Participatory exploration of the heterogeneity in household socioeconomic, food and nutrition security status for the identification of nutrition-sensitive interventions in the Rwandan Highlands

Nester Mashingaidze[1*], Beatrice Ekesa[2], Pierre Celestin Ndayisaba[3], Emmanuel Njukwe[1], Jeroen C. Groot[4], Munyaradzi Gwazane[5], Bernard Vanlauwe[6]

[1]International Institute of Tropical Agriculture, Burundi, [2]Bioversity International (Uganda), Uganda, [3]Rwanda Agriculture Board, Rwanda, [4]Wageningen University and Research, Netherlands, [5]Midlands State University, Zimbabwe, [6]International Institute of Tropical Agriculture (IITA), Kenya

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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

Author contribution statement

NM and BE led the conceptual development of the farming system and nutrition research protocols and writing of 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 research protocols and manuscript. All authors contributed to manuscript revision, read and approved the submitted version.

Keywords

Household typology, Livelihood capital, agricultural biodiversity, food consumption, Anthropometry

Abstract

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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 determine differences in 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. 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 land holdings (~1 ha), highest agricultural biodiversity, total and farm income annum-1. This probably resulted in better diets for women and children and 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. Over 50% of the children were stunted including some from the more food secure HRE households. Un-diversified, nutritionally inadequate diets and bouts of illness likely contributed to chronic malnutrition of children. Making agriculture programs more nutrition-sensitive, creating diverse employment opportunities and sensitizing communities on nutrition and adequate feeding practices of children could complement the interventions identified by households to improve their food and nutrition security.

Contribution to the field

Despite improvements in economic growth and food availability, food and nutrition security still remains a challenge in Rwanda with 20% of households food insecure and 38% of children stunted. The majority of these households are in rural areas where food security is largely a function of available arable land and household income. The differences in socioeconomic status of Rwandan households likely contributes to differential physical and economic access to food. Literature shows an association of high socioeconomic status with improved household food security but the relationship with nutritional status is not always straightforward. Knowledge of which segment of the population is food and / or nutrition insecure may lead to better targeting of nutrition-sensitive food system interventions. To identify household types in the Rwandan Highlands, we constructed a participatory household typology and used a mixed research methods and multidisciplinary approach to collect nutrition and household / farm system data from case study households representing identified household types. Our study showed that participatory household typology construction was effective at capturing significant differences in socioeconomic and food consumption among household types. Household types proposed different strategies to address food and nutrition insecurity highlighting the need for targeted cross-disciplinary nutrition-sensitive interventions.

Ethics statements

Studies involving animal subjects

Generated Statement: No animal studies are presented in this manuscript.

Studies involving human subjects

Generated 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.

Inclusion of identifiable human data

Generated Statement: No potentially identifiable human images or data is presented in this study.

Data availability statement

Generated Statement: The datasets generated for this study are available on request to the corresponding author.

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Contribution to the Field Statement

Despite improvements in economic growth and food availability, food and nutrition security are a challenge in Rwanda with 20% of households food insecure and 38% of children stunted. The majority of the food insecure households are found in rural areas where differential household food security status is often a function of access to resources for food production and income to purchase food. The relationship between socioeconomic status and nutrition security is, however, reported to be more complex. Involving the community in identifying their nutrition challenges and solutions to these has been reported to improve the sustainability and effectiveness of interventions. We found no studies in Sub-Saharan Africa that used a participatory and multidisciplinary approach to understand the relationship between livelihood capitals and food availability, access and utilization at household level. Focus group discussions were used to develop hypotheses on the heterogeneity of households in the Rwandan Highlands, the hypotheses on household livelihood capitals and food security, nutritional status of women and children were tested using case study households representing the identified household types. The approach we used adds a new dimension to the discourse on household food and nutrition insecurity that may contribute to the development of multi-sectoral nutrition-sensitive interventions.

