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Commercialization and dietary diversity of Rwandan smallholder farmers: A focus on women and youth headed households

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ABSTRACT

Using a household dietary diversity score as a proxy for household access to nutritious foods, this paper assesses the relationship between commercialization and nutritional outcomes of Rwandan

smallholder farmers, with a particular emphasis on women and youth headed households. The results indicate that commercialization has a strong, positive effect on household dietary diversity but mixed results between sub-categories of households. For instance, male-headed households have higher overall dietary diversity compared to female-headed ones, but much of that variation can be explained by higher asset ownership and income. However, relative to male headed households, female headed households appear to respond to increasing levels of commercialization by consuming more diverse foods, an insight that could be useful for targeted interventions. Importantly, youth-headed households exhibit greater household dietary diversity than those households headed by older individuals, despite having both lower levels of assets and crop commercialization. General determinants that positively influence household dietary diversity include the level of commercialization, household non-farm assets, market access, education of the household head, the presence of children under five in the household, irrigation use, land size, and livestock holdings. The goal of this research is to enable policy makers to better identify the drivers of household dietary consumption, particularly among more vulnerable households, and how to encourage a more diverse diet for better nutritional outcomes.

1. INTRODUCTION

Research generally supports the thesis that smallholder crop commercialization provides a variety of benefits, including rising incomes, reduced poverty and food insecurity, increased resilience and generally aiding in a country's agricultural transformation. In addition, crop commercialization is often promoted to increase the availability and accessibility of foods to improve overall consumption patterns. While the evidence is not universal, most commercialization research has been shown to contribute to improved household dietary diversity due to higher incomes allowing households to purchase more diverse foods (Ogotu et al. 2019). However, research also shows that gender and youth designations can influence the pathways between commercialization and nutrition. For example, spending of proceeds from crop sales can vary significantly depending on whether the household head is male or female. Several studies indicate, when the income is controlled by men, a lower household consumption of calories and micronutrients can occur. Conversely, women tend to spend more on nutritious foods (Ogutu et al. 2019, Hoddinott and Haddad 1995, Fischer and Qaim 2012). In addition, the age of the household head can also affect dietary consumption patterns, with older household heads having different priorities in which they do not access as diverse a diet as younger headed households (Jateno et al. 2023).

In Rwanda, the agriculture sector contributes approximately 25 percent to the country's GDP (NISR 2023), of which smallholder farmers contribute 75 percent of total agricultural production. Women comprise a significant share of the agricultural workforce, generally with fewer resources. For example, 25 percent of rural households are headed by women and according to CFSVA (2021), female headed households are more food insecure than male-headed households (27 percent and 18 percent, respectively), have less formal education, and smaller asset ownership (DFID 2020, NISR 2018). For women, this includes smaller land size, more degraded farmland, less access to inputs, higher dependency ratios and greater exposure to climate change (MINAGRI 2018). All of these contribute to challenges that disproportionately hinder women's productivity, commercialization, and ultimately, potential access to nutritious foods. Another category, frequently understudied, is youth headed households which while exhibiting many similarities to female headed households, have some important differences.

According to MINAGRI (2018) the majority of Rwandan youth headed households (15-34) are rural (77%) and farming remains their primary source of employment. More specifically, over 50% of people between 16-24 years old work solely in agriculture. Even though rural youth are considered a major asset for agricultural transformation, they are grappling with various challenges such as un- and under-employment, a lack of necessary skills for the labor market, limited assets such as land, finance extension support, inputs, and technologies (MINAGRI 2019). While productivity and commercialization have been emphasized by the Rwandan Government for improving food security and more inclusive growth, specific government nutrition-related policies have also been formulated.

Both female and youth headed agricultural households are considered as disadvantaged groups since they lack many of the assets needed to effectively participate in commercialization. To tackle this inequality, many initiatives have been put in place for improved livelihoods and more inclusive development (MINAGRI 2019). These initiatives include the development of support systems to help women and youth access markets and enhance their representation across value chains, enable them to access extension, finance, inputs and technologies that enhance productivity, introduce new approaches to foster mindset and behavior change at the community and household levels and strengthen institutional systems to foster inclusive growth (MINAGRI 2019).

