Table 4. Percent of households reporting "Yes" to six FEIS questions

FIES Questions: **In the last 12 months, because of lack of money or other resources, was there a time when...**	Percent Responses = Yes	N
1. ...you or others in your household were worried about not having enough food to eat?	92.1	951
2. ...you or others in your household were unable to eat healthy and nutritious food?	88.7	948
3. ...you or others in your household ate only a few kinds of foods?	90.1	948
4. ...you or others in your household had to skip a meal?	86.1	950
5. ... you or others in your household ate less than you thought you should?	87.4	945
6. ...you or others in your household ran out of food?	50.8	947

household were worried about not having enough food to eat?) receiving the most affirmative answers and question 6 (... you or other in your household ran out of food?) receiving the lowest percent of affirmative responses. Of all questions on the FIES, households only said they ran out of food ("yes" response to question 6) unless they had recorded a "yes" response to the other five questions. This implies that question 6, with households self-identifying that they "ran out of food", reveals a potentially different (more severe) level of food insecurity compared with questions 1 through 5 on the FIES. About half of households responded "yes" to all six FIES questions, indicating the lowest level of food security, with only 3.7% responding "no" to all questions, indicating that these households are very food secure.

Regression model

In our regression model using the FIES score as the dependent variable, we included education, asset tertiles, urban, owns livestock, purchases from market, household size, number of reproductive females in the household, and works in the agriculture sector as our independent variables (Table 5). Level of education, asset tertile, location of residence (urban/rural), and purchases from market were significant determinants of food security, as measured by the FIES. Therefore, if a household has more education, owns more assets, lives in an urban area, or purchases the majority of their food from a market they are more likely to be food secure.

Dietary Diversity

Descriptives

Surveyed households in Musanze had a typical diet of cereals/tubers/roots, together with pulses and vegetables (Figure 4). This aligns with the 2015 CFSVA description of households "with the lowest dietary diversity" (WFP, 2016). Fewer than 20% of all respondent households indicated that they had consumed any kind of animal source food (dairy, meat, eggs) in the past 24 hours. National data indicates that on average, Rwandans consume 6 out of 12 food groups (WFP, 2016). These 12 food groups, taken from the Household Dietary Diversity Score (HDDS), are similar to the 10 food groups in the MDD-W, yet include two additional food groups (sugar or honey and condiments, coffee, tea) and fewer categories that include fruits or vegetables (Swindale and Bilinsky, 2006).

Surveyed households in Musanze reported consuming on average 2.95 out of the 10 MDD-W food groups; even if we assume that all households also consumed food from the additional two categories in the HDDS, this would mean that these households are consuming 5/12 food groups, which is still lower than the Rwandan and Northern Province average levels of 6/12.

In US government reporting, consumption of five out of ten food groups (from the MDD-W) is considered to be a minimum diversity diet" for a household. On average, therefore, households in Musanze are not reaching this minimum diversity diet. Instead, diets revolve around cereals, roots and tubers, pulses, and vegetables or leafy greens groups. These foods are the most commonly produced in Musanze and are also cheaper (by weight) than animal-source foods and high value horticultural crops, which may contain valuable essential micronutrients lacking in the standard Musanze household diet.

Table 5. Regression results: Food Security as dependent variable (Adjusted R-squared = 0.409)