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[1]International Institute of Tropical Agriculture (IITA), Bujumbura, Burundi
[2]Farming Systems Ecology Group, Wageningen University and Research, Wageningen, The Netherlands
[3]Biodiversity International, Kampala, Uganda
[4] Rwanda Agriculture and Animal Resources Development Board, Musanze, Rwanda
[5]Department of Agronomy, Midlands State University, Gweru, Zimbabwe

*** Correspondence:**
Nester Mashingaidze
MashingaidzeN@ufs.ac.za

Keywords: **Household typology, livelihood capital, agricultural biodiversity, food consumption, anthropometry**

Abstract

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 determine differences in 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. 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 land holdings (~1 ha), highest agricultural biodiversity, total and farm income annum^{-1}. This probably resulted in better diets for women and children and 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 of children. Making agriculture programs more nutrition-sensitive, creating diverse employment opportunities and sensitizing communities on nutrition and adequate feeding practices of children could complement the interventions identified by households to improve their food and nutrition security.

1 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 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 nutrition experts as contributing to reducing micronutrient deficiencies in food insecure regions (Herforth & Ballard 2016; Fanzo *et al*. 2011). 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 without that livestock. Fanzo *et al.* (2011) measured agricultural biodiversity as species richness of crops, livestock, trees on a farm or landscape while Ekesa *et al*. (2008) included area under 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 (DeClerk *et al*. 2011) leading to improved nutrition (Powell *et al*. 2013).

There are several dietary diversity indicators used to assess an individual's micronutrient adequacy. These include the household dietary diversity score based on 12 food groups, 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 food groups 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 (Rakonirainy *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 proxy measure of food utilisation (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 & Rossi 2003). Differences in these human, physical, financial, natural and social capitals among households results 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 diarrheal and 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 & Kennedy (1994) there were no relationships between anthropometric indicators, income and calories 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 statistical clustering.

The Western Province of Rwanda is a Highland region which despite high food production has over a third of households classified as food insecure and the highest levels of child stunting in Rwanda (WFP 2016; Nzayisenga 2015). 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 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 on 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.

2 Materials and Methods

2.1 Study site

The study was carried out in Kadahenda cell, Karago sector of Nyabihu District ($01^{0}64$'S, $29^{0}51$'E; 2,500 m above sea level), one of the seven districts comprising the Western Province of Rwanda (Fig. 1). The district is found within the volcanic agro-ecological zone, and has a tropical temperate highland climate with rainfall of between 1200 and 1500 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 with 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.

2.2 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 (Fig. 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 and 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 that comprised 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, 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' perception on how resources were distributed across households and identify household types from which case study households were selected for detailed characterization of livelihood capitals, 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.

2.3 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:

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

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 five years to the general population in Rwanda (RDHS 2014 – 15), a household sample size of 188 households was arrived at. To take care of attrition due to incomplete questionnaire 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 (Fig. 3) for detailed household / farm system characterization.

2.4 Data collection

2.4.1 Nutrition survey

A nutrition survey (n = 199) was carried out during 9 – 13 November 2015 (season A) using face-to-face administration of a questionnaire to the female household head or primary care giver. Informed consent was obtained from each respondent prior to the interview. Data on the general household characteristics, on-farm agrobiodiversity and wild species collected for food, distance to open air market and trade center 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 and reduce the quantity of food prepared. The water, sanitation and health environment were assessed through questions on the household's commonly used water source, distance to and from the safest water source and health facility.

At the individual level, a qualitative open 24-hour diet recall (FAO 2011) was used to assess diet quality and meal frequency for mother/ caregiver and one child (reference child) aged between 6 – 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 child was determined by looking for physical signs of malnutrition through observing their hair color, pallor of skin and diagnosing for bilateral oedema using clinical tests recommended by WHO (2014). The healthcare-seeking behavior of the household was determined through questions on immunization, vitamin A supplementation and occurrence of sickness in previous month and treatment received for the reference child. The proportion of reference children who received Vitamin A supplementation, were immunized, showed physical signs of malnutrition, were sick in past 30 days and received treatment for sickness was determined per household type. Provision of safe water, adequate feeding practices under normal and periods of food scarcity as well as access to health facilities when sick were used as indicators of good child caregiving. Nutritional status of child and mother / caregiver were determined through anthropometry. The reference child's age, sex and birth weight were recorded and the mid upper arm circumference (MUAC), height (cm) and weight (kg) measured following the recommended protocols of CDC (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 checked for plausibility using the Emergency Nutrition Assessment for Standardized Monitoring and Assessment of Relief and Transitions software (ENA 2011).