Beyond commercial engagement, Rwanda is formulating agricultural related policies to create a healthier population through policy documents such as the *Nutrition Sensitive Agriculture Mainstreaming Guideline* (MINAGRI 2020). The policy is aligned with the United Nations SDG1 (end extreme poverty) and SDG2 (zero hunger, improved nutrition, and sustainable agriculture), among others. Important quantitative indicators include the *Comprehensive Food Security and Vulnerability Analysis* CFVSA's (2021), which determined that 20.6 percent of households are food insecure and according to DHS (2020), 33 percent of children under five are stunted, one percent are wasted, and eight percent are underweight. In order to track general nutritional status, Rwanda uses several periodic surveys that employ dietary diversity indicators at both the household and individual level. These surveys provide updates on the general state of Rwandan nutritional status.

The Government of Rwanda acknowledges dietary diversity as one of the approaches to overcome malnutrition and micronutrient deficiencies (MINAGRI 2020). Every three years, the Ministry of Agriculture (MINAGRI) and National Institute of Statistics of Rwanda (NISR), in collaboration with the World Food Program (WFP), conduct a quantitative research review entitled *Comprehensive Food Security and Vulnerability Analysis* (CFVSA) which aims at providing a situational analysis on the food and nutrition security situation in Rwanda. In this study, the household dietary diversity score is measured to indicate the progress of how diverse foods are accessed in different districts of Rwanda and to provide practical recommendations for improving nutrition. Findings from the latest CFVSA (2021) demonstrate that food insecure households generally consumed less than five food groups in a 24-hour period.

Dietary diversity at the individual level is also measured, every five years, by the National Institute of Statistics of Rwanda (NISR) in collaboration with the Ministry of Health (MOH). Together, they conduct a Demographic and Health Survey (DHS) where important indicators such as stunting, wasting, underweight, overweight and anemia are measured and, minimum dietary diversity for children (MDDC) is also measured as a proxy for adequate micronutrient density of foods (DHS 2020). Moreover, the National Child Development Agency (NCDA) in its mandate, prioritizes dietary diversity of women and children to prevent stunting (NCDA 2023) and the Ministry of Education (MINEDUC 2021) in its school feeding operational guidelines, meal diversity for pupils is necessary and should include six food groups for adequate nutrition. Overall, the Government expresses serious concerns about the state of Rwandans' nutrition status and tracks several quantitative indicators on a periodic basis.

Commercialization of smallholder production figures prominently in the Theory of Change section of Rwanda's Fifth Strategic Plan for Agriculture Transformation (PSTA5). The policy's stated goal is to transition from subsistence farming to market-oriented production aiming to stimulate economic growth and improve farmer's livelihoods (MINAGRI 2024). This is consistent with several previous documents addressing the development of Rwanda's agricultural sector. Since 2007, the government of Rwanda, through the Ministry of Agriculture, introduced the Crop Intensification Program (CIP) aiming to improve agricultural productivity and food security through monocropping and commercialization of nine crops, including maize, wheat, rice, white potato, beans, cassava, banana, soybean, and vegetables (Nsabimana et al. 2021, Del Prete et al. 2019). Commercialization of agricultural produce is a crucial aspect for farmers since it contributes to higher income and typically increases nutrient intake from purchased foods (Ogutu and Matin 2019). Recent research indicates that 78% of rural Rwandan smallholder farmers sell at least some portion of their produce and that commercially oriented farm households are increasingly likely to access more diverse diets than non-commercially oriented ones (Warner et al. 2024). There is due, at least in part, to wealth effects because they have greater financial means of purchasing additional foods that supplement their own production.

Overall, commercialization has been shown to have positive effects on household food security (Justus et al. 2015). However, our results indicate that there are many factors contributing to household dietary diversity. This suggests that marginalized groups, not fully participating in commercialization, have mixed to negative effects regarding accessing nutritious foods. Specifically, women headed households typically consume less diversified foods, but this effect is offset when income is controlled for in our econometric model (Section 4.2), as they consume more diverse foods the greater their level of crop commercialization. On the other hand, youth-headed households consume more diverse foods, despite having lower assets and income.

1.1 Methodologies for measuring dietary diversity

While tracking nutrition status is critical for policy, there are several potential nutrition measurement methodologies. Some are relatively complex and time-consuming, like anthroponomic measures or detailed consumption diaries. On the other hand, there are easier methods that, while they may not be as detailed and precise, can provide a reasonable estimation of overall access to diverse nutritious foods. One such measure, the dietary diversity scores (DDS) provide a relatively effective, cost efficient, quantitative indicator of a household's (or individual's) access to a diverse set of foods.

Most research indicates that dietary diversity is highly correlated with nutritional outcomes, including the reduction of stunting (Nyiraneza et al. 2019, Lung'aho et al. 2015, Weatherspoon et al. 2019). Other research indicates that increased women's control over resources has several positive outcomes for most members of the household, including child nutrition (Kurz & Welch 2001).