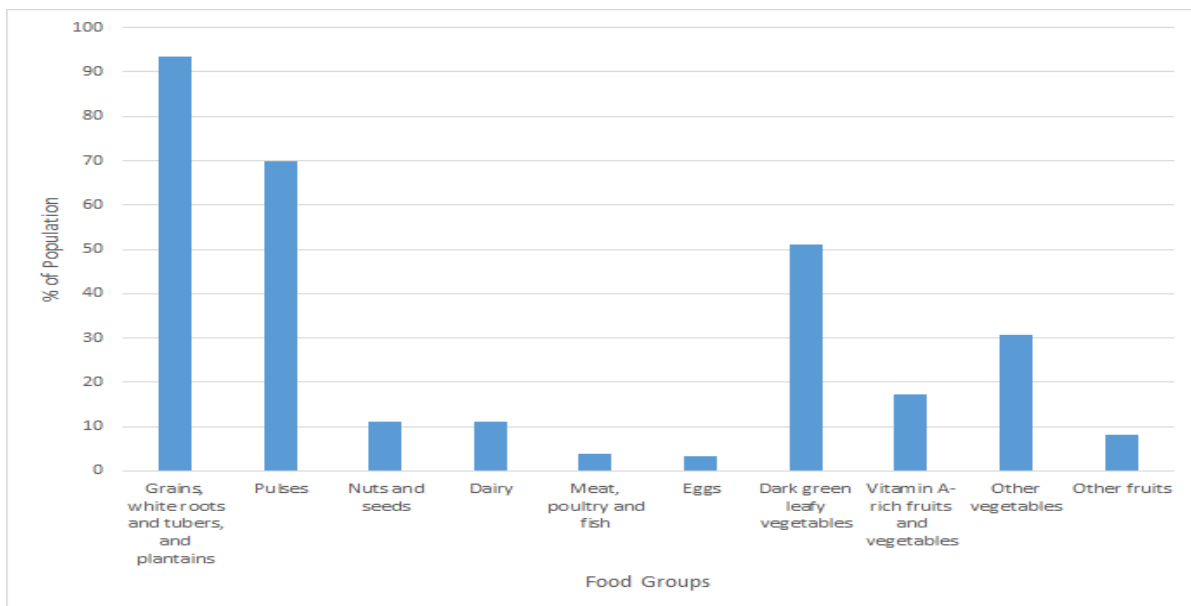| Variable	B	SE	p-value
Education	-0.61	0.088	0.000*
Assets	-1.607	0.112	0.000*
Urban	-0.764	0.091	0.000*
Purchases food from market	-0.334	0.09	0.000*
Owns livestock	0.134	0.102	0.189
Household size	0.001	0.027	0.977
Number of females of reproductive age	-0.03	0.053	0.580
Work in agriculture sector	0.034	0.089	0.701

* = significant at p<0.05

Figure 4. Percent of population eating each food group in three sectors in Musanze District, Rwanda (24 hour recall)

Regression Model

Using the same independent variables as the previous model, we calculated a linear regression model with dietary diversity (MDD-W score, i.e. number of food groups eaten in the past 24 hours) as the dependent variable (Table 6). Education, asset tertile, and urban were the significant determinants of dietary diversity in the district. No additional variables were statistically significant in this regression model (p<0.05). This model shows that a household's dietary diversity score improves if someone in the household has an education beyond primary school, if the household owns more assets, or if they live in an urban area.

Table 6. Regression results: Dietary diversity as dependent variable (Adjusted R-squared = 0.331)

Variable	B	SE	p-value
Education	0.513	0.099	0.000*
Assets	1.068	0.126	0.000*
Urban	1.236	0.103	0.000*
Purchases food from market	0.111	0.102	0.275
Owns livestock	0.007	0.115	0.952
Household size	-0.013	0.03	0.662
Number of females of reproductive age	0.096	0.06	0.111
Work in agriculture sector	0.042	0.101	0.678

* = significant at p<0.05

DISCUSSION

Number of assets owned, living in an urban area, and having a household member with an education beyond primary school were found to be the main determinants of food security in Musanze District for both measures (FIES and MDD-W). As number of assets owned is generally a proxy measure for wealth, this finding was not unexpected. Specifically in the context of rural Rwanda, Habyarimana (2015) found that household assets were a significant variable in household food security changes. Food insecurity and dissolution of assets can be a vicious cycle for low income households: food insecurity may result in selling off assets (land, livestock, equipment, etc.) in order to provide food for the household. In turn, the loss of assets can result in fewer household productive resources to provide food or generate income to secure food for the household (Guo, 2011).

Our results also show that location matters. Households in urban areas are more likely to be food secure than those in rural areas, which corresponds with the national statistics that indicate that average food insecurity in urban areas is 9.5% versus 22.9% in rural areas (WFP, 2016). Living in an urban area provides greater ease of access to larger quantities of diverse types of foods due to the prevalence of large central markets that are not found in more rural areas. Muhoza sector households are much closer in proximity to the main markets in and around Ruhungeri town, compared to those households in Gataraga and Kinigi sectors. In addition, those households located in rural areas may

lack access to transportation for themselves or their agricultural produce in order to purchase or sell food in urban centers. There are also more income generating opportunities in urban centers, drawing youth from Kinigi and Gataraga to Ruhungeri town to hunt for jobs. This rural-urban migration is juxtaposed with the continuing rapid rise in population in Musanze (and across Rwanda), in an already densely-populated country. Rural households will soon no longer be very far from an urban center in Musanze, with the spread of Ruhungeri town along major roadways, and the growth of urban centers along and near international borders, such as Gisenyi (in Rwanda), as well as Goma (Democratic Republic of Congo) and Kabale (Uganda). If Musanze urban populations are more food secure, will this urbanization trend lead to improved food security? Will enhancements in food access through urbanization be offset by reductions in food availability through people moving out of the agricultural sector? These questions deserve further research, and to this end, we are collecting an annual baseline survey for at least the next two years in Musanze to assess trends in the district's household food security landscape.