2.4.2 Household typology construction

A total of six FGDs were conducted at a central location in each of the four villages from 14 to 18 November 2015. The aims of the FGDs were to determine the participants' perspective of household heterogeneity and the factors that varied between households, identify and characterize o 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 include 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 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 that 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 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 and 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 household.
5. Formation of groups based on household type – participants were invited to identify into which type their household belonged and thereafter form groups. Using flip charts, each group characterized in detail a 'typical' household for the identified household type, discussed and summarized 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 (Fig. 3).

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

2.4.3 Detailed characterization of case study households

Household surveys were conducted on the 18 case study households during 16 - 24 November 2015 using the IMPACTLite survey tool which is an adaption of The Integrated Modelling 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-hour diet recall for woman and child. The general household information was categorized into human, natural, physical, financial, 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, timber trees per household and area under crop and food production per year for 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 (~100g) were collected from the upper 20 cm of the field that was closest to the homestead and analyzed for soil texture (percentage 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 of 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-hour diet recall for female respondent and reference child was carried out during this time so as to check if there were differences in consumption patterns with seasons. During August 2016, case study households' heads and their spouses were interviewed on how they perceived their household was 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 making use of resources available to the household. Since the same interviewers were used in all interviews and the household numbers 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 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 two 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 was converted to an 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.

2.5 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 diversity and evenness index (Magurran 2004). The method of Rahman and Kazal (2015) was used to calculate Shannon diversity index (H') for crops:

$$Crop\ H' = -\sum(\propto i \times ln \propto i) \quad (2)$$

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

H' index for livestock was calculated using

$$Livestock\ H' = -\sum(pi\ \times \ln pi) \quad (3)$$

where the quantity pi is the proportion of individuals found in the i^{th} species; ln is natural log

and species evenness (J) was calculated as:

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

where J is the relationship between the observed number of species and 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, sick child in past 30 days and the health-service seeking behavior (Vitamin A supplementation, immunization and treatment of sick child at health facility) was determined. Scores from self-assessment of household types' performance towards 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, grouped into categories and the percentage per household type identifying each strategy calculated. The effect of household types on household characteristics, soil properties, household capitals, agricultural biodiversity, CDDS, MDD-W score, FCS, 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 a random factor at the significance of 5%. Household socioeconomic data from the IMPACTLite survey was used as it was more detailed than that from nutrition survey. Due to missing data and quality issues, anthropometric data was 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) excluded from analysis (ENA 2011). After checking data for violation of assumptions of ANOVA, financial capital data was square root (x+0.5) transformed to homogenize variances. The Least Significant Difference at 5% level of significance was used to separate treatments means. For transformed data, untransformed means are presented and separated based on ANOVA results. The relationship between 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.

3 Results

3.1 Household types from participatory household 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 was identified as the most important factor 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 sell 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 land (> 0.5 ha), have the largest and most diverse number of livestock and 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.

3.2 Socioeconomic status of household types for case study households

All the case study households were headed by males with spouses. Although 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; distribution of wives' ages, education level of household heads, natural, physical, financial and social capitals significantly ($P < 0.05$) differed with household type (Table 2). The heads in 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× that available to LRE households (Table 2). Kitchen gardens were small (52 ± 90 m^2) and did not differ significantly across household types. The acidic loamy soils did not significantly differ in soil organic 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 ~ 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. Total annual income ranking was HRE ≥ MRE ≥ 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 services providers of 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 past year of which half of these households were from the LRE group. Only two HRE households reported that they had a meeting with agents dealing with water supply or Water, Sanitation and Hygiene (WASH).

3.3 Agricultural biodiversity

Reflecting the trend in land ownership, 2.1 ha was cropped per annum under HRE farms and this was 42× 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 crops, 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 cropped area 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 ≥ 75% of area under food crops across household types. The area under kitchen garden per annum, 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 reduced area under vegetables. Although he wanted to increase the area under vegetables, he was confined to growing them on the the small area around his homestead as they were not permitted to grow vegetables on the fields. The remainder of the area under HRE farms was under tress such as eucalyptus and *Alnus acumunata* and fodder crops such as napier (data not shown). 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 less than 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.

