



Participatory Exploration of the Heterogeneity in Household Socioeconomic, Food, and Nutrition Security Status for the Identification of Nutrition-Sensitive Interventions in the Rwandan Highlands

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Food insecurity and malnutrition are challenges in rural Rwanda that are presumed to be affected by differential household socioeconomic status, but the relationship between food and nutrition security and socioeconomic status is not well-understood. We used a participatory and multidisciplinary study comprising nutrition survey, focus group discussion (FGD), detailed household/farm characterization, and interviews to construct a participatory household typology and to determine differences in the socioeconomic, food, and nutrition security status of 17 households representing the identified household types in Nyabihu District of Western Province. Strategies to improve household food and nutrition security were identified by the case study households themselves. During the FGDs, it was hypothesized that financial, physical, and natural capitals varied, resulting in high, medium, and low resource endowed households, abbreviated as HRE, MRE, and LRE, respectively. The HRE households had the most educated household heads, largest landholdings (~1 ha), and highest agricultural biodiversity and total farm income per annum. This probably resulted in better diets for women, children higher household food consumption relative to the other households. In contrast, the LRE households were the least food-secure, with poor household food consumption and low dietary diversity across seasons, probably due to limited physical and economic access to food. However, anthropometry of women and children did not differ with household type. Half of the children were stunted, including some from the more food-secure HRE households. Undiversified, nutritionally inadequate diets and bouts of illness likely contributed to chronic malnutrition in children. Making agricultural programs more nutrition-sensitive, creating diverse employment opportunities, and sensitizing communities to nutrition and adequate feeding practices of children could complement the interventions identified by households to improve their food and nutrition security.

Keywords: household typology, livelihood capital, agricultural biodiversity, food consumption, anthropometry

INTRODUCTION

Rwanda is one of the few countries in Sub-Saharan Africa that has registered sustained economic growth and improved food availability; however, about 20% of its households are food insecure, and 38% of children aged 5 years and below are stunted (CFSVA, 2015). According to the FAO (1996), food security exists when all people have physical and economic access at all times to adequate, safe, and nutritious food of their preference to meet their dietary needs for an active and healthy life. Identifying the demographic most affected and the causes of household food and nutrition insecurity may contribute to improved targeting of nutrition-sensitive food system interventions and the attainment of food security. The majority of food-insecure households in Rwanda are found in rural areas where the amount of food produced is often related to land, livestock, and agricultural asset ownership (Nzayisenga, 2015). Household income is another determinant of food security, as the majority of households in Rwanda are highly dependent on markets for food purchases (CAADP, 2013). Market-dependent households with low purchasing power are reported to have reduced access to food even when the food is widely available in markets (WFP, 2016). Therefore, differences in food production, income, and market distance can result in differential access to sufficient food by households.

Another key household food security indicator is the consumption of a variety of foods in sufficient amounts to ensure an adequate intake of nutrients (Meerman et al., 2015). Agriculture's role in the production of diverse crops and livestock is recognized by nutritional experts as contributing to reducing micronutrient deficiencies in food-insecure regions (Fanzo et al., 2011; Herforth and Ballard, 2016). In Sub-Saharan Africa, Sibhatu et al. (2015) found that on-farm production diversity was positively correlated with dietary diversity under subsistence farming. Hetherington et al. (2017) reported higher consumption of animal source foods in households that owned livestock compared with households that did not. Fanzo et al. (2011) measured agricultural biodiversity as the species richness of crops, livestock, and trees on a farm or landscape, while Ekesa et al. (2008) included the area under a food crop and food items obtained from natural habitats. Differences in dietary diversity have been attributed to variations in agroecosystem diversity, with more diverse agroecosystems producing a more varied nutrient output (DeClerck et al., 2011) leading to improved nutrition (Powell et al., 2013).

Several dietary diversity indicators are used to assess an individual's micronutrient adequacy. These include the household dietary diversity score based on 12 food groups and the women and children's dietary diversity score based on 9 food groups (FAO, 2011). The minimum dietary diversity for women (MDD-W) of reproductive age is a dichotomous indicator that is based on 10 food groups and has a cut-off point of 5 (FAO, 2018). For children aged 6–23 months, minimum Dietary Diversity (MDD) is achieved when four or more food groups out of seven are consumed (Dagmawit et al., 2017). The majority of adults and children in Sub-Saharan Africa consume undiversified diets dominated by cereal and tuber staples with limited animal-source

foods, fruits, and nutrient-rich vegetables. Dietary diversity scores of less than four were reported in households with the lowest living standards in South Africa (Labadarios et al., 2011) and for children below 5 years from households of low socioeconomic status in Madagascar (Rakotonirainy et al., 2018). These poor diets contribute to protein-energy malnutrition and micronutrient deficiencies, which may lead to undesirable long-term effects on physical and cognitive development and, at times, even death in children (Hetherington et al., 2017). Child growth is the most widely used indicator of a community's nutritional and health status (WHO, 2014), with anthropometry used as a proxy measure of food utilization (Jones et al., 2013). Chronic malnutrition is observed as stunted growth, while wasting with or without bilateral oedema, sparse hair, and skin changes is associated with acute malnutrition (Cloete, 2015). Sub-Saharan Africa has the highest rates of child malnutrition globally, with high levels of stunting and wasting in resource-limited households (Akombi et al., 2017).

A person's access to desired resources such as education, skills, healthcare, infrastructure, material goods, money, land, power, and social networks is defined as their socioeconomic status (Oakes and Rossi, 2003). Differences in these human, physical, financial, natural, and social capitals among households result in differential livelihood strategies and outcomes (DFID, 2000). Persistent socioeconomic inequalities are reported to increase vulnerability to food insecurity (Hamelin et al., 2011), with the poorest households in Sub-Saharan Africa the worst-affected by famines (Sasson, 2012), chronically food insecure (Sonandi, 2018), consuming undiversified diets, and malnourished (CFSVA, 2015). In addition to access to food, the quality of feeding and caregiving practices, sanitary environment, and access to health facilities can vary between households and contribute to malnutrition (UNICEF, 2013). This is because, without proper sanitation and hygiene and access to safe drinking water, children are prone to diarrhea, parasitic diseases, and damage to intestinal development, which will result in undernutrition and stunting.

However, the relationship between socioeconomic status and nutritional and health outcomes is not always straightforward. According to von Braun and Kennedy (1994), there were no relationships between anthropometric indicators, income, and calorie consumption in a number of countries, including Rwanda and Kenya. Brown et al. (2017) reported that in Sub-Saharan Africa, undernourished women and children were found across household wealth and consumption categories, suggesting issues of inequalities in intra-household food distribution and/or in nutrition awareness. In a study across eight countries in Sub-Saharan Africa, Hetherington et al. (2017) found that the association between anthropometric measures of children and livestock ownership were either positive or negative depending on the community, suggesting the need to control for factors such as household size, wealth, and sex of household head. Although all Rwandan households are placed into *Ubudehe* categories that reflect their socioeconomic status, ranging from the poorest to the richest households, as set by the Ministry of Local Government (Chika, 2017), poor correlation between these categories and household poverty and food consumption

was found by Nizeyimana et al. (2018). Furthermore, over half of households surveyed by (Uwamariya, 2013) in Huye district did not agree with the categories they were placed in. Rigidity in categories and limited participation of community members in the development of categories were identified as issues. Quantitative statistical and/or qualitative participatory methods have been used to summarize household heterogeneity through household typology development. In a study in Ghana, Kuivanen et al. (2016) found participatory typology construction useful for identifying diversity and its causes in a more location-specific way than was statistical clustering.

The Western Province of Rwanda is a Highland region in which, despite high food production, over a third of households are classified as food insecure and that has the highest levels of child stunting in Rwanda (Nzayisenga, 2015; WFP, 2016). A study was carried out in the Rwandan Highlands to assess how the community perceived the heterogeneity between households and to determine to what extent these differences influenced household food and nutrition security status and the strategies proposed to address identified issues. The specific objectives were to: (i) identify household types using a participatory household typology construction method, (ii) determine differences among household types in socioeconomic characteristics, agrobiodiversity, food consumption, nutrition, and health status by using case study households, (iii) examine the relationships between household characteristics and food and nutrition security indicators, and (iv) explore the interventions identified to improve household food and nutrition security. By improving understanding of the determinants of food and nutrition security in rural households, the findings of this study will add to the discourse on nutrition-sensitive interventions and may contribute to improving programs such as the Community-Based Nutrition Program in Rwanda (Ministry of Health, 2010). According to Sanders (1999), there is increasing evidence to show that involving the community in the design, execution, and evaluation of programs results in effective and sustainable nutrition programs.

MATERIALS AND METHODS

Study Site

The study was carried out in Kadahenda cell, Karago sector of Nyabihu District (01°06'4"S, 29°51'1"E; 2,500 m above sea level), one of the seven districts comprising the Western Province of Rwanda (Figure 1). The district is found within the volcanic agro-ecological zone and has a tropical temperate highland climate with rainfall of between 1,200 and 1,500 mm per annum. Rwanda has two rainfall seasons, season A, during which rain is received from September to December, and season B, with rain falling between March and June, and has dry seasons in January–February and June–August. The area is within the Eastern Congo-Nile Highland Subsistence farming zone, and agriculture is the main activity, with Irish potatoes (*Solanum tuberosum* L.) and common field bean (*Phaseolus vulgaris* L.) being the dominant food crops. Tea (*Camellia sinensis* (L.) Kuntze) and pyrethrum (*Chrysanthemum cinerariifolium* (Trevir.) Vis.) are grown as cash crops. Season A's main crop harvest is between

December and February, while that of Season B is in June and July. The months prior to the crop harvest are referred to as the main (October–December) and minor (April–June) lean seasons, during which household food stocks and income are at their lowest (CFSVA, 2015). Although livestock, including cattle, small ruminants, and chickens, are present on farms, the numbers are low.