Improving women's access to resources and household decision making likely increases a household's dietary diversity. Research indicates that women, relative to men, typically have stronger preferences for better nutritional outcomes which is made especially clear with control over income expenditures. Empowering women is more likely to have preferable outcomes as women empowerment is linked positively to household welfare (Hoddinott and Haddad 1995). According to the World Bank (2009), when women control income, they generally spend it on food and children's needs since they oversee food selection, preparation, care, and children feeding. The 2020 Rwanda Demographic and Health Survey revealed that increasing a mother's education or wealth is related to decreasing child stunting (Iruhiriye et al. 2019). Yimer and Tadesse (2015) demonstrate that Ethiopian women's empowerment is positively related to improved dietary diversity for both children and women. For instance, women who exert greater control over income and access to credit, as reflected in empowerment indicators, contribute to more diverse foods in the households (Larson et al. 2019, Mukuka and Sambo 2019). Therefore, increasing both female headed household's empowerment and/or increased access to resources for production would likely increase commercialization and improve dietary outcomes for the household (Okonya et al. 2019).

Studies suggest that youth are susceptible to malnutrition since most are not consuming the United Nations recommended 2,100 kcal/day and are at risk of inadequate dietary intake due to poor consumption of nutrient dense food that are rich in vitamins and minerals, such as vitamin A, iron, zinc, and iodine (Justine et al. 2011). According to Adeyanju et al. (2023), food security among young farmers in Kenya, Nigeria and Uganda consist mainly of cereals, root tubers and fats and oils. Consumption of foods rich in protein, minerals and vitamins is very low as are pulses and fruits, suggesting low dietary diversity among young farmers. Given the rural economic challenges faced by youth in Rwanda, it is presumed that achieving improved nutrition is difficult, based in part, because so little is known about dietary diversity in youth headed households. This paper seeks to better identify how commercialization is related to dietary diversity, especially through traditionally disadvantaged groups like youth and female headed

households and seeks to identify key drivers that influence dietary diversity to help shape the evidence-based decision making between policy and healthier food consumption.

The remainder of the paper is organized as follows: Section 2 reviews household dietary diversity (HDDS) studies in Rwanda and explores the potential drivers of HDDS found in other research. Section 3 outlines the data and methods used for this study, while Section 4 presents the main results, and then discusses these results. The final section concludes with policy recommendations based on the findings.

2. BACKGROUND

2.1 Relevant dietary diversity studies

In Rwanda, one of the key indicators used for dietary guidance is the dietary diversity index which is a measure of how varying consumption can effectively contribute to improved nutrition status (MINAGRI 2020). Various studies have been conducted in Rwanda to assess the determinants of dietary diversity, shed light on the country's nutritional situation and to provide recommendations for promoting diet diversification. Factors such as stable, predictable income, having kitchen gardens, adoption of improved seeds and cash transfers have all been positively associated with improved household dietary diversity.

Adequate diet diversity of households in rural areas of Rwanda remains a public concern and an important emphasis of government policy. According to the 2021 Rwanda Comprehensive Food Security and Vulnerability Analysis (RCFSVA), urban households have a higher average dietary diversity (6.7) than households in rural areas (5.3). The typical Rwandan diet is primarily based on staples, vegetables, pulses (beans) and oil (CFVSA 2021) and are low in animal-based proteins (Weatherspoon et al. 2017). Typically, foods higher in carbohydrates and starches are consumed in poorer and rural households (Nsabimana et al. 2020). Numerous studies indicate factors associated with improved dietary diversity are, for instance, dependable income sources and/or kitchen gardens (Sly et al. 2023, Habimana and Muhawenayo 2023, Issahaku et al. 2023). Larochelle and Alwang (2021), also indicate that adoption of improved seeds can increase dietary diversity and reduce food insecurity through income from selling surplus generated from the high yielding properties of these varieties and purchasing more diverse foods in the market. Weatherspoon et al. (2017) found that dietary diversity was higher in households in higher income quintiles. McIntosh and Zeitlin (2018) also found that cash transfers to lower-income households improved dietary diversity.

Several studies have been conducted to determine the correlation between dietary diversity and relevant socio-economic factors including gender of household head, age, commercialization, education, farm crop diversification, market access, ownership of assets and irrigation. Of particular interest here are the gender and age of household heads which have had mixed effects on household dietary diversity while the remaining drivers have mostly consistent effects with most research literature.