Households who had a member who had completed primary school were likely to be more food secure. This link between educational attainment and food security is synchronous with other recent research on household food security in East Africa (Mutisya et al., 2016; Sseguya et al., 2018). This also aligns with the findings in the CFSVA, that a household head's level of education is strongly positively related to a household's food security

status (WFP, 2016). However, our analysis addressed the highest level of education obtained by anyone in the household, recognizing that this education level may be obtained by someone other than the head of household. The education variable serves as a proxy for the utilization dimension of food security. More education can lead to an increase in knowledge about food safety, nutrition and healthy eating, including which foods to consume, how to prepare these foods in healthy ways, and how to maintain a healthy household. Education can also lead to people obtaining higher incomes from higher-skilled jobs. This in turn can lead to a secondary nutritional improvement pathway, through using income to purchase more and healthier foods (including new and diverse choices) for household consumption.

Rwanda has experienced a rapid increase in formal education of its youthful population - primary school completion rates rose from just 22% in 2000 to 74% in 2009, following the introduction of universal basic education (Republic of Rwanda 2010). Intra-household dynamics are therefore changing, as households switch towards having children with higher formal educational levels than their parents. What then does this mean for intra-household knowledge and decision-making dynamics when the young hold the scientific knowledge, but may not have the decision-making power (and/or experience) in the household? This question is worthy of further exploration, not only for the Rwandan context but also for the wider sub- Saharan region, which is experiencing rapid rises in formal education of burgeoning youthful populations.

An additional determinant for household food security that was significant for the FIES regression model was "purchase from market". Our survey also found that households in Musanze spend a large portion of their income (67%) on food purchases. This may represent a greater share of their income being spent on food than other areas of the country, as the WFP (2016) reports that country-wide Rwandans spend 47-76% of their total expenditures (not income) on food. Our regression findings indicate that if a Musanze household purchases the majority of its food from a market, as opposed to producing it for home consumption, they are more likely to be food secure. This could be linked to income, if a household makes more money, it can buy more food from the market and is not solely reliant on its own food production. Another reason could be the increase in access to more types and possibly cheaper foods if a household has increased access to markets. Other expenditures for a household can include agriculture inputs and schools fees which can make up a large proportion of expenditures. Therefore, if food expenditures in Musanze District are using a large portion of a household's income, there is either not much money left to purchase other necessities, or other necessities

are bought instead of food, resulting in less food secure households.

Implications

These findings lead us to three implications to assist those who seek to implement appropriately-targeted interventions to address household food insecurity. Our first two recommendations are broad and can be generalized to situations both within and beyond Rwanda. While the final recommendation is specific to the Musanze District setting, it may also have application to other districts across Rwanda and the East African region.

Use multiple measures for food security characterization

First, our approach provides a robust exploration into food security determinants in Musanze because we analyze both food insecurity and dietary diversity. By using two scores and analyzing the determinants, we are able to triangulate our findings. From this, we find that the same variables rose to the surface in both regression models as determinants of food security when using FIES and MDD-W as dependent variables. Characterizing food security and understanding its root causes for a particular geographic region are only as strong as the methods and tools used. Ideally, multiple measures should always be used for food security characterization (e.g. Bhalla et al., 2018).

Indeed, the Government of Rwanda's National Institute of Statistics takes such an approach for national level food security statistics, combining food consumption data, food expenditure shares and livelihood coping strategies, to classify each household into one of four food security categories (WFP, 2016). Recent literature calls for better international focus and coordination around measures for food security characterization and monitoring that concur with this implication (Carletto et al., 2013).Use of multiple measures can also help to offset limitations inherent to a single particular measure. No measure is immune from limitations, and both the FIES and MDD-W have been critiqued (Cafiero et al., 2014; Kano et al., 2017).

For example, one critical challenge to using the FIES is the assumption we make that each question lends equal weight towards a household's overall FIES score. The new US government (USG) Feed the Future indicator handbook (USG, 2018) has outlined an updated eight-question FIES as its standard indicator for measuring food security for a country or region. With this measure, the USG highlights the   assumptions   that each question on the FIES is independent and has the same power with respect to food security, thus

the FIES can be assumed as an interval scale. In our analysis, we treat the FIES as an interval scale, but it is unclear as to whether all questions carry equal power - perhaps the FIES is an ordinal scale at best.