Conceptual Framework

The idea of this study was premised on the UNICEF conceptual framework for malnutrition, which identifies basic, underlying, and immediate causes of malnutrition (Figure 2). At community level, the basic causes of malnutrition derive from a household's access to and control of available resources. Low livelihood capital leads to the underlying causes of malnutrition, namely household food insecurity, inadequate care and feeding practices, an unsanitary household environment, and inadequate access to health services. This, in turn, results in sub-optimal dietary intake and diseases/infections, the immediate causes of malnutrition. The study was part of the Cluster 4 project carried under the Humidtropics program (<https://humidtropics.cgiar.org/>) in Rwanda, which included nutrition and farming system analysis research components, among other disciplines. A nutrition survey was carried out to establish household demographics, resource access, water and sanitation status, child care and feeding practices, and the nutrition and health of women and children. To complement this survey, a series of focus group discussions (FGD) and detailed household/farm system characterization were carried out on a subset of the nutrition survey population. Due to the time-consuming nature of FGDs and characterization of households using the IMPACTLite survey tool, a decision was made to focus on a subset of villages sampled in the nutrition survey. The aims of the FGDs were to determine the community's perception of how resources were distributed across households and to identify household types from which case study households would be selected for detailed characterization of livelihood capitals and food and nutrition security outcomes. The information from FGDs was used to formulate hypotheses on household heterogeneity that were tested using data from case study households. The data collected from the nutrition survey primarily provided data on the underlying and immediate causes to do with nutrition and health, while data on livelihood capitals was collected from the detailed household characterization. Food security indicators were obtained from both surveys, and where the same data was collected in both surveys, the data source that provided a more complete data set was used.

Sample Population

A cross-sectional nutritional survey was carried out during November 2015, during which 10 villages were randomly selected from Kadahenda (nine villages) and Gihirwa (one village) cells. To determine the number of households to be sampled, Fisher's formula was used:

$$n = \frac{t^2 \times p(1-p)}{m^2} \quad (1)$$

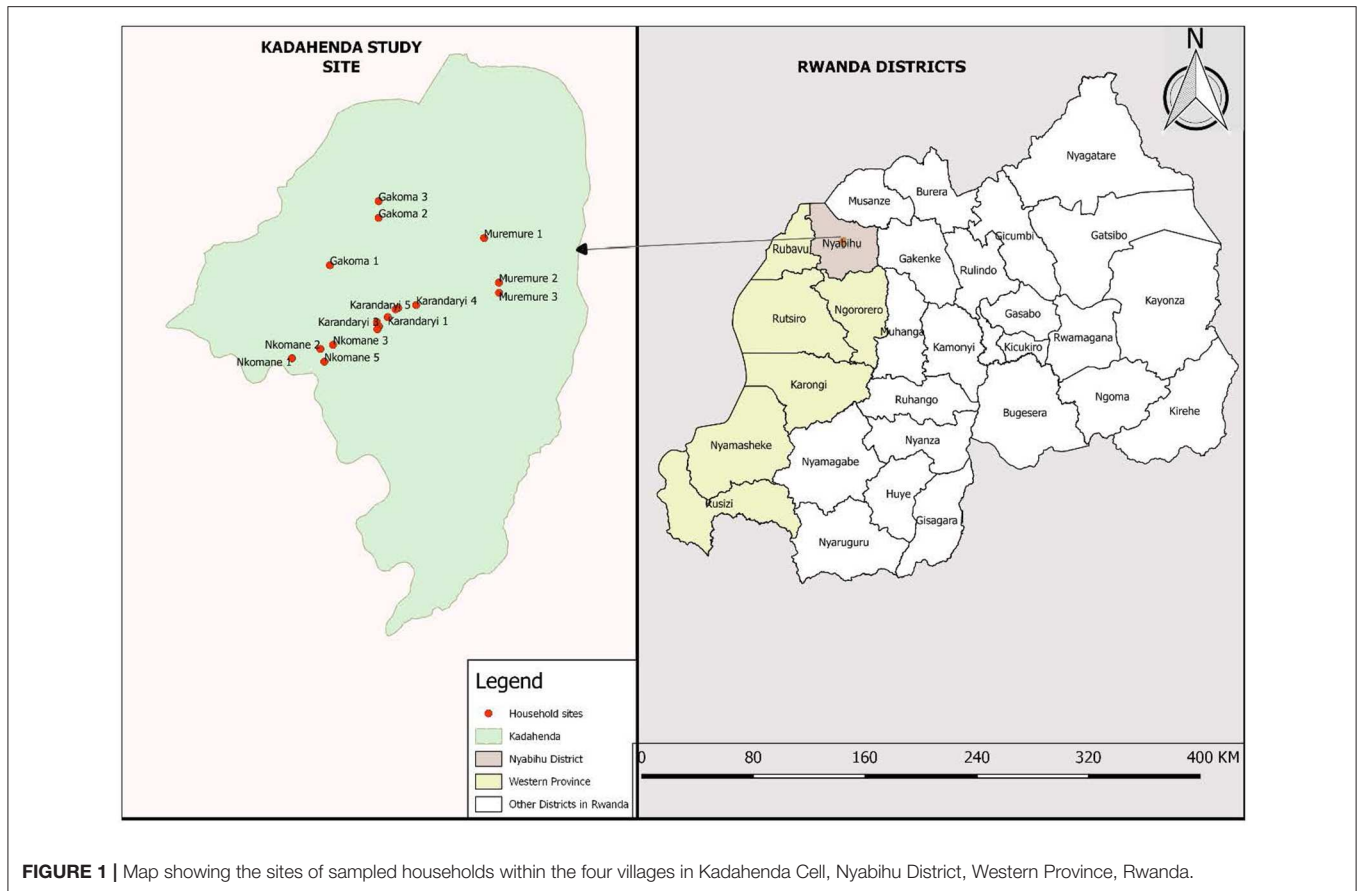


FIGURE 1 | Map showing the sites of sampled households within the four villages in Kadahenda Cell, Nyabihu District, Western Province, Rwanda.

where n = required sample size, t = confidence level at 95% (standard value of 1.96), p = estimated proportion of children aged 6–59 months with regard to total population of the area, m = margin of error at 5% (standard value of 0.05) (Magnani, 1997).

Using 14.2% as the proportion of children under 5 years to the general population in Rwanda (Rwanda Demographic and Health Survey (RDHS), 2015), a household sample size of 188 households was arrived at. To take care of attrition due to incomplete questionnaires or any other unforeseen causes, 11 households (6%) were added to give a sample size of 199 households with children aged 6–59 months. Through the support of village heads, lists were obtained of households with children aged 6–59 months in the selected villages, and systematic random sampling was used to select the 199 households.

For the study reported in this paper, the four villages of Karandaryi, Gakoma, Nkomane, and Muremure were randomly selected from the original 10 villages. From these four villages, 93 households, including a subset of households sampled during the preceding nutrition survey, participated in FGDs to develop a participatory household typology. Two sex-disaggregated FGDs were done in Karandaryi and Nkomane, and one mixed-sex FGD was carried out per village in Gakoma and Muremure. At the end of each FGD session, one household was randomly selected

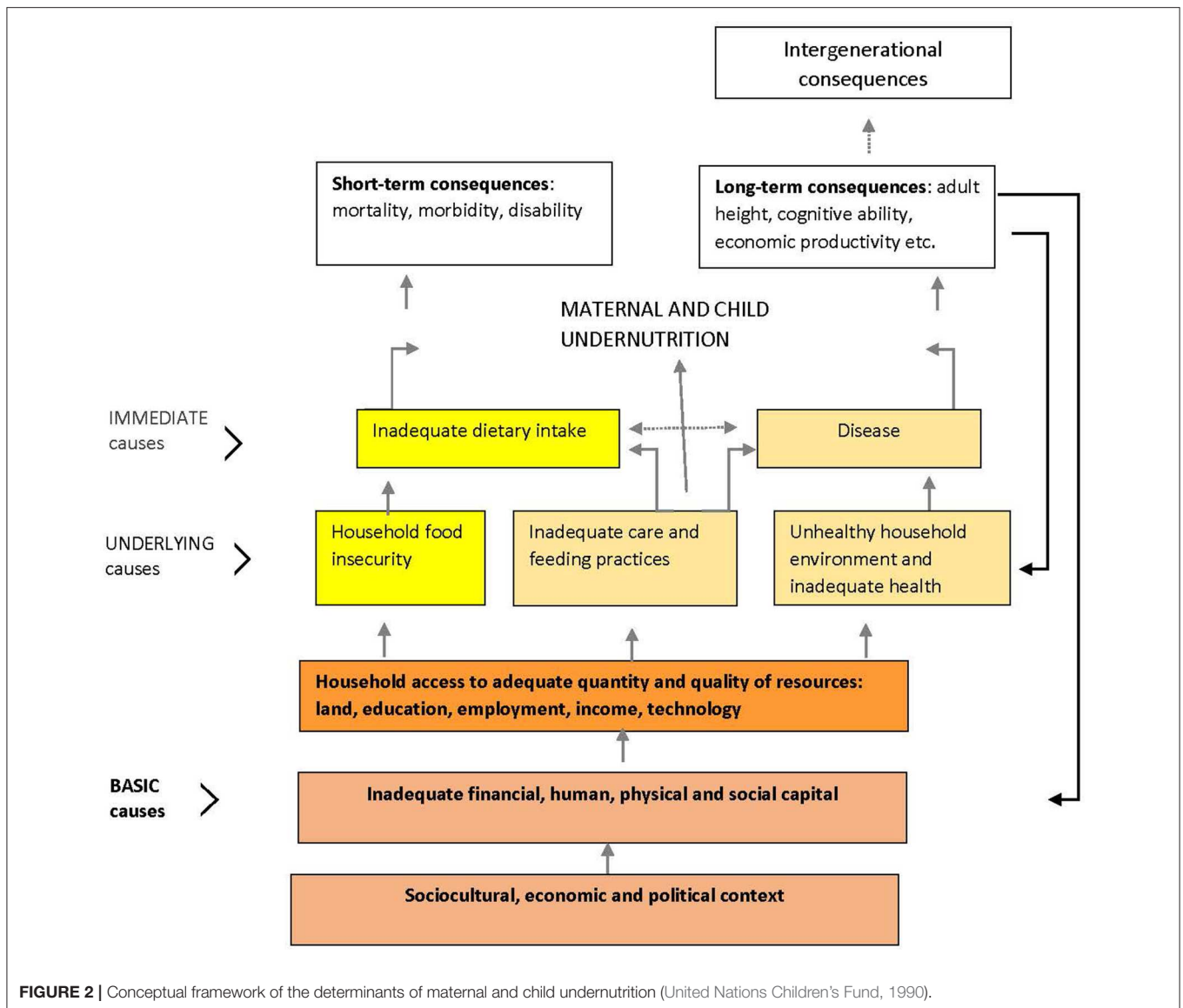
from each of the three identified household types to give a total of 18 case study households across the four villages (Figure 3) for detailed household/farm system characterization.