Table 1 summarizes the dietary diversity literature of research goals, sample size, dietary measurement methodology, average dietary scores, and findings. Overall, the table reveals that several factors that have been consistently found to improve the household dietary diversity in different countries and include crop production diversity, age, gender and education level of the household head, access to irrigation, and livestock ownership.

Table: 1 Meta analysis on drivers of household dietary diversity

	Survey	Authors	Sample size	Survey purpose	Method of DD	Analysis method	Average HDDS	Key findings
1	Uganda	Sekabira and Nalunga 2020	3,300 HHs	Is farm production diversity important for dietary diversity (using panel data)	24hr recall	*Descriptive *Panel regressions	7.6	Farm production diversity significantly improved household dietary diversity
2	Malawi	Koppmair et al. 2016	1,482 farm HHs	Measures association between farm production diversity, market access and dietary diversity in rural smallholder households	24hr recall	*Regression models	4.1	Production diversity is positively associated with dietary diversity, but effects are small. Access to markets for buying food and selling production and fertilizers use greater
3	Kenya	Muthini et al. 2020	779 HHs	Production diversity on dietary diversity of HH, women and children	7-day recall	*Descriptive statistics *Poisson model	9	Farm production diversity is significantly associated with household dietary diversity
4	Ethiopia	Jebessa et al. 2019	183 HHs	Determinants of household dietary diversity and consumption behavior in South-West Ethiopia	24h recall	*Descriptive analysis *Chi-square, ANOVA one way and ordinal logistic regressions	5.5	Intermediate factors like age, education of head, livestock ownership, home gardening, total income, irrigation, awareness of dietary diversity, positively influences household dietary diversity
5	Burkina Faso	Bandyopadhyay et al. 2021	10,860 households	HH dietary diversity in Burkina Faso and assess whether the choice of a diversity metric matters	7-day recall	*Poisson model	6.8	Female head, HH head education, HH wealth, on-farm production diversity, warmer climate, positively associated with dietary diversity.
6	Tanzania, Bahi and Mbarali districts	Ochieng et al. 2017	204 respondents	Factors influencing dietary diversity of the household, children under five years, and women.	24hr recall	*T-test and chi-square test * Poisson regression model	6.28	Gender and education of the household head, food preparation and nutrition training are also important
7	Ghana	Batame 2023	200 HHs	Dietary diversity, and food and nutrition security status among male and female-headed cocoa producing households	24hr recall	*Descriptive statistics	Medium (5-8) to high (9-12) dietary diversity	Male-headed households had higher dietary diversity compared to female-headed households
8	South Africa	Taruvinga et al. 2013	181	Estimate rural household dietary diversity	24hr recall	*Multinomial logistic model	Low DDS (0-3) 29%, med. (4-6) 36%,	Positive influence of irrigation, female headship, education, income, access to home gardens and

							(7-9) high 35%	ownership of small livestock
9	Nigeria	Obisesan and Awolala 2022	5,000	Crop diversification, socio-economic factors, and gender	7-day recall	*Tobit regression	high dietary diversity (7-12) 45%	Crop diversification found to have a positive effect on household dietary diversity.
10	Zimbabwe	Murendo et al. 2018	2,815	Role of nutrition education, farm production diversity and commercialization on household, women, and children dietary diversity in Zimbabwe	24hr recall	*Negative binomial regression	7	Nutrition education increased household, women, and child dietary diversity while farm production and crop diversification increased household and women dietary diversity.

The gender of the household head has had mixed significance in terms of dietary diversity scores. While men and women tend to have different food and nutrition consumption priorities the analysis is complicated by the fact that most male headed households have higher income/assets which generally has a positive effect on dietary diversity. Several studies have determined that male headed households have higher dietary diversity when compared to female headed households (Mekuria et al. 2017, Misker et al. 2016, Sarkar 2014, Workicho et al. 2016, Ochieng et al. 2017, Batame 2023) but this is likely because male headed households generally have greater income and assets. However, some studies determined that female headed households have higher dietary diversity claiming that since women are involved in food preparation and food selection and typically have more nutritional knowledge which would drive them to consume more diverse foods (Taruvinga et al. 2013, Jateno et al. 2023, Ochieng et al. 2017, Sekabira and Nalunga 2020, Bandyopadhyay et al. 2021). Other factors, including women's relative empowerment, are related to higher dietary diversity in female headed households as this correlates with improved household diet choices (Belmondo et al. 2016). Farm crop production diversity affected the increased dietary diversity in female headed households when compared to their male counterparts in Malawi (Jones et al. 2014). Obisesan and Awolala (2021) find that Nigerian diets are more diverse in female headed households due to spending more on high food quality than male headed households.