For example, there may be elements of these questions that get "lost in translation" - these questions may not translate effectively into the local, cultural context. One question (question 6 of FIES) indicated that almost half of surveyed households ran out of food in the past year. Yet, further data is needed to understand how frequently these households ran out of food. Is it just once or multiple times in the past year? Also, how do these households conceptualize "running out of food"? Food security interventions and messaging to households around food security hit at the core of household decision making in low income households. These households are faced daily with the challenge of assigning any income towards immediate needs (e.g. household food/nutrition and medical care) versus longer-term investments (e.g. school fees). Our regression models indicated that having someone in the household (regardless of whether that person is household head) who had completed primary school was a determinant of household food security. By including the top educational level of someone in the household, our results highlight that sustained investment in education of a household member could lead to real change in terms of household food security.

Interventions addressing food insecurity in Musanze should therefore consider integrating food and nutrition education through both long-term and short-term training. Long-term training may involve investments from national or local level governing authorities to incorporate formal, school-based learning around food and nutrition at all levels of education.

This could involve both classroom-based and hands-on learning, such as through the implementation of school garden curriculum. At the household level, village, cell or sector-wide nutritional training on a regular basis can help address low levels of household dietary diversity. For example, our results revealed that very few households (less than 20% total) consumed animal protein (milk, meat and/or eggs).

Nutrition training that targets mixed meal plates, cooking demonstrations with less familiar food ingredients, and focuses on increasing the consumption of animal source foods, fruits, nuts, and Vitamin-A rich foods while taking into account the average amount households in the area have to spend on foods should be integral to food security programming in Musanze and other districts across Rwanda. Training programs do exist, an example is offered by a Rwandan-led non-governmental organization, Gardens for Health International, which provides household nutrition training as part of their integrated health package for rural Rwandan communities.

This same organization co-design and implement nutrition-sensitive gardens for improving household

Do households interpret this as "had zero food available in the household" or that they "were missing one or more food groups considered important to the household, e.g. cereals"? We can therefore use the FIES to make inferences about the relative scale of food insecurity between households, but it may be more difficult to make inferences about the comparative severity of food insecurity between households, assessing how much more food secure one household is than another.

Food security interventions should consider multiple educational pathways for long-term, sustainable impact.
nutrition outcomes as a result of a direct link between household agricultural production and consumption. Further studies are needed to explore how comprehensive nutrition training approaches (including those directly linked with nutrition-sensitive agricultural approaches) could be tailored appropriately to meet needs of diverse households.

Base food security interventions on appropriate-scale data, including spatial context, to result in intended impacts.

When characterizing food security at a local level, in this case in rural Rwanda, there is usually not available data on household food security. Researchers need to gather this data about the local food security landscape, often with a goal of using the data to inform interventions. Indeed, this was the challenge we faced when beginning to embark upon a broiler chicken production intervention in Musanze District, which has an overarching goal of improving household food security. With only district level broad statistics on food security, how could we understand the diversity of the household food security landscape within Musanze District? These data are then only as useful as the measures used to collect them, and it is easiest to use only one measure to assess household food security. If data are not sufficient, there is the tendency to rely on statistics generated at a larger geographic level (regional, national, etc.) and, from these higher-level data, make inferences about the food security characteristics at the local level. For example, surveyed households in Musanze consumed less than three food groups in the past 24 hours; this finding is lower than the average number of reported food groups for the Province level.

This supports other research that indicated food insecurity may be under-reported at macro-scales when compared to findings from local-level household surveys (Barrett, 2010). There is, therefore, a need for appropriate level data at the scale of which an intervention intends to be implemented and have impact. For our broiler production intervention, it is essential we have disaggregated data to understand the differences in household food security among different sectors in

Musanze District, some urban and some rural. Disaggregated data enable project implementers to appropriately target cells, villages and households who may best benefit from planned interventions. Disaggregated data also enable implementers to design and target groups within households (i.e. women, children).

Findings from this research indicate the large disparity in the level of food security between urban and rural sectors. Key areas, such as education level and percentage of household food purchased at the market, illustrate that there are distinct differences between urban and rural areas that cannot be dismissed when developing food security interventions. Subsequently, we have planned further studies to not only further examine urban/rural disparities, but explore disparities within each context.

Not all rural areas are homogeneous, nor are all urban areas. While the rural sectors in this study were found to be less food secure overall as compared to the urban sector, different factors between villages in rural areas will influence the food security and thus have implications on context-specific interventions.

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Compliance with ethical standards

All procedures performed in studies involving human participants were in accordance with the ethical standards of the University of Tennessee's Institutional Review Board under IRB #UTK IRB-17-03708-XP and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

Conflict of interest

The authors declare that they have no conflict of interest.

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