Data Collection

Nutrition Survey

A nutrition survey ($n = 199$) was carried out during November 9–13, 2015 (season A), using face-to-face administration of a questionnaire to the female household head or primary caregiver. Informed consent was obtained from each respondent prior to the interview. Data on the general household characteristics, on-farm agrobiodiversity, wild species collected for food, and distance to open-air markets and trade centers were collected. The respondent was asked to name the household's main coping strategy during periods of food shortage, and the response was classified under one of the following strategies: do nothing/stay hungry, rely on food aid, borrow from relatives or friends, work for food or money, reduce the number of meals, or reduce the quantity of food prepared. The water, sanitation, and health environment were assessed through questions on the household's commonly used water source and distance to and from the safest water source and health facility.

At the individual level, a qualitative open 24-h diet recall (FAO, 2011) was used to assess diet quality and meal frequency for mother/caregiver and one child (reference child) aged



between 6 and 59 months in the household. The foods consumed were recorded and classified into 16 listed food groups that were later re-grouped based on seven food groups for child dietary diversity score (CDDS) after Grijalva-Eternod et al. (2018) and 10 food groups for minimum dietary diversity for women (MDD-W) according to FAO (2018). In addition to dietary diversity and meal frequency, the number of months of exclusive breastfeeding and type of complementary food were recorded to assess the feeding practices for the reference child. The health status of the child was determined by looking for physical signs of malnutrition through observing their hair color and pallor of skin and diagnosing for bilateral edema using clinical tests recommended by the WHO (2014). The healthcare-seeking behavior of the household was determined through questions on immunization, vitamin A supplementation, occurrence of sickness in the previous month, and treatment received for the reference child. The proportions of reference children who

received Vitamin A supplementation, were immunized, showed physical signs of malnutrition, were sick in the previous 30 days, and received treatment for sickness were determined per household type. Provision of safe water, adequate feeding practices under normal conditions and in periods of food scarcity as well as access to health facilities when sick were used as indicators of good child caregiving. The nutritional statuses of the child and mother/caregiver were determined through anthropometry. The reference child’s age, sex, and birth weight were recorded, and their mid-upper arm circumference (MUAC), height (cm), and weight (kg) were measured following the recommended protocols of the Centre for Disease Control (2007). All measurements were taken twice and averaged. The female respondent’s weight and height were recorded for calculation of body mass index. The weight-for-age (WAZ), height-for-age (HAZ), and weight-for-height (WHZ) z scores were computed for the reference child per household and the data

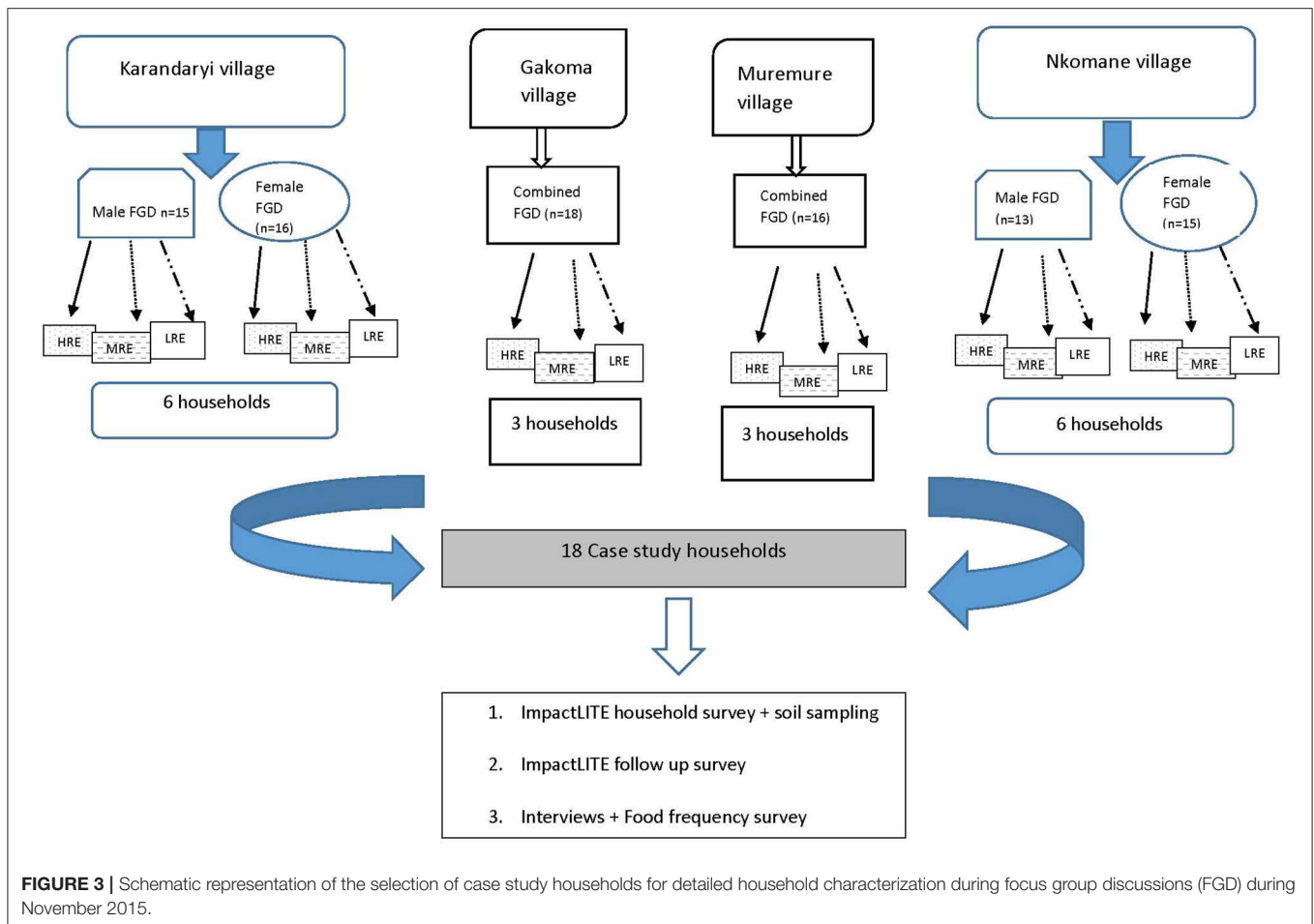


FIGURE 3 | Schematic representation of the selection of case study households for detailed household characterization during focus group discussions (FGD) during November 2015.

checked for plausibility using Emergency Nutrition Assessment for Standardized Monitoring and Assessment of Relief and Transitions software (ENA, 2011).

Household Typology Construction

A total of six FGDs were conducted at a central location in each of the four villages from November 14 to November 18, 2015. The aims of the FGDs were to determine the participants' perspective on household heterogeneity and the factors that varied between households, identify and characterize the household types within the village, and select case study households.

Purposive sampling was used to select, on average, 15 participants for each FGD session with a view to including the households that had been sampled in the nutrition survey. This was because the nutrition and health data had already been collected in the preceding nutrition survey such that the use of other sampling methods may have excluded these households. Village heads were encouraged to invite members from the poorest households in the village so as to ensure that households spanned the wealth spectrum of the village. The FGD facilitators were provided with a checklist of questions to guide the discussion while the assistant facilitator transcribed detailed notes of the discussion, which was carried out in the local

Kinyarwanda language. The following steps were followed during each FGD session:

1. Definition of a farm household—participants were invited to provide a definition for a farm household.
2. Listing of factors that differ between households—participants determined whether households in their village were homogenous or heterogeneous. If households differed, the factors responsible were identified and ranked according to importance by participants. This was done in turn for each of the identified factors through the facilitator asking participants to show by raising their hand if they believed a factor was position 1, 2, etc. The votes for each factor were tallied to determine ranking. Facilitators encouraged the participation of all members.
3. Identification of household types—based on the factors identified in step 2, participants identified and estimated the proportion of the household types found in the village. Discussions were had on proposed household types, after which the number and names of household types were arrived at.
4. Characterization of household types—participants discussed and developed a model of each household type on a flip chart showing the land area owned and cropped, household

demographics, crop and livestock production, and resource flows into and out of the household.

5. Formation of groups based on household type—participants were invited to identify which type their household belonged to and thereafter form groups. Using flip charts, each group characterized in detail a “typical” household for the identified household type and discussed and summarized the performance of the household with reference to farm production, natural resource management, food security, nutrition security, income generation, and empowerment. These objectives represented the intermediate development outcomes of the Humidtropics program. Discussions in each group were guided by facilitators.
6. At the end of the FGD session, one household was randomly selected from each group to give 18 case study households (Figure 3).

The information from the FGDs was collated and used to develop hypotheses on the heterogeneity of household types, which were subsequently tested using quantitative data collected from case study households.

Detailed Characterization of Case Study Households

Household surveys were conducted on the 18 case study households during November 16–24, 2015, using the IMPACTLite survey tool, which is an adaption of The Integrated Modeling Platform for Mixed Animal Crop systems (IMPACT) survey tool (IMPACTLite, 2017). Informed consent was obtained from each respondent prior to the interview. The data collected included information on the household composition, on-farm and off-farm activities, farm and off-farm income, household expenditure on food and non-food items, farm assets, household food consumption over the seasons, and qualitative open 24-h diet recall for woman and child. The general household information was categorized into human, natural, physical, financial, and social capitals according to the livelihood framework approach (DFID, 2000). The on-farm agrobiodiversity was measured as species richness computed as a count of the number of species of crops, livestock, fruit trees, and timber trees per household, area under crop, and food production per year for the household following the approaches of Fanzo et al. (2011) and Ekesa et al. (2008). The number of livestock was also converted into Tropical Livestock Units. Soil samples (~100 g) were collected from the upper 20 cm of the field that was closest to the homestead and analyzed for soil texture (percentages sand, clay, and silt), total nitrogen, soil organic carbon, phosphorus, and soil pH (water) using standard methods outlined by Anderson and Ingram (1993).