The age of the household head (our youth designation) also has a mixed correlation with dietary diversity because older heads of households are sometimes linked to better nutrition education, experience and higher income that all influence purchasing more diverse foods. Several studies indicate that age is positively correlated with dietary diversity (Jebessa et al. 2019, Sambo et al. 2022, Khandoker et al. 2022, Sinyolo et al. 2021, Chinnadurai et al. 2016). However, other researchers such as Ochieng et al. (2017) found that as the age of the household head increases, the Child Dietary Diversity Score (CDDS) and Minimum Dietary Diversity for women (MDD-W) decrease. Conversely, conflicting literature determines that old age is associated with lower HDDS scores (Sekabira and Nalunga 2020, Amao et al. 2023, Huluka and Wondimagegnhu 2019, Ahiman et al. 2021, Iftikhar et al. 2020, Magaji et al. 2020). This might be because the older the household head becomes, the less likely they are to engage in off-farm employment for more income, which can be used to purchase diverse food to diversify their diet.

Education of the household head potentially influences dietary diversity since it plays a crucial role in acquiring knowledge, skills, and information. Research indicates that education levels of the household head have a positive influence on household dietary diversity because they likely have a better understanding of the importance of consuming diversified diet (Bandyopadhyay et al. 2012, Taruvinga et al. 2013, Jones et al. 2014, Koppmair et al. 2016, Ahiman et al. 2021, Sinyolo et al. 2021). Moreover, literacy status of the mother, and nutrition training/knowledge have also been associated with improved dietary diversity of households (Mbwana et al. 2016, Harris et al. 2015, Murendo et al. 2018, Gupta et al. 2020). While a variety of socio-economic variables have varying impacts on access to nutritious foods, one of the primary drivers that has been emphasized is crop commercialization and farm management decisions more generally.

Overall, crop commercialization is expected to increase dietary diversity at the household level since it is thought that the more households are commercialized, the more diverse foods are purchased from the market. Several studies suggest that more commercialized households have higher household dietary diversity scores (HDDS) and women dietary diversity scores (WDDS) (Muthini et al. 2020, Murendo et al. 2018, Zheng and Ma 2023, Ogutu et al. 2019). Commercialization was positively and significantly associated with household dietary diversity and nutrition as indicated by Kuijpers (2018).

Studies also show that farm production diversification is positively associated with household dietary diversity (Ecker 2018, Sinyolo et al. 2021, Muthini et al. 2020). Crop production diversity is positively associated with household dietary diversity, regardless of the purpose (sales or consumption), as households producing more diverse foods either directly consume or sell for income and consume more diverse (Obisesan and Awolala 2021, Gbenga et al. 2020, Amao et al. 2023, Bandyopadhyay et al. 2021, Sekabira and Nalunga 2020, Kissoly et al. 2020, Murendo et al. 2018, Hossain et al. 2016 and Huang et al. 2023).

Several researchers found that market access, measured in lower travel time to markets, has larger positive effects on dietary diversity (Sibhatu et al. 2015, Davidson and Kropp 2017, Matita et al. 2021, Koppmair et al. 2016, Usman and Haile 2022). Improved market access exposes households to a broader range of food choices that are available and this enhances the ability of the household to potentially consume more diverse foods. Accessible markets might also be a good opportunity to introduce new nutrient dense foods.

Assets ownership is another driver that has a positive and significant relationship with dietary diversity as wealth typically leads to consuming more diverse food diets (Amao et al. 2023, Bandyopadhyay et al. 2021). An increase in asset ownership is typically a positive indicator on food expenditures.

Finally, irrigation has been associated positively and significantly with household dietary diversity (Jebessa et al. 2019, Moyo and Machethe 2016, Taruvinga et al. 2013, Passarelli et al. 2018). Because irrigation enables farmers to grow a variety of crops, households can improve dietary diversity. Additionally, cash crops might increase the purchasing power of the households that practice irrigation through the pathway of increasing household incomes. Mekonnen et al. (2022); Passarelli et al. (2018) indicated that among Tanzanian and Ethiopian households who reported facing a drought, irrigating households had higher HDDS when compared to non-irrigators.