3.4 Food consumption patterns, coping mechanisms and behaviors during food shortage

During November 2015 in Season A, three to four food groups 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 in 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 less than five 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 meeting their minimum dietary diversity. During March there was increased consumption of fruits, flesh foods, nuts and seeds by women in HRE households than in November (Table 5). Food consumption status in the LRE and HRE households was maintained at poor and acceptable, 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 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 (Fig. 4) due to lack of land to produce food, low crop productivity and income to purchase food. The majority of HRE households rated their performance towards 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 main constraints to diversifying diets (Fig. 4). The LRE households admitted that their performance towards 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" that 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.

3.5 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 supplement. They all had birth weights of greater than 2.5 kg and were observed to have no oedema with skin and hair in good condition (data not shown). All children were exclusively breastfed for six months except for one child from the MRE households. Five children were still being breastfed including one from MRE household aged 27 months and another from 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 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% 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 hospital, medication purchased from pharmacy and 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 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).

3.5 Access to water, markets and health facilities

There were no significant (P > 0.05) differences in the round trip distance to 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. Borehole was the most commonly used water source in Kadahenda.

3.6 Relationship between household characteristics and food security indicators

No significant (P > 0.05) relationships were found between 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 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 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 number of goats and sheep in November and 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 that 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).

3.7 Self-assessment of household performance and strategies identified to improve identified objectives

All households believed husbands and wives were empowered (Fig. 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, food and nutrition security as good resulting in an overall score of five for household well-being. The perception of MRE on their performance placed them intermediate to 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 Kadahenda as means to improve their household's performance can be classified as 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 the production, attain food security and increase 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 on

> 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 births, 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 household will be improved."

However, not all respondents were so positive about prospects for improving their livelihoods. A 33-year-old married female from Karandaryi village with 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 wellbeing 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 of 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 less 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 for fields etc. which they could use on their own pieces of land.

4 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 that 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 from 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 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 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 as 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 education level of household head, building values, crop and livestock diversity, number of sheep and goats, off-farm income, total household income and 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 Darmon & Drewnoski (2008) and Nzayisenga (2015) that there is increased household food security with high socioeconomic status and also found a positive relationship of household dietary diversity with on-farm diversity as reported by Sibhatu *et al*. (2015) and CFVSA (2015). Following reported trends in 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. 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 clinic compared to those from HRE households. This was perhaps due to 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 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 on the 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 six months, they were reported to consume diets that did not greatly differ from that 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 source 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 household level. There is, therefore, a need to continue sensitizing caregivers and the community on 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 increase in number of livestock owned in this study. There have been reports of stunting in households that own livestock due to creation of an unhealthy environment where children are exposed to faecal material and zoonotic pathogens (Kagari and Kanyari 2010; Marquis *et al.* 1990). From interactions with members of the community, there seemed to be poor knowledge of nutrition and its importance suggest the need to raise nutrition awareness of households by increased trainings 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 nation-wide (Rwanda Agriculture and 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, international research and development organisations than LRE. The observed lack of differences in the size 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 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 was 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 less than 0.5% of cropped area on HRE farms with 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 (Delprete *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 the farmer from MRE group. Increasing the participation of farmers in program formulation and choice of crops to include as 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 & 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 diversity household diets and incomes. Having the community have a voice in anaysing 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 mobilise 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 use of improved seed and fertilisers. Entry points for improving food and nutrition security for these households can be focused on increasing and diversifying farm / crop productivity strategies classified by Fiorella *et al*. (2016) as enhancement and diversification agricultural interventions. The proposed strategies highlighted the knowledge base of the respondents which was generally strong in agriculture probably due to that most of the external service ageants households met with in the preceeding 12 months were from this sector. Nutrition and health-related interventions tended to be given in general terms suggesting the need for more interactions with MINISANTE and organisations working on nutrition and health as interactions of households with these were low. The land-limited LRE households strategies are more livestock production-oriented with a focus on small livestock such as sheep, rabbits and chickens.