Follow-up interviews with household heads and/or spouses of the 18 case study households were done in season B during March 2016 to clarify issues identified during preliminary data analysis. In addition, all the participants in November FGDs were invited and grouped by household type to discuss availability and household access to different types of food and feed across the seasons in a second round of FGDs. From the FGDs, a list of available food and feed per season was compiled for each household type. A second qualitative

open 24-h diet recall for the female respondent and reference child was carried out during this time so as to check whether there were differences in consumption patterns with season. During August 2016, the heads of case study households and their spouses were interviewed on how they perceived their household to be performing with respect to farm productivity, income, food security, nutrition security, natural resources management, gender empowerment, and general wellbeing. Household performance was scored on a 5-point rating scale. For objectives with scores of ≤ 3 , respondents were invited to propose strategies to increase the score by making use of resources available to the household. Since the same interviewers were used in all interviews and the household numbers were relatively small, interviewers were able to probe the respondents on the strategies they were proposing and question their feasibility, as the household's available resources had been documented. Additional information on the household's knowledge of and interaction with social groups and external service agents active in the village within the past year was collected to augment information on social capital. A food frequency questionnaire was administered to respondents to obtain information on the frequency of consumption of food items per month (categories: daily, every other day, twice a week, once a week, once every 2 weeks, once a month, or not consumed at all) during the past 12 months by the household using a comprehensive list of food items developed during the FGDs in March 2016. The food frequency data were converted to average 7-day food frequency data for the months of November (season A) and March (season B), followed by grouping of all the consumed food items into specific food groups, after which the food consumption score (FCS) were determined according to WFP (2016). The household food consumption status was determined using the following FCS thresholds: 0–21: poor; 21.5–35 borderline; > 35 acceptable.

Data Analysis

Descriptive statistics were used to summarize differences in household types from the FGDs. Emerging observations that were common to participants or unique from the FGDs and interviews were presented as direct quotations. The information obtained from the FGDs was used to develop hypotheses on socioeconomic factors that varied with the identified household types, and the hypotheses were subsequently tested using statistical analysis for case study households. Of the 18 case study households, one household had missing nutrition and health data and was dropped from this study to give 17 households. On-farm agrobiodiversity was calculated using Shannon's diversity and evenness indices (Magurran, 2004). The method of Rahman and Kazal (2015) was used to calculate the Shannon diversity index (H') for crops:

$$\text{Crop } H' = - \sum (\alpha_i \times \ln \alpha_i) \quad (2)$$

where H' measures species diversity through the proportional abundance of species, with a higher value signifying greater diversity, α_i is the area share occupied by the i^{th} crop species in the cropped area per household, and \ln is the natural log.

The H' index for livestock was calculated using

$$\text{Livestock } H' = - \sum (p_i \times \ln p_i) \quad (3)$$

where the quantity p_i is the proportion of individuals found in the i^{th} species and \ln is the natural log.

Species evenness (J) was calculated as:

$$J = \frac{H'}{\ln N} \quad (4)$$

where J is the relationship between the observed number of species and the total number of species (N), with a greater value indicating greater uniformity between species abundances.

The percentage per household type of children with physical signs of malnutrition, a sick child in the past 30 days, and health-service seeking behavior (Vitamin A supplementation, immunization, and treatment of a sick child at a health facility) was determined. Scores from self-assessment of household types' performance in meeting household objectives were presented in a Radar diagram. The different strategies proposed by case study households to improve food and nutrition security were listed and grouped into categories, and the percentage per household type identifying each strategy were calculated. The effect of household types on household characteristics, soil properties, household capitals, agricultural biodiversity, CDDS, MDD-W score, FCS, and children's and women's anthropometry was determined using a General Linear Model Univariate Analysis of Variance (Statistical Package for the Social Sciences—SPSS Version 20) with household type as a fixed factor and village as a random factor at the significance of 5%. Household socioeconomic data from the IMPACTLite survey were used as they were more detailed than those from the nutrition survey. Due to missing data and quality issues, anthropometric data were used from 14 of the 17 households. For the 14 households, the normality of z scores was checked using the Shapiro–Wilk Test and z -scores with WHO flags that were likely to be in error (WHZ -5 to 5 ; HAZ -6 to 6 ; WAZ -6 to 5) were excluded from analysis (ENA, 2011). After checking data for violation of assumptions of ANOVA, financial capital data were square root ($x+0.5$)-transformed to homogenize variances. The Least Significant Difference at a 5% level of significance was used to separate treatment means. For transformed data, untransformed means are presented and separated based on ANOVA results. The relationship between household characteristics and food security indicators was determined using multiple linear regression analysis (SPSS Version 20). Prior to running regression, a multicollinearity test was performed through Collinearity diagnostics in SPSS and the Variance Inflation Factors (VIF) value was checked. Participants' perceptions and beliefs were used to enrich the discussion of results from the quantitative analysis.

RESULTS

Household Types From Participatory Typology Development

The majority of the FGD participants understood a farm household to consist of a husband, wife, and children. Only two out of the six focus groups included household assets as components of a household system, with one group stating that “A farm household is made of a husband, a wife, and children and their assets like farms, finances, livestock, etc. Assets include both fixed and movable.” During the FGDs, similar factors were identified across villages and by sexes as determinants of the differences between households in Kadahenda (**Table 1**). Four household types were initially identified—the “rich,” “moderately poor,” “poor,” and “very poor”—but were reduced to three when it emerged that the very poor group comprised mostly orphans with neither land nor houses. Since the main differences between the household types were based on resource endowment, the household types will hereafter be referred to as High Resource Endowed (HRE) for the rich, Medium Resource Endowed (MRE) for the moderately poor, and Low Resource Endowed (LRE) for the poor. The amount and source of household income were identified as the most important factors that varied between households (**Table 1**). The HRE households were estimated to have the highest annual income of up to RWF400,000, which was obtained from regular employment and sale of farm produce, while LRE households made the least, earning $< 60,000$ RWF per annum from casual labor. The HRE households were reported to own the largest amount of land (> 0.5 ha), have the largest and most diverse number of livestock, and to have the best houses relative to MRE and LRE households (**Table 1**). Although the type of household head was identified in 50% of FGDs, with LRE household heads reported to be female, widowed, young males, or the elderly, this was ranked as the least important factor. In each village, over half of the households were estimated to be MRE, with HRE in the minority at 10% (**Table 1**). Participants were of the belief that HRE households had greater financial, natural, and human capitals than the other household types in Kadahenda.

Socioeconomic Status of Household Types for Case Study Households

All the case study households were headed by males with spouses. There were no significant ($P > 0.05$) differences among the household types in the age of the household head, wives' education level, household size, and available family labor, but the distribution of wives' ages, education level of household heads, and natural, physical, financial, and social capitals significantly ($P < 0.05$) differed with household type (**Table 2**). The heads of HRE households were the most educated, having at the least attended secondary school. In contrast, the majority of household heads in MRE and LRE households had not completed primary school. The HRE households had higher ($P < 0.01$) natural capital than the other household types, as they owned (0.968 ha) and cropped (1.01 ha) land, which was at least $30\times$ that available to LRE households (**Table 2**). Kitchen gardens were small ($52 \pm 90 \text{ m}^2$) and did not differ significantly across household types. The acidic loamy soils did not significantly differ in soil organic

TABLE 1 | Categorization of household types according to factors identified and ranked by focus group discussion participants ($n = 93$) in Kadahenda Cell, Western Province of Rwanda.

Importance ranking	Factor	Household types (Est. mean % of households per village)		
		HRE (10%)	MRE (51%)	LRE (29%) [∞]
1.1	Estimated annual income ^β	200,000–400,000 RWF	60,000–200,000 RWF	< 60,000 RWF
1.2	Main sources of income	Regular employment and sale of farm produce	Casual employment and sale of farm produce	Casual employment
2	Land owned	$0.5 < x \leq 1.5$ ha	$0.2 < x \leq 0.5$ ha	≤ 0.2 ha
3	Livestock number and types	1–3 cows; 1–5 goats/sheep/pigs and 1–3 chickens/rabbits	1–5 goats/sheep/pigs; 1–3 chickens/rabbits	None
4.1	Building types	Main house, kitchen, and livestock shelter(s)	Mostly only main house	Main house
4.2	Condition of main house	“Good,” iron sheet roof, painted walls, cement floor, glass windows	“Moderate,” iron sheet roof or tile roof, mud walls	“Bad,” small house, tile roof, mud walls, wooden windows
5	Household head	Male-headed	Male-headed or female-headed (widows)	Female-headed (widows), child-headed (orphans), and young male heads

Factor ranked 1 the most important; [∞]Estimated average percentage of household type per village—the “very poor” category comprises the remainder; HRE, high resource endowed, MRE, medium resource endowed; LRE, low resource endowed; ^β November 2015 exchange rate 1USD = 746 RWF.

carbon, total N, and available P with household type (Table 2). Across household types, land was owned by both husband and wife, who jointly made decisions on its use and management.