This section highlights the complex range of factors that influence household dietary diversity scores (HDDS) and how these factors are interconnected in determining the overall outcomes for a household. Drawing on the research literature above we include age, gender and education of the household head, percentage level of crop commercialization and diversity of production, market access, relative asset

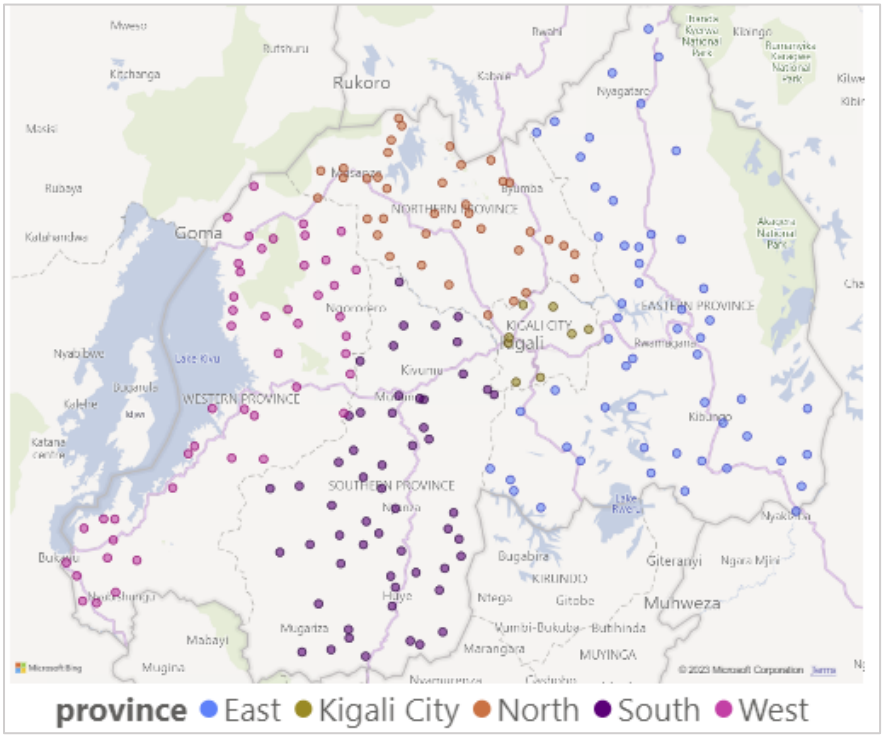
ownership, irrigation, as well as other variables (eg. children under five in the household, inorganic fertilizer use) in both our general statistical and econometric models. Policymakers and development practitioners should consider these interrelated elements when designing interventions aimed at improving household nutrition and food security.

3. DATA AND METHODS

3.1 Household Data

This paper uses data from the Rwandan smallholder commercialization survey conducted by the International Food Policy Research Institute (IFPRI) in collaboration with the Rwanda Ministry of Agriculture in thirty districts of Rwanda in the lean season between October and November 2022. Two thousand and twenty households were interviewed and are representative at the province level. The survey questionnaire collected household data including household roster, household characteristics, migration, shocks that affected household, agricultural production and input use, livestock and animal byproducts, household expenditures, food consumption, transfer in and out of the household, wage employment of household members, household businesses and household participation in social programs.

Figure 1. Sampled villages.



Authors' calculations

3.2 Household dietary diversity score

For this study, FAO (2007) guidelines for measuring household dietary diversity were used to indicate the diversity of the consumed diet. The household heads were asked the number of different food items

consumed by any member of the household in the past twenty-four hours. Overall, shorter recall periods tend to increase accuracy when compared with longer recall periods such as seven days.

A total of 1,741 household respondents were able to respond to the questions regarding household dietary diversity.[1] Respondents were asked about their consumption of thirty-one items which were categorized into twelve foods groups, namely cereals, roots and tubers, vegetables, fruits, meats and poultry and offal, eggs, fish and seafood, pulses/legumes/nuts, milk and milk products, oils and fats, sugar and honey, as well as spices and condiments, and beverages. These groups were used to calculate the HDDS. The respondents have been asked if they ate or drank, whether at home or outside the home, different food groups in the previous 24 hours. The HDDS was calculated by adding the number of different food groups consumed by the household over the 24-hour recall period and a score of 1 was given to each food group consumed for a maximum of 12 points. The rule is if the answer is "YES" then one point is scored and if the answer is "NO" score zero points are assigned.[2]

3.3 Household dietary diversity score methodology

The developing world is grappling with a lack of dietary diversity since diets are predominantly based on starchy staples with few fruits and vegetables and little or no animal products (Ruel 2006). Dietary diversity has been recognized as an index measurement of food consumption that reflects household access to diverse foods (FAO 2013). Several indexes are known as comprising key elements for consuming a variety of foods and many have been recommended in dietary guidelines. Different indicators such as the household or individual dietary diversity score (HDDS or IDDS, respectively) are used and depend on the subject being studied (Swindale and Bilinsky 2006, Kennedy et al. 2011).