Inteventions 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 organisation 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 demostrations. Of importance would be the farmer-to-farmer extension as for example, the HRE were already aware of some of the challenges of keeping chicken and goats / sheep in the area such as diseases and fodder unavailabilty. 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 faecal matter and zoonotic diseases as a result of rearing livestock. All these factors needed to be carefuly considered before programs are implemented. Improving 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 can

potentially increase household income that may be used to purchase more food from the markets. With nutrition training, this can translate to purchase of more nutritious food if its available on 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 found in an agroecology with high agriculture 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 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 imore 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 sell of farm produce highlighting the importance of this revenue stream. The diversity seen in crops was also reflected in the number of crops sold A 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 vegetables such as carrots and cabbages. Interventions that increase productivity, diversify value chains and access to markets are crucial for increasing the income of such household. While for the land-limited LRE households, 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 emloyment opportunities for all household types. In such an interconnected community benefits to one household type can accrue to other households resultung 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, 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 nutrients /

micronutrients that are not being provided from 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 peope may not consume it opting instead to sell it and /or purchase foods with limited nutrient value. In the case of Kadahenda where knowledge of nutrition was low, a possible stategy that has been successfully used in Malawi and Zambia is to include nutrition education as part of agriculture training programs. This is highlighted by Dumas *et al*. (2018) with the respect to the relationship of livestock to child nutrition which can be both positive or negative. It is positive if households are aware of the nutritional value of animal source foods and include these in family diets but can lead to stunting if children are exposed to faecal matter due to poor hygiene. There is, therefore, a need to train households in management, link households to markets and increase knowledge of 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 expanding the number of crops considered in programs such as CIP to include vegetables and other non-staple crops to address identified micronutrient deficiencies in a area. In addition, there is need to develop infrastructure and markets as well as provide research and extension services that recognize the importance of prioritising 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.

5 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 head, landholdings of ~ 1 ha, highest agricultural biodiversity, most valued 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 households' capital indicators and food security indicators 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 and nutrition insecure with a poor food consumption score and 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, increase farm and off-farm income in combination with increased nutrition awareness advocacy.

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.

6 Author Contributions

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

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9 Data Availability Statement

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

10 Ethics statement

The studies involving human participants were reviewed and approved internally by senior researchers at the Rwanda Agriculture and Animal Resources Development Board, Bioversity and IITA after careful evaluation of the content, methodology, and oral informed consent statement built-in to the survey. Oral informed consent was obtained from all participants prior to survey.

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1085 Table 1. Categorisation of household types according to factors identified and ranked by focus group discussions participants (n=93) in
1086 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 sell of farm produce	Casual employment and sell 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 wall, wooden windows
5	Household head	Male headed	Male headed or female headed (widows)	Female headed (widows), child headed (orphans) and young male heads

1087 Factor ranked 1 the most important; [∞]Estimated average percentage of household type per village - the 'very poor' category comprise the
1088 remainder; HRE, high resource endowed, MRE, medium resource endowed; LRE, low resource endowed; [β] November 2015 Exchange rate
1089 1USD= 746 RWF

Table 2. Effect of household type on 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.
	Household head age, years	45	39	33	ns
	Spouse age, years	43	36	29	*
Human capital	Household head age education level$^{\infty}$	3a	2b	1b	*
	Spouse education level$^{\infty}$	2	1	1	ns
	Household size	7	6	5	ns
	Available family labour	2	2	2	ns
Natural capital	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
	pH (H_2O)	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$^{\infty}$, 0 – No formal education; 1 – Primary School not completed; 2 – Primary School completed; 3 – Secondary School not completed 4-Secondary School completed

1096 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' 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

1097 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;
1098 LRE, low resource endowed; MRE, medium resource endowed; HRE, high resource endowed

1099 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				

1100 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;
1101 MRE, medium resource endowed; HRE, high resource endowed,

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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 hour 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	*Ndagara* (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	*Ndagara* (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 bracket

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		
	MDD-W	Food consumption score	MDD-W	Food consumption score	Height-for-age z 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.

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(n=6)	MRE(n=6)	LRE(n=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 loam	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 year	0	33	0
	Diversify kitchen garden	17	0	0
	Change planting dates	33	0	0
	Rent more land	0	0	20
	Increase area under trees	17	33	0
Livestock production	Rear chickens / rabbits	17	0	40
	Rear sheep	0	17	40
	Rear cow	0	17	0
	Increase area under fodder	17	17	0
Consumption	Purchase food not grown on farm	33	50	60
	Consume animal source food	0	17	0
Knowledge application	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