Physical capital varied ($P < 0.05$) with household type, with the estimated value of buildings in LRE households being ~40% of that in other household types and the value of farm equipment owned by HRE households at least four times that in MRE and LRE households (Table 2). In Kadahenda, households generated income through a variety of means. In the HRE households, most household heads were either teachers or ran agro-related micro-enterprises in addition to farming. The majority of husbands and wives in MRE households were farmers and also worked as casual laborers on farms. Members of LRE households were mostly involved in casual employment on their neighbors' farms. The main income source was farming for HRE and MRE households and casual employment for LRE households (data not shown). There was no significant ($P > 0.05$) difference in the estimated annual household off-farm income and household savings (Table 2). The HRE households had the highest ($P < 0.001$) annual farm income of over RWF700,000 compared to less than RWF2,000 obtained in LRE households. The total annual income ranking was HRE \geq MRE \geq LRE, with farm income contributing over 50% to the income in MRE and HRE households. Conversely, in LRE households, total annual income consisted of 98% off-farm income. Decisions on how to use available household income were made jointly by spouses in all household types. Although there was no difference in memberships of local social groups, HRE households engaged with three times the number of external service providers as LRE households (Table 2). Of the 13 external services identified, 10 were from the agricultural sector with the Rwanda Agriculture and Animal Resources Development Board (RAB), the most frequently mentioned agent across villages and household types, followed by organizations such as ICRAF, CIP, ACIAR, and IITA (data not shown). The Ministry of Health (MINISANTE)

was listed as one of the agents met, with six out of the 17 households having interacted with MINISANTE during the past year, of which half of these households were from the LRE group. Only two HRE households reported that they had met with agents dealing with the water supply or Water, Sanitation, and Hygiene (WASH).

Agricultural Biodiversity

Reflecting the trend in land ownership, 2.1 ha was cropped per annum under HRE farms, and this was 42 \times the area cropped on LRE farms (Table 3). The number of plant species on LRE farms was about half of the 11 species recorded on HRE farms, with species richness intermediate on MRE farms. Of these plant species, household type had a significant ($P < 0.01$) effect on multi-purpose tree species richness, with LRE farms the least species-rich. There was no difference in crop, fruit tree, and fodder species number with household type (Table 3). On-farm Shannon's plant species diversity (< 1.5) and evenness (~ 0.5) did not significantly ($P < 0.05$) vary with household type. Of the area cropped per year, about 60% was under food crops on HRE and MRE farms as compared to close to 100% on LRE farms. The HRE farms had the greatest area under food crops (Table 4). Irish potato and common field beans dominated the farms and occupied $\geq 75\%$ of the area under food crops across household types. The area under kitchen garden per annum and food crop species richness, diversity, and evenness did not differ across household types. A male respondent from the MRE households was of the view that the Land Use Consolidation Program and its requirement to plant one crop per season was contributing to a reduced area under vegetables. Although he wanted to increase the area under vegetables, he was confined to growing them on the small area around his homestead as it was not permitted to grow vegetables on the fields. The remainder of the area under HRE farms was under trees such as eucalyptus and *Alnus acuminata* and fodder crops such as napier (data not shown).

TABLE 2 | Effect of household type on the livelihood assets of the case study households ($n = 17$) in Kadahenda cell, Rwanda.

Livelihood asset	Characteristic	HRE ($n = 6$)	MRE ($n = 6$)	LRE ($n = 5$)	Pr.
Human capital	Household head age, years	45	39	33	ns
	Spouse age, years	43	36	29	*
	Household head age education level [∞]	3a	2b	1b	*
	Spouse education level [∞]	2	1	1	ns
	Household size	7	6	5	ns
Natural capital	Available family labor	2	2	2	ns
	Land owned, ha	0.968a	0.296ab	0.031b	***
	Cropped land, ha	1.01a	0.296b	0.026b	**
	Kitchen garden, ha	0.005	0.007	0	ns
	Sand, %	43.4	48.3	47.3	ns
	Silt, %	39.9	33.4	36.0	ns
	Clay, %	16.8	18.1	16.8	ns
	soil pH (H ₂ O)	5.4	5.4	5.9	ns
	Soil organic carbon g/kg	0.75	0.702	0.75	ns
	Total N, g/kg	0.020	0.022	0.022	ns
	P, ppm	111.0	84.6	80.4	ns
Physical capital	Est. buildings value, RWF	2604875a	1725125a	103750b	*
	Est. value of farm equipment, RWF	57088a	15100b	2550b	**
Financial capital	Est. annual off-farm income, RWF	479375	255400	114985	ns
	Est. annual farm income, RWF	771244a	277888ab	1625b	***
	Est. annual total income, RWF	1250619a	533288ab	116610b	**
	Est. annual household savings	100476	55560	17250	ns
Social capital	No. of social groups known	3	3	4	ns
	No. of social groups household member of	2	1	1	ns
	No. of known external services providers	6	4	4	ns
	No. of external service providers engaged with	6a	4ab	2b	*

Means in a row followed by the same letter are not significantly different at $P < 0.05$; *, $P < 0.05$; **, $P < 0.01$; ***, $P < 0.001$; ns, not significantly different; LRE, low resource endowed; MRE, medium resource endowed; HRE, high resource endowed; Est., estimated; Education level scores[∞], 0 – No formal education; 1 – Primary School not completed; 2 – Primary School completed; 3 – Secondary School not completed; 4 – Secondary School completed.

The HRE households had, on average, six livestock, consisting of cattle, sheep, goats, chickens, and rabbits, compared to no livestock in LRE households (Table 3). The HRE farms had the highest livestock diversity, with a Shannon's diversity index of 0.8 for livestock. The number of species collected from the wild and used for food was <2 across the household types (Table 3). During the FGDs, HRE households identified insufficient fodder due to limited land as the main constraint to increasing the number of cattle. In addition, the wet and cold weather was reported to be unsuitable for chickens, often resulting in diseases and death. Sheep were preferred to goats as they were viewed as being more adapted to the environment and easier to rear together with cattle.

Food Consumption Patterns, Coping Mechanisms, and Behaviors During Food Shortage

During November 2015 in Season A, three to four food groups being consumed by women and children and dietary diversity did not differ with household type (Table 4). In general, diets consisted of mostly Irish potato, field beans, and vegetables,

and there was limited to no consumption of fruits, meat, and eggs (Table 5). During this major lean season, only the children from HRE households were meeting the minimum dietary diversity. Household food consumption during this period was acceptable in HRE households, borderline in MRE, and poor in LRE households, where the FCS of 20 was less than half of that in HRE households (Table 4). The number of meals consumed by children did not differ with household type, with the majority of children consuming three meals. In the face of food deprivation, 50% of HRE and 60% of MRE and LRE households' members engaged in more work than before to obtain money to purchase food (data not shown). The second most common coping strategy was to reduce meal numbers in HRE households, while members of LRE and MRE households either borrowed cash and food or did nothing. During lean periods, all households reported that they prioritized the feeding of children aged <5 years over other household members. During season B in March 2016, there were significant ($P < 0.05$) differences in MDD-W and FCS among the household types but not in CDDS (Table 4). The highest MDD-W score of 6 for HRE was twice as much as the scores for the other household types, with the women and children from HRE households

TABLE 3 | Agricultural biodiversity available on-farm and in the wild for the case study households ($n = 17$) by type in Kadahenda Cell.

Location	Species	Characteristic	Household type			Pr.	
			HRE	MRE	LRE		
On-farm	All plants	Cropped ha ⁻¹ annum	2.1a	0.65b	0.05b	**	
		Plant species number	11.0a	9.0b	5.3c	*	
		Crop species number	6.5	5.6	3.5	ns	
		Multi-purpose tree species number	2.5a	1.8ab	1.0b	**	
		Fruit tree species number	0.9	0.9	0.1	ns	
		Fodder species number	1.3	1.0	0.6	ns	
		Shannon's species diversity	1.1	1.2	0.8	ns	
		Shannon's species evenness	0.5	0.6	0.5	ns	
		Food crops	Food crop ha ⁻¹ annum	1.26a	0.40b	0.05b	*
			Kitchen garden ha ⁻¹ annum	0.005	0.007	0.000	ns
	Irish potato ha ⁻¹ annum		0.57a	0.15b	0.02b	*	
	Bean ha ⁻¹ annum		0.49a	0.15b	0.02b	**	
	Food crop species number		6.8	6.5	3.6	ns	
	Shannon's diversity index		0.9	1.1	0.7	ns	
	Shannon's evenness		0.5	0.6	0.7	ns	
	Livestock	Livestock number	6a	1.0b	0b	*	
		Livestock species number	2.5a	0.6b	0b	**	
		Tropical Livestock Units	1.1	0.2	0	ns	
		Number of cattle	1.4	0.3	0	ns	
		Number of goats and sheep	2	0.5	0	ns	
Number of chickens and rabbits		2	0.4	0	ns		
Shannon's diversity index		0.8a	0.0b	0.0b	***		
Communal area	All	Number of wildlife species used for food	1.9	1	0.1	ns	

Means in a row followed by the same letter are not significantly different at $P < 0.05$; * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$; ns, not significantly different; LRE, low resource endowed; MRE, medium resource endowed; HRE, high resource endowed.

TABLE 4 | Food consumption and anthropometric data of the different case study households by household type in Kadahenda Cell.

Indicator		Sampling time and household type								
		November 2016 (season A)				March 2016 (season B)				
		HRE	MRE	LRE	Pr.	HRE	MRE	LRE	Pr.	
Food consumption	Child dietary diversity score	4	3	3	ns	4	3	3	ns	
	Child meal frequency	3	3	2	ns					
	Minimum dietary diversity-women	4	3	4	ns	6a	3b	3b	*	
	Food consumption score	59a	32b	20b	*	59a	61a	20b	*	
Anthropometry	Child	Mid-upper arm circumference	15.1	14.0	15.6	ns				
		Height-for-age Z score	-3.3	-2.2	-2.3	ns				
		Weight-for-age Z score	-2.3	-1.9	-0.9	ns				
		Weight-for-height Z score	0.8	-0.6	0.75	ns				
	Maternal	Mid-upper arm circumference	26.0	26.1	23.4	ns				
		Body mass index	24.2	23.4	22.0	ns				

Means in a row followed by the same letter are not significantly different at $P < 0.05$; * $P < 0.05$; ns, not significantly different; LRE, low resource endowed; MRE, medium resource endowed; HRE, high resource endowed.

meeting their minimum dietary diversity. During March, there was increased consumption of fruits, flesh foods, nuts, and seeds by women in HRE households compared to November (Table 5).