HDDS can also be used as a proxy measure of the socio-economic level of household food security (Ruel 2002, Hoddinott and Yohannes 2002). The household dietary diversity score is an attractive proxy indicator, because of its association with several improved outcomes in areas such as weight, child anthropometric status and improved hemoglobin concentrations. Moreover, a more diversified diet has been correlated with caloric and protein adequacy, percentage of protein from animal sources and household income (Hoddinott and Yohannes 2002). Household dietary diversity scores can also be used for monitoring for a change assessment before and after an intervention or after a certain disaster and it can be used to compare sub-populations (Kennedy et al. 2011). In addition, HDDS can also be used to estimate nutrient adequacy (Mekonnen et al. 2020).

Collecting data and obtaining information on dietary diversity is relatively easy since the questions are straightforward and involve respondents' answers to be whether a food group has been consumed in a relatively short time period. In addition, it is not resource intensive, unlike other nutrition related surveys that require detailed food consumption diaries. HDDS also reflects dietary quality, as a higher HDDS is an indication of a diversified household diet and shows the likelihood of more balanced macronutrient intakes while a low HDDS is suggestive of a high consumption of starchy staples which are low in micronutrients.

Although HDDS is a good proxy for household socio-economic status, it has limitations. Some of these limitations include not providing information on the actual amount of consumption of different foods at the intra-food group level and overall dietary diversity by individuals in the household. Overall, the household

[1] Only 1,741 of our total sample 2,020 household have dietary scores because of shortcomings of the initial survey design. In addition, two respondents claimed to not have consumed any type of food in the previous 24 hours and were therefore dropped from the analysis.

[2] During the data collection, respondents also reported foods and snacks consumed outside the house which are not included in the FAO guidelines for determining household dietary diversity (FAO 2007; Swindale and Bilinsky 2006). All responses were combined in the general categories of foods consumed in the designated food group.

dietary diversity score does not indicate the quantity of food consumed and there is no universally accepted cut-off for adequate or inadequate HDDS (Kennedy et al. 2011). Different research considers households that consumed food groups between six and twelve to be high, making it feasible to categorize the households into distinct groups or categories based on their level of dietary diversity.

3.4 Ordered probit models

An ordered logistic econometric model is used to analyze the household dietary diversity scores because of the unique characteristics represented by the index (ie. the dependent variable). As a categorical variable, where higher values represent better, but not explicitly quantifiable improvements, we believe that ordered probit models are best suited for methodological reasons. Predictors for the model are independent variables that the research literature has identified as potential drivers of diverse nutrition consumption within the household and include variables discussed in Section 2. More specifically, ordered probit models are typically used when the dependent variable is a categorical variable with a natural hierarchal value that is not quantifiable (eg. survey responses that range from *poor*, *fair*, to *excellent*). In our case this value is summed from the total number of food groups consumed; where additional group consumption is better, but there is no explicit value concerning how much better.[3]

In an ordered probit model, there is an observed ordinal variable, Y_n. Y, in turn, is a function of another variable, Y*, that is not measured. The continuous, unmeasured latent variable Y*, whose values cross certain thresholds (so-called cut points) that transition to the next value. The value on the observed variable Y depends on whether you have crossed a particular threshold. Assuming three "thresholds," the model takes the following form:

$Y_i = 1$ if Y_i^* is $\leq \vartheta_1$ (1)

$Y_i = 2$ if $\vartheta_1 \leq Y_i^* \leq \vartheta_2$ (2)

$Y_i = 3$ if $Y_i^* \geq \vartheta_2$ (3)

The continuous latent variable (Y*) approximates the actual categorical variable (Y_i) up until the next threshold is reached (ϑ_n) and then takes the subsequent value (eg., 1,2,3). Y* is represented by the equation below.

$$Y_i^* = \sum_{K=1}^{K} \beta_k \ \beta X_{ki} \ + \ \varepsilon_i = Z_i + \varepsilon_i \quad (4)$$

Equation 4 assumes K independent variables used to predict the latent variable (Y*) via the estimated coefficients (β_k), jointly aggregated in Z_i, with an assumed standard logistic error term (ε_i). For theoretical reasons, we assume that there may be heteroskedasticity errors at the sampled village level of our survey[4] and we seek to correct for it in our model using a specific heteroskedastic ordered probit model. This type of model can account for differences in variability across demographic segments, providing a more accurate understanding of HDDS. Hence, using the estimated value of Z and the assumed logistic distribution of the disturbance term, the ordered logit model can be used to estimate the

[3] For example, while an HDDS score of 4 is better than 3, and a score of 7 is better than 6, the improvement is only relative and not equal to 1 "unit." For this reason, ordered probit models best reflect this mathematical assumption and are often used in satisfaction indexes, or Likert scales, that approximate this type of HDDS score.