List of figures

Figure 1.JPEG

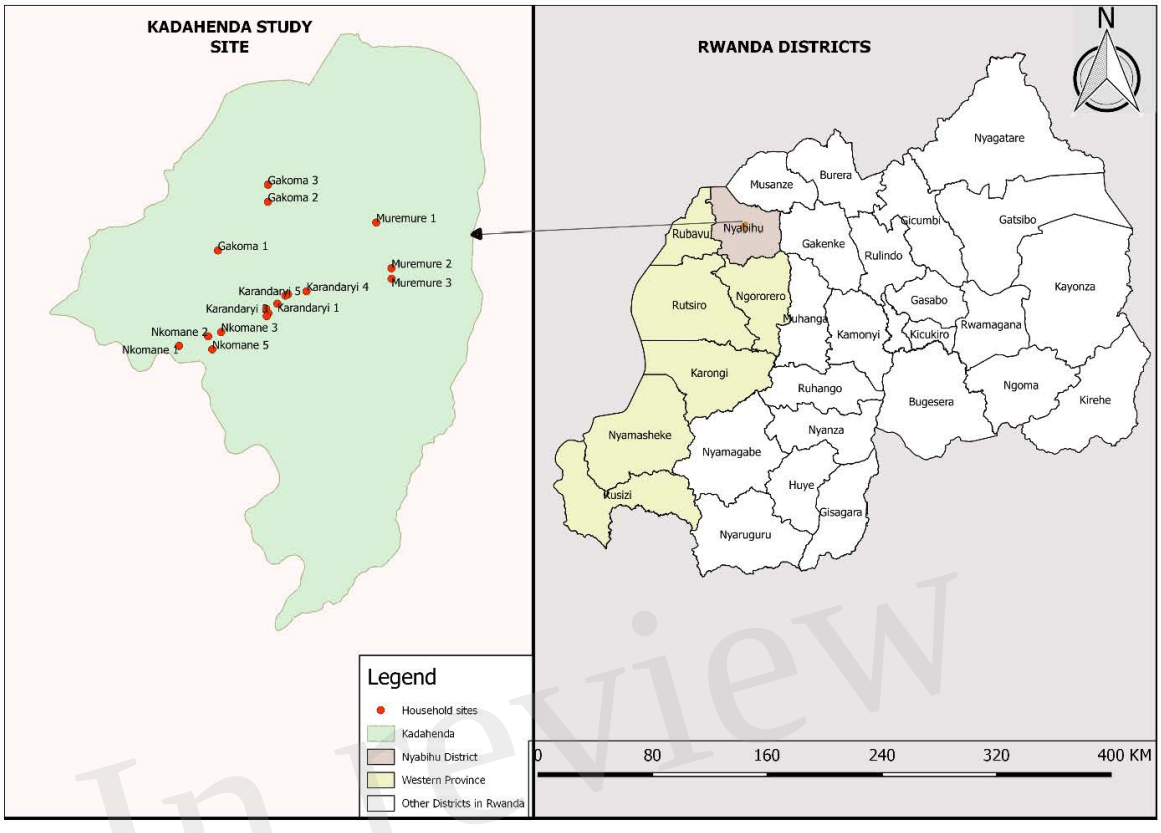

Figure 1.