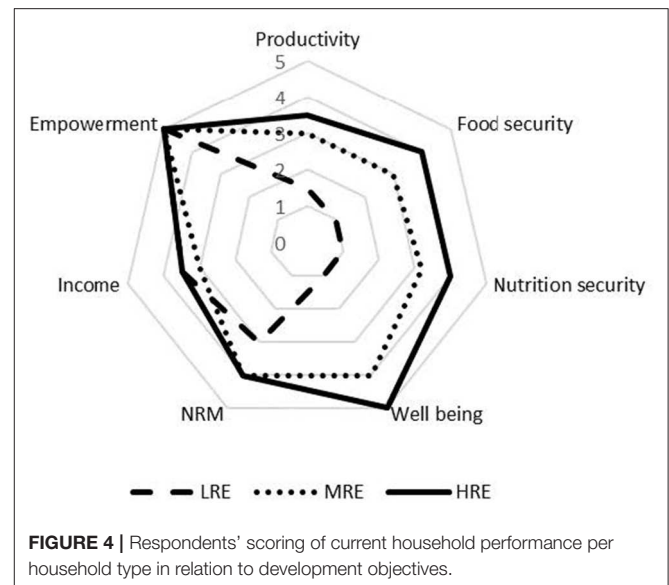
Food consumption status in the LRE and HRE households was maintained at poor and acceptable levels, respectively. The March FCS in MRE households was almost double that in

November, leading to an acceptable food consumption status (Table 4). A greater proportion of MRE households than before reported consuming fruits and meat in March (Table 5). In both seasons, there was no consumption of meat and eggs in LRE households. In all households, there was not much difference in the composition of children's and adult's diets.

It was evident from the interviews held during August 2016 that having sufficient food quantities for all household members was an important household objective. However, the LRE and MRE households reported that they were not achieving this objective (Figure 4) due to a lack of land to produce food, low crop productivity, and a lack of income to purchase food. The majority of HRE households rated their performance toward achieving household nutrition security highly, although issues such as limited income to purchase food from markets, weather-related challenges, and insufficient knowledge about sources and preparation of food for balanced diets were identified as barriers to achieving nutrition security. Although nutrition security was important in MRE households, low on-farm production and lack of income to purchase food from markets were identified as the main constraints to diversifying diets (Figure 4). The LRE households admitted that their performance in meeting nutrition security was poor, and furthermore, it emerged that achieving nutrition security was not seen as an important household objective by some respondents. This was illustrated by the statement, "Nutrition does not matter. What is important for us is to eat plenty," which was made by a 40-year-old woman from Karandaryi village, with the same view shared by a 31-year old female from Gakoma village.

Anthropometric and Health of Women and Children

The reference children consisted of 6 boys and 8 girls, with the majority aged 30–53 months and the youngest 8 months old. Reference children from LRE households were all older than 30 months. All the children were reported to be fully immunized and had received vitamin A supplements. They all had birth weights of >2.5 kg and were observed to have no edema, with skin and hair in good condition (data not shown). All children were exclusively breastfed for 6 months except for one child from an MRE household. Five children were still being breastfed, including one from an MRE household aged 27 months and another from an HRE aged 42 months. Porridge was the most commonly identified complementary food, followed by household food. There were no significant ($P > 0.05$) differences in the MUAC (14.9 ± 1.52), HAZ (-2.06 ± 1.2), WAZ (-0.89 ± 1.1), and WHZ (0.37 ± 1.2) of reference children (Table 4). Half of the reference children were stunted (HAZ < -2). Over 40% of the women and children had been sick in the last 30 days. Of the reference children, 60% of those from LRE households were sick compared to 40% from MRE and HRE households (data not shown). All the sick children from HRE households were taken to the hospital. Two-thirds of sick children from MRE households received treatment at a hospital, while the remainder received no treatment. Treatment for sick children from LRE households was equally divided



among treatment in a hospital, medication purchased from a pharmacy, and treatment by a traditional healer. None of the mothers/caregivers from HRE households were sick, compared to 60% in both LRE and MRE households. Of the sick in MRE households, one did not seek treatment, while treatment for the remainder was obtained from either a hospital or a traditional healer. Only a third of sick mothers/caregivers from LRE households sought treatment, and this was obtained at a hospital. Two LRE households had both a mother/caregiver and a child being sick during this period, and in each case, treatment was received at the hospital. There were no significant differences in women's MUAC and BMI (23.7 ± 3.36) among household types (Table 4).

Access to Water, Markets, and Health Facilities

There were no significant ($P > 0.05$) differences in the round-trip distance to the safest water source, open-air markets, trade, and health facilities among the household types (data not shown). The safest and nearest water sources, open-air markets, trading centers, and health facilities were more than 2 km round trip distance for the majority of the households. A borehole was the most commonly used water source in Kadahenda.

Relationship Between Household Characteristics and Food Security Indicators

No significant ($P > 0.05$) relationships were found of socioeconomic characteristics with WAZ and WHZ. There was a moderately strong ($r^2 = 0.47$) significant ($P = 0.005$) positive relationship between MDD-W, off-farm income, and livestock species number during November, highlighting improvements

TABLE 5 | The percentage of women and children per household type for case study households ($n = 17$) that reported consuming food from standard food groups during 24-h recalls conducted in November 2015 and May 2016 in Kadahenda Cell.

Individual	Food groups	Commonly consumed foods	Consumption per household type (%)					
			November 2015 (season A)			March 2016 (season B)		
			HRE ($n = 6$)	MRE ($n = 6$)	LRE ($n = 5$)	HRE ($n = 6$)	MRE ($n = 6$)	LRE ($n = 5$)
Woman	1. Grains, white roots and tubers, and plantains	Irish potato, maize, sorghum, rice, wheat, sweet potato	100	83	80	100	100	80
	2. Dark green leafy vegetables	Amaranth, nightshade, cassava	83	50	100	83	83	60
	3. Other Vitamin A-rich fruits and vegetables	Carrots and pumpkins	17	17	20	0	0	20
	4. Other vegetables	Tomato, onion, cabbage	67	50	20	83	33	40
	5. Other fruits	Avocado	0	0	0	100	33	20
	6. Flesh foods	<i>Ndagara</i> (whitebait) fish	0	0	0	50	0	0
	7. Eggs		0	0	0	0	0	0
	8. Pulses	Field beans, groundnuts, peas	100	83	80	100	50	40
	9. Nuts and seeds	Groundnuts	0	0	0	67	0	0
	10. All dairy	Milk	0	0	0	17	0	0
Child	1. Cereal, roots, and tubers	Irish potato, maize, sorghum, rice, wheat, sweet potato	100	67	80	100	100	80
	2. Vitamin A-rich fruits and vegetables	Carrots and pumpkins	83	50	100	83	67	60
	3. Other fruits and vegetables	Avocado, tomato, onion, cabbage	67	50	60	100	67	40
	4. Meat products	<i>Ndagara</i> (whitebait) fish	0	17	0	50	0	0
	5. Eggs	Chicken eggs	17	0	0	0	0	0
	6. Legumes and nuts	Field beans, groundnuts, peas	100	83	80	100	50	40
	7. Milk and milk products	Milk	33	17	0	17	33	0

HRE, high resource endowed; MRE, medium resource endowed; LRE, low resource endowed; number of households surveyed per type in brackets.

in women's dietary diversity, with increased household off-farm income and livestock species number (Table 6). A similar relationship was also observed for CDDS and the same predictors ($r^2 = 0.42$; $P = 0.01$) at this time (data not shown). During March, the household head's education level and estimated value of buildings explained 88% of the variance in MDD-W, indicating an increase in women's dietary diversity with an increase in the two predictors (Table 6). The same predictors explained 69% of variance in CDDS during March. Food consumption score significantly increased with total household income in both seasons, together with the number of goats and sheep in November and the number of external services agents engaged with by households in March (Table 6). Height-for-age score for children aged 6–59 months had a significant but negative moderately strong relationship with livestock number, which indicated that an increase in livestock number by one unit caused a decrease in HAZ of 0.25 after controlling for the positive but non-significant effect of household head's age (Table 6).

Self-assessment of Household Performance and Strategies Identified to Improve Identified Objectives

All households believed husbands and wives were empowered (Figure 4) to make decisions on how to use household resources. However, the issue of husbands in the LRE households spending money on alcohol instead of on items that could benefit the whole family often emerged during FGDs. Although income and farm productivity were scored below four due to biotic and abiotic constraints, HRE households rated their natural resource management and food and nutrition security as good, resulting in an overall score of five for household well-being. In MRE households, their perception of their performance placed them intermediate between the other household types, with scores of around three. The LRE households viewed their well-being as poor, as scores were below three for farm productivity and food security, while nutrition security was scored at 1. The activities proposed by case study households in

TABLE 6 | Relationship between households' characteristics and food consumption indicators and anthropometry for case study households in Kadahenda Cell.

Characteristic	Food consumption indicators				Anthropometry
	November 2015		March 2016		Height-for-age z score
	MDD-W	Food consumption score	MDD-W	Food consumption score	
β coefficients					
Constant	2.6 (0.29)	22 (5.36)	1.4 (0.30)	16 (9.88)	-4.1 (1.06)
Head's age					0.06 (0.3)
Head's education level			0.9*** (0.14)		
Livestock #					-0.25* (0.08)
Livestock species #	0.3 (0.15)				
Goats and sheep #		4.1 (2.46)			
Off-farm income	2E-06* (6E-07)				
Total income		2E-05** (6E-06)		3E-05*** (9E-06)	
Est. buildings value			5E-07*** (9E-08)		
# of external agents interacted with				5.0 (2.59)	
Adjusted R ²	0.47	0.59	0.88	0.60	0.49
Pr.	0.005	0.001	0.000	0.001	0.019
Observations	17	17	17	17	12

Standard error of coefficient in parentheses; * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$, MDD-W, minimum dietary diversity - women, household characteristics, and food security indicators with non-significant ($P > 0.05$) relationships are not shown.

Kadahenda as means to improve their household's performance can be classified into those that increased household income, crop production, livestock production, food consumption, and the acquisition and/or application of knowledge (Table 7). For both HRE and MRE households, the focus was on improving farm productivity, as shown by the strategy proposed by a 37-year-old female respondent from an MRE household in Gakoma village,

"We work for wages from a terrace making project where we can save up to 20,000 RWF per month. This saving will be used to buy good planting materials of potatoes and, within one year, buy a cow. Using improved planting materials will help in increasing production, attaining food security, and increasing income. The cow will help to get manure for soil fertility management (NRM) and milk for balanced nutrition. The cow will be fed fodder planted in erosion control trenches. Both husband and wife will save money. The whole activity will contribute to the family wellbeing."

For LRE households, 80% of respondents identified joining savings groups and using savings to purchase small livestock such as sheep, rabbits, and chickens, which would be sold for income and provide manure to increase crop yields. A 23-year-old married woman with two children from Muremure village said that,

"The only solution I have is to work with savings groups, because I am convinced that there is strength in unity. Savings groups will help me to be able to buy a sheep, which will provide us with manure to improve soil fertility. By using manure in the farm, the farm productivity will increase, and when the farm productivity increases, the food security will increase as well. The money I

spend on buying food will reduce, and then this money will be used for other needs like buying other food that is not produced on the farm (nutrition security improved). When the sheep gives birth, I will sell some of the lambs in order to increase income. This income will serve for different needs like buying agricultural inputs or renting farms (in order to increase farm productivity), buying clothes, paying health insurance, etc. through which the wellbeing/social development of the household will be improved."

However, not all respondents were so positive about the prospects for improving their livelihoods. A 33-year-old married female from Karandaryi village with a similar educational background and resource base to the 23-year-old quoted above could see no way of improving the food and nutrition security or well-being of her family of four, as when they got a chance to be employed, she and her husband only earned 1000 RWF per day. All the money was spent on food, which was not enough to feed the whole family. Since they could not afford to buy improved potato seed, they were only growing climbing beans on their land, which was 0.05 ha in area.

Looking for more employment opportunities was identified by only a few respondents as a feasible strategy. During the FGDs, it emerged that there were not enough employment opportunities in Kadahenda. Although people would have wanted to work for more days, this was not possible unless they traveled to Kigali to find work. In addition, women had fewer employment opportunities than men, as women reported that men were preferred and hired first for any jobs that were not casual labor on farms. The need to earn a daily wage with which to purchase food limited the employment opportunities for LRE households. In addition to being paid daily, the other reported advantage of working for their neighbors was that they could be paid in kind, i.e., with seed for vegetables, manure

TABLE 7 | Strategies proposed by case study households to improve food and nutrition security by household type in Kadahenda Cell.

Activity	Proposed strategy	Percentage per household type		
		HRE(<i>n</i> = 6)	MRE(<i>n</i> = 6)	LRE(<i>n</i> = 5)
Increase household income	Employment	17	0	20
	Sell crops	17	17	0
	Sell livestock	0	0	80
	Better financial management	33	33	20
	Borrow money	0	17	0
	Join savings group	0	17	80
	Apply for bank loan	17	0	0
	Invest more in off-farm enterprise	17	0	0
Crop production	Purchase improved seed and inorganic fertilizers	67	67	60
	Use manure	17	33	80
	Maintain kitchen garden throughout the year	0	33	0
	Diversify kitchen garden	17	0	0
	Change planting dates	33	0	0
	Rent more land	0	0	20
Livestock production	Increase area under trees	17	33	0
	Rear chickens/rabbits	17	0	40
	Rear sheep	0	17	40
	Rear cow	0	17	0
Consumption	Increase area under fodder	17	17	0
	Purchase food not grown on-farm	33	50	60
Knowledge application	Consume animal-sourced food	0	17	0
	Use RAB training	17	17	0
	Engage with leaders on land consolidation policy	0	17	0

HRE, high resource endowed; MRE, medium resource endowed; LRE, low resource endowed.

for fields, etc., which they could use on their own pieces of land.

DISCUSSION

According to the community in Kadahenda, households differed in financial, natural, and physical resources, resulting in three household types. Analysis of the case study households showed that the three types of households lay along a gradient of livelihood capitals and significantly differed in on-farm agrobiodiversity and food consumption. The better food security status in HRE relative to LRE households was a reflection of the moderately strong relationships observed between household characteristics and food security indicators. Although all households in Rwanda are placed in an *Ubudehe* category, Nizeyimana et al. (2018) concluded that these categories were not truly reflective of the socioeconomic status of Rwandan households, as they had poor correlation with household poverty and consumption. Consequently, the use of a participatory household typology construction method in this study provided for a context-specific categorization of households in Kadahenda.

The HRE households' heads were the best educated and worked as teachers or ran micro-enterprises. In contrast, the

less educated members from the LRE households were mostly involved in casual wage employment on nearby farms. It emerged from discussions that the poorest households preferred to work as farm laborers despite the lower remuneration compared to tea estates, which pay on a monthly basis. Thus, the need to purchase food from markets daily due to low on-farm production was excluding the LRE households from better-paying employment opportunities. Given this need by LRE households to purchase food with income from employment, programs such as the Integrated Development Program should consider creating jobs that have several wage payment options to meet the immediate income needs of the poorest households. The low wages and little to no income coming in from farming due to owning and cropping the smallest amounts of land with the least agrobiodiversity were probably the reasons LRE households had the least household income. Since rural households in Sub-Saharan Africa mainly access food through their own farm production and/or purchase of foods from the local markets using on-farm and off-farm income (Fraval et al., 2019), the LRE households had limited physical and economic access to food. This was seen in the poor household food consumption and failure to meet the minimum dietary diversity for women and children during both November and March.

The significant relationships of the education level of the household head, buildings value, crop and livestock diversity,

number of sheep and goats, off-farm income, total household income, number of external service agents engaged with, and food consumption indicators underscored the better food security in HRE households. Our results confirm the findings of Damon and Drewnowski (2008) and Nzayisenga (2015) that there is increased household food security with high socioeconomic status and also showed a positive relationship of household dietary diversity with on-farm diversity, as reported by Sibhatu et al. (2015) and CFSVA (2015). Following reported trends in Sub-Saharan Africa, dietary scores of ≤ 4 were recorded during November for all households and in March for LRE and MRE households. The major lean season in Rwanda falls in October and November, during which time most of the harvested food is depleted and households access food through markets (WFP, 2016), and this may explain the poorer food consumption observed across households in November compared to March. Prices for most annual crops like Irish potatoes and beans peak just prior to this major lean season (CFSVA, 2015), resulting in reduced access to foods, especially for households with limited financial means. In this study, LRE and MRE households identified taking on more work to earn additional income to purchase food as a coping strategy during the major lean season. However, respondents indicated that there were generally limited opportunities for employment in the area. Members of LRE households and women reported not being able to consistently secure work on HRE farms. The same issue was raised by the other household types with respect to access to work on tea estates and the Vision *Umurenge* Program.

Physical access to safe water sources, markets, and health centers was unlikely to be a barrier to food and nutrition security, as all survey households in Kadahenda had reasonable access to these. The health service-seeking behavior of households was generally good, although a greater proportion of sick children and women in LRE and MRE households were not taken to a clinic compared to those from HRE households. This was perhaps due to a lack of money or medical insurance in the less resourced households. Inadequate feeding practices and diseases were likely the causes of child stunting in Kadahenda, where HAZ was 2 standard deviations below international standards for 50% of reference children. This finding was consistent with the report of CFSVA (2015) that 42% of children in the Western Province were stunted. It was also observed that stunted children were found across all household types in Kadahenda, including in households that had the highest socioeconomic and food security status. The majority of children surveyed were aged 30–53 months, an age associated with a higher risk of stunting in Rwanda due to inadequate nutrition, according to Habimana and Biracyaza (2019). Although the level of nutrition education was not directly assessed in this study, Ho and McLean (2011) found that caregivers in Rwanda lacked knowledge of appropriate feeding practices of young children to address micronutrient deficiencies. What was observed in this study was that although most children had been exclusively breastfed for 6 months, they were reported to consume diets that did not greatly differ from those of the rest of the household, and meal frequencies were less than four. This likely led to micronutrient deficiencies, given

the low consumption of animal-sourced and fatty foods, even in HRE households, where diets were relatively more diverse than those in the other household types. Timler et al. (2020) found that despite purchases of food from markets to supplement the food produced on maize-bean-dominated smallholder farms in Kenya, there were still deficits in micronutrients such as calcium, iron, zinc, and vitamin A at the household level. There is, therefore, a need to continue sensitizing caregivers and the community to improved feeding practices for infants and children as part of the ongoing Maternal, Infant, and Young Child Nutrition program. Furthermore, increased promotion by MINAGRI and RAB of crops fortified with Vitamin A, zinc, and iron such as the maize, sweet potato, beans, and rice cultivars being promoted in Rwanda by HarvestPlus (Oparinde et al., 2015) can be another way of tackling the issue of micronutrient deficiencies. Increased production will eventually translate into more of the bio-fortified crops being available on markets. The inadequate nutrition may have contributed to diseases/infections, as, in this study, 50% of children had been sick during the month prior to the nutrition survey. In addition to food inadequacy, an unhealthy household environment may have resulted in children being sick. An unhealthy environment in households with livestock may be the reason for the decrease in HAZ with an increase in the number of livestock owned in this study. There have been reports of stunting in households that own livestock due to the creation of an unhealthy environment where children are exposed to fecal material and zoonotic pathogens (Marquis et al., 1990; Kagira and Kanyari, 2010). From interactions with members of the community, there seemed to be poor knowledge of nutrition and its importance, suggesting the need to raise the nutrition awareness of households by increased training on balanced diets and how these differ for members of households.