Figure 2.JPEG

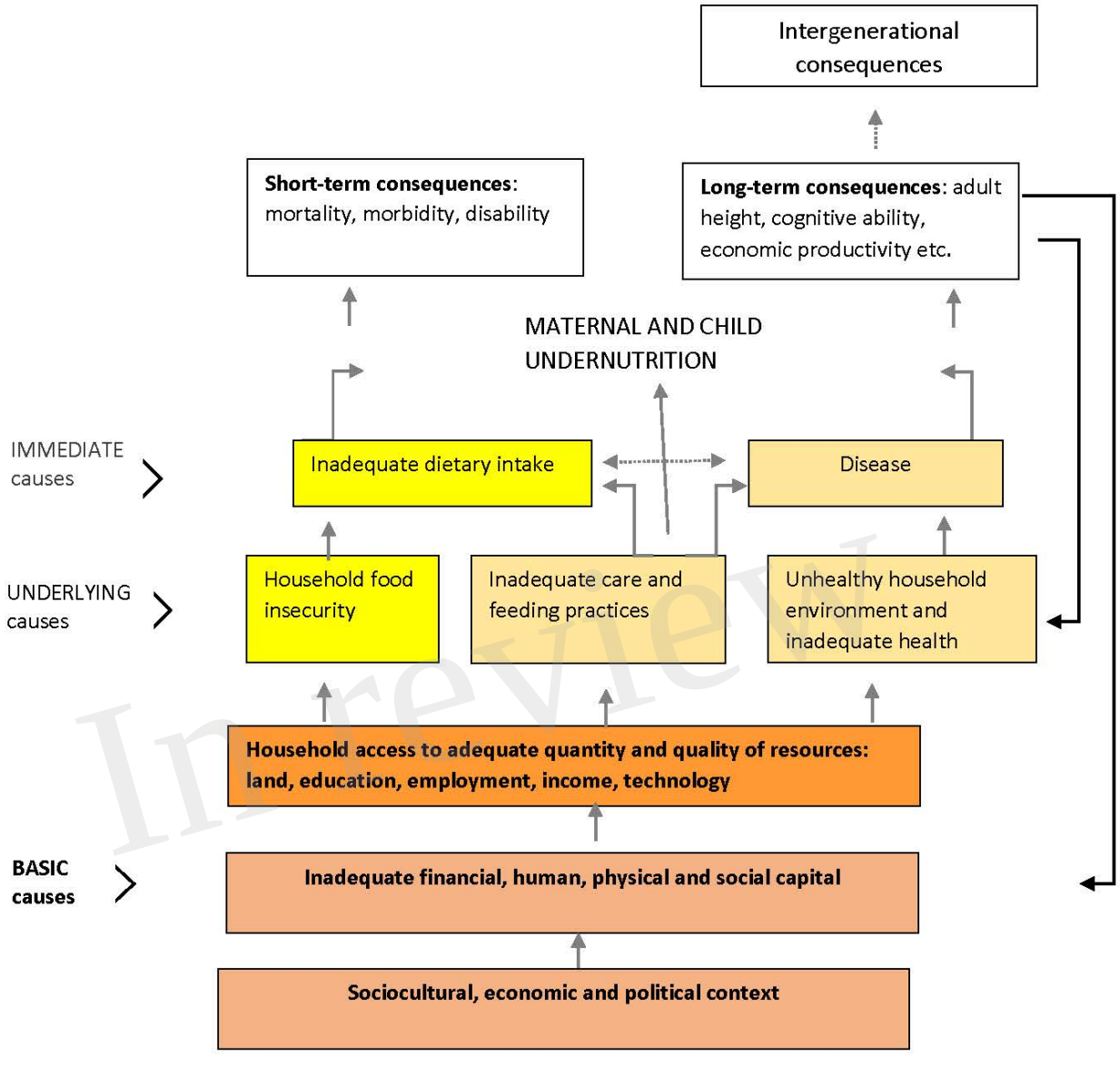

Figure 2

Figure 3.JPEG