The small area under the kitchen garden and lack of differences in fruit tree diversity among household types were surprising findings given that the Government of Rwanda introduced the Kitchen Garden Program nationwide (Rwanda Agriculture Animal Resources Development Board, 2019) as a program to improve household nutrition. We were expecting significant differences between household types, given that MRE and HRE households had a high level of engagement with external service agents such as RAB, government ministries, and international research and development organizations than did LRE households. The observed lack of differences in the sizes of kitchen gardens may have been due to farmers adhering to the structure of kitchen garden promoted by the Ministry of Agriculture and Animal Resources (MINAGRI) under the Kitchen Garden Promotion Program. According to Sommers and Schalkwijk (2017), there is a need for more flexibility in the promotion of the kitchen garden in Rwanda, with less emphasis placed on structure and more on the crops to be included to ensure that they address the specific nutritional needs of the community. The low species diversity and evenness indices across farms in our study were probably due to the small area of kitchen garden and lack of diversity in vegetables and fruits. For example, although HRE farms had more than 10 plant species, most of the area was under the staple Irish

potato, common field beans, and woodlots with eucalyptus and *Alnus acuminata*. Avocado was the only commonly grown fruit, while kitchen gardens were, on average, <0.5% of the cropped area on HRE farms, with a similar trend observed for the other household types. The Land Use Consolidation program, a pillar of the Crop Improvement Program, has traditionally focused on maize, rice, Irish potato, wheat, cassava, beans, and soybeans as the priority crops, and this is likely the reason for the reduced diversity on farms. While these policies have had a positive impact on the consumption of staple crops, there has been a reduction in the consumption of meat, fish, and fruits (Del Prete et al., 2019). There is, therefore, a need to make these programs nutrition-sensitive through considering both yield and nutrient productivity. Options include the promotion of bio-fortified crops and including nutrient-rich vegetables as crops, as was suggested by a farmer from the MRE group. Increasing the participation of farmers in program formulation and the choice of crops to include in the program may be a good strategy going forward. According to Ntihinyurwa and Masum (2017), the land use consolidation program in its current form is using a top-down approach, with limited farmer participation in its formulation. Increasing the kitchen garden area and number of fruit trees are potential entry points for diet diversification in Kadahenda, as Keding and Cogill (2013) found a direct link between the production of traditional vegetables and their consumption by households. In addition, Timler et al. (2020) found that traditional vegetables such as African nightshade (*Solanum americanum* L.) and purple amaranth (*Amaranthus blitum* L.) had high economic returns. Programs to identify livestock species adapted to an area and feed resources are another potential entry point to diversify household diets and incomes. Giving the community a voice in analyzing and proposing solutions to their problems may be more sustainable than the top-down approach traditionally used in nutrition interventions, as communities can take the initiative to mobilize resources to solve their own problems (WHO, 2001).

The strategies proposed by households to address the challenges of food and nutrition security reflected the livelihood assets available to the household types. The HRE and MRE households were more focused on better financial management of available income and resources so that they could improve crop productivity through the use of improved seed and fertilizers. Initial strategies for improving food and nutrition security for these households can be focused on increasing and diversifying the farm/crop productivity strategies classified by Fiorella et al. (2016) as agricultural enhancement and diversification interventions. The proposed strategies highlighted the knowledge base of the respondents, which was generally strong in agriculture, probably due to most of the households that had met with external service agents in the preceding 12 months being from this sector. Nutrition and health-related interventions tended to be given in general terms, suggesting the need for more interactions with MINISANTE and organizations working on nutrition and health, as interactions of households with these were low. The strategies of the land-limited LRE households

are more livestock production-oriented, with a focus on small livestock such as sheep, rabbits, and chickens.

Interventions such as savings groups, access to loans, and knowledge to intensify crop and livestock productivity were identified as important. Small stock pass-on programs similar to the pass-on-a-cow/*Girinka* scheme may be one option that can be considered by government and development organizations as an intervention for LRE households in Kadahenda. However, although most households were quite positive about the potential of their plans to move them from their current positions of food and/or nutrition insecurity, there is a need for households to access technical information through training and demonstrations. Of importance would be farmer-to-farmer extension, as, for example, the HRE households were already aware of some of the challenges of keeping chicken and goats/sheep in the area, such as diseases and fodder unavailability. Most the LRE households seemed to be largely unaware of these challenges, since they had no experience in livestock production. Another important consideration, given the small homestead of LRE households, is the issue of exposing children to fecal matter and zoonotic diseases as a result of rearing livestock. All these factors need to be carefully considered before programs are implemented. Improving the amount of household income through employment was lastly seen as unfeasible since the opportunities for employment were limited in the area. Programs that can provide for various types of employment throughout the year could potentially increase household income, which may be used to purchase more food from the markets. With nutrition training, this can translate into the purchase of more nutritious food if it is available at local markets.

While our study corroborates the findings of other studies with respect to the general relationship between household socioeconomic status and food security, the use of a participatory approach and qualitative data captured the perception of the community in Kadahenda on their food and nutrition status and how this can be improved. The strategies proposed by the respondents in Kadahenda showed that they were aware of the need for a multi-pronged approach to tackle the social, economic, and technical causes of household food and nutrition insecurity. Based on emerging evidence from Fraval et al. (2019) and Heumesser and Kray (2019), interventions that prioritize on-farm productive diversification have the potential to enhance household food and nutrition security while at the same time improving ecosystem resilience in areas such as Kadahenda and elsewhere. This is because Kadahenda is located in an agroecology with high agricultural potential but a fragile ecosystem susceptible to land degradation. In this study, most farms were growing a number of crops for different purposes, including for food, fodder, income generation, and soil conservation. Although livestock numbers were low, with the majority of HRE and MRE households having < 1 Tropical Livestock Units, livestock production was identified by all household types as a strategy to improve multiple household objectives, including food and nutrition security. Enhancing on-farm diversity in Kadahenda through the introduction and promotion of improved livestock species and crop varieties

adapted to the climatic and biotic challenges faced by farmers is one pathway that can be used to improve food and nutrition security as well as the resilience of households and farms. This is because diversification leads to a better-functioning ecosystem that is more resilient to stresses and shocks (Heumesser and Kray, 2019). Furthermore, Fraval et al. (2019) found that in Sub-Saharan Africa, household members of farms with more productive diversity had better nutritional outcomes than those whose farms had less on-farm diversity. This was attributed to the observation that the households were not purchasing food from markets that nutritionally complemented the food produced on-farm. Increased production of nutrient-dense and diverse food on farms is expected to translate into increased availability of nutritious food in markets.

Households require income to purchase food such that increasing household incomes is another means to improve household food and nutrition security. For households such as the HRE and MRE households in our study, over 50% of household income was derived from the sale of farm produce, highlighting the importance of this revenue stream. The diversity seen in crops was also reflected in the number of crops sold, with the proportion sold varying with crop, household, and season. According to the farmers, there was a relatively good market for their farm produce, especially for vegetables such as carrots and cabbages. Interventions that increase productivity, diversify value chains, and improve access to markets are crucial for increasing the income of such households. For the land-limited LRE households, meanwhile, interventions that create more opportunities for off-farm employment can result in improvements in food and nutrition security. As seen in this study, these poor households depend mainly on income to purchase food, as their own production is low. In an area such as Kadahenda, agriculture is central to livelihoods, such that improvements of activities along the different value chains can potentially result in more employment opportunities for all household types. In such an interconnected community, benefits to one household type can accrue to other households resulting in a food- and nutrition-secure community. Increased off-farm employment also means having multiple income streams, which would protect MRE and HRE households in the face of a bad agricultural season. The increased household income can potentially be used to purchase inputs for agriculture and food from markets and improve the family's well-being. However, increases in income do not always translate into improvements in household nutrition, as this depends on what is purchased from markets. If income is used to purchase processed foods and/or foods that do not compensate for the nutrients/micronutrients that are not being provided by food produced on-farm, the contribution of increased income in improving food and nutrition security is limited. For this reason, Heumesser and Kray (2019) also include the food environment as another pathway to food and nutrition security. This is because even if nutritious foods are available on the farm and/or markets, without nutrition awareness, people may not consume it, opting instead to sell it and/or purchase foods with limited nutritional value. In the case of Kadahenda, where knowledge of nutrition was low, a possible strategy, which has been successfully used in Malawi and

Zambia, is to include nutritional education as part of agriculture training programs. This is highlighted by Dumas et al. (2018) with respect to the relationship of livestock to child nutrition, which can be both either positive or negative. It is positive if households are aware of the nutritional value of animal-sourced foods and include these in family diets but can lead to stunting if children are exposed to fecal matter due to poor hygiene. There is, therefore, a need to train households in management, link households to markets, and increase knowledge of the nutritional benefit of interventions. The role of government in enacting policies that sustainably increase agricultural yield and nutrient productivity is important. These policies may entail an expansion in the number of crops considered in programs such as CIP to include vegetables and other non-staple crops to address identified micronutrient deficiencies in an area. In addition, there is a need to develop infrastructure and markets as well as to provide research and extension services that recognize the importance of prioritizing both food and nutrition security. With support from the government and demand for diverse and nutritious food, farmers are likely to produce and consume foods that lead to improved nutrition and health.

CONCLUSION

Socioeconomic status was perceived to differ among households in Kadahenda, with high, medium, and low resource endowed household types identified during participatory household typology construction. Case study households representing the household types were found to differ significantly ($P < 0.05$) in human, natural, physical, financial, and social capital. The HRE households had the most educated household heads, landholdings of ~ 1 ha, highest agricultural biodiversity, and most valuable buildings and farm equipment, earned the highest farm income and total household income, and engaged with the most external service agents. The significant relationships found between the capital indicators and food security indicators of households probably explained the better food security in HRE households across seasons relative to the other household types. Food security was intermediate and diets poor in the MRE households. The LRE households were both food insecure and nutrition insecure, with a poor food consumption score, and the minimum dietary diversity was not met for women and children. However, nutritional status did not vary with socioeconomic status, as there was no difference in the anthropometric data of women and children. Half of the children were stunted (height-for-age z-score -2.06 ± 1.2), including those in HRE households, probably because of inadequate diets that did not vary from those of adults and poor health. Improvements in farm productivity, including kitchen gardens and small livestock, and opportunities to diversify household income generation were identified by community members as potential solutions to food and nutrition insecurity. Household food and nutrition security in Kadahenda can, therefore, be enhanced through interventions that improve on-farm production diversity and increase farm and off-farm income in combination with increased nutrition awareness advocacy.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation, to any qualified researcher.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by senior researchers from Rwanda Agriculture Board, Bioversity and IITA. Oral informed consent was obtained from all participants given considerations of participants' literacy in the study area. Written informed consent from the participants' legal guardian/next of kin was not required to participate in this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

NM and BE led the conceptual development of the farming system and nutrition research protocols and the writing

of the manuscript. CN led the data collection. NM and BE conducted the statistical analysis, with MG providing comments. CN, JG, EN, and BV provided extensive comments on the research protocols and manuscript. All authors contributed to manuscript revision and read and approved the submitted version.

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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