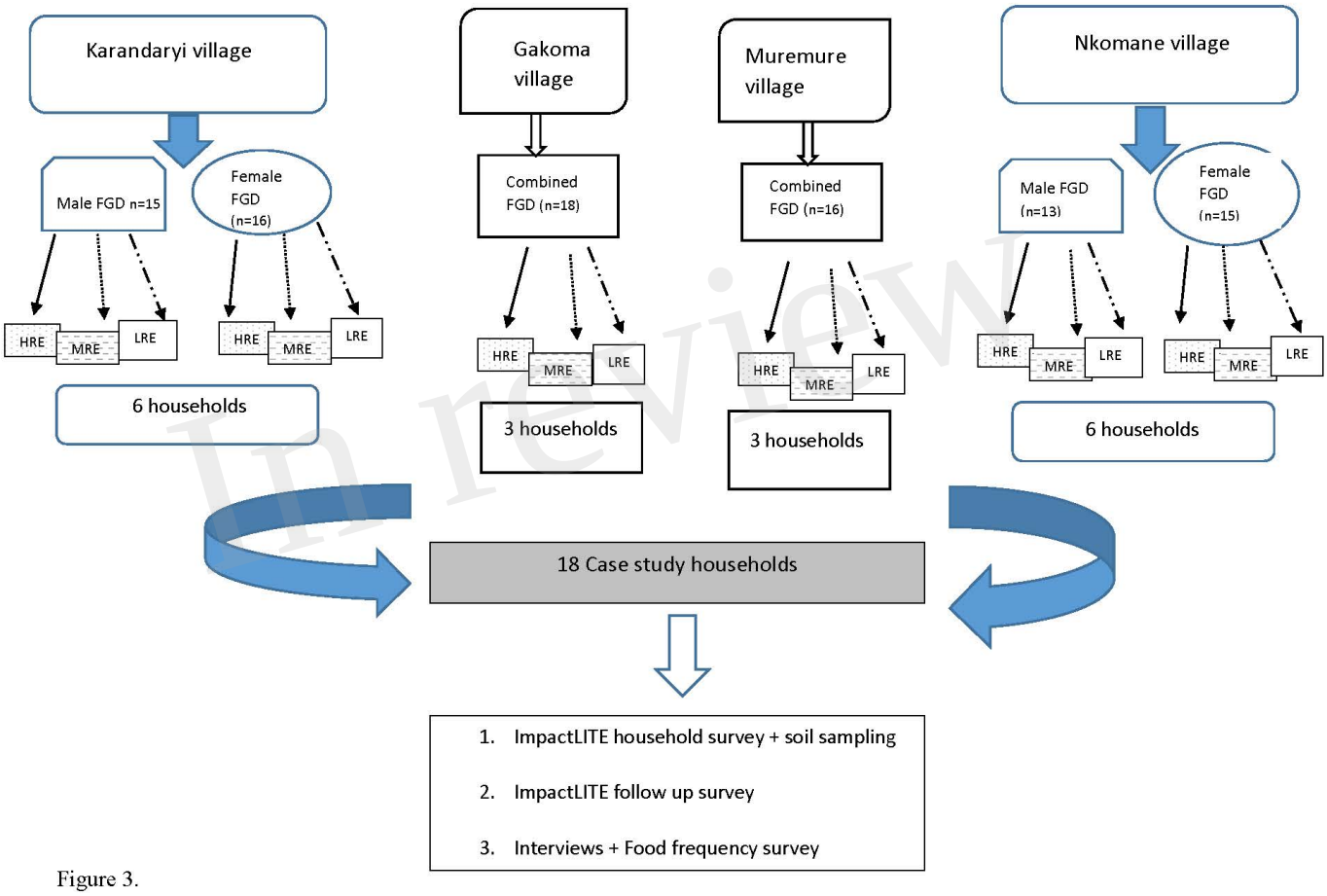

Figure 3.

Figure 4.JPEG

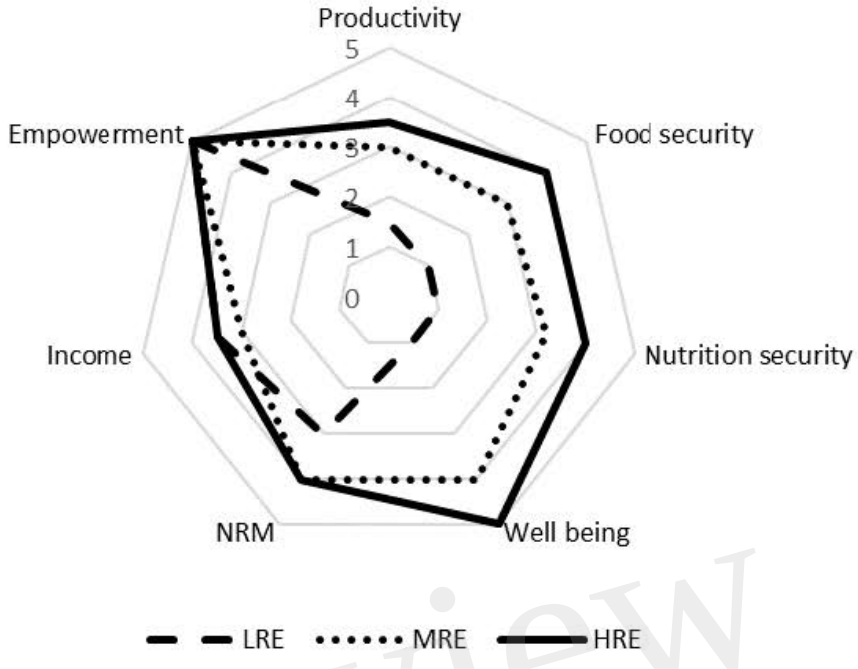

Figure 4.