[4] We assume that individual villages may have random highly correlated HDDS scores that we correct for using a standard correction for potential local heteroskedasticity.

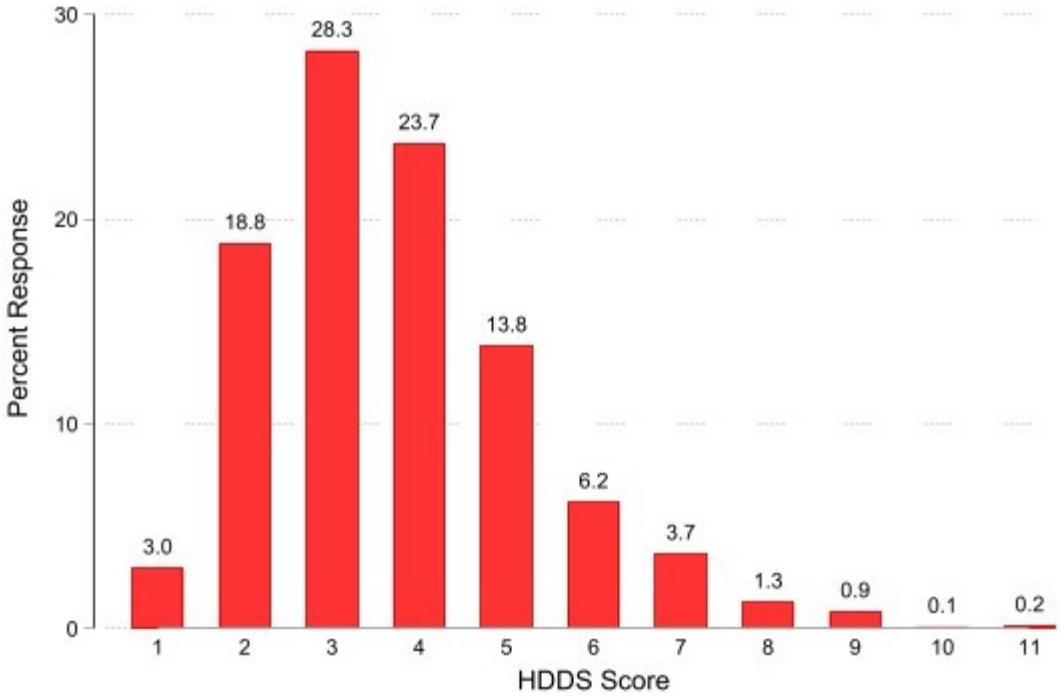
probability that the unobserved variable Y* falls within the various threshold limits. The following section depicts detailed results from our survey using selected variables of interest.

4. RESULTS

4.1 Descriptive statistics

This section reviews some basic statistics of the HDDS and how it varies based on some variables of interest derived from literature as well as with discussions with local experts. We begin with a basic histogram that captures all available responses in our survey (Figure 2). The overall mean of the household diversity score is 3.7 which is considered a low value within a general scoring framework.[5] Three is the most common response and scores range from one to eleven but only seven percent of all respondents reported consuming seven or more food groups. Table 3 breaks down the score by categorical variables of interest and provides insights into how dietary diversity varies across several variables of interest. Figure 3 depicts the average HDDs score by consumed food group to better understand what food groups are most consumed. Statistical differences in consumption of these food groups, by gender and age of household head, are depicted in Table 4. All of these results provide a general understanding of how dietary diversity scores vary across different rural Rwandan households of interest, albeit in a low seasonal consumption period.

Figure 2: Household dietary diversity scores



Authors' calculations

[5] The timing of the survey (October-November 2022) may explain a relatively low overall score. This is likely for at least two reasons. From a seasonal perspective, this is after planting but before the major Season A harvests starting in January. Sales and consumption rise during and after harvesting. In addition, there were several international shocks that created large food inflation and supply chain disruptions that likely caused a reduction in both diversity and overall food consumption during this unique period.

Table 2 indicates HDDS per province, age, sex and level of education of the household head, children under 5 years of age, crop marketed share, distance to market, land holdings, number of crops produced, fertilizer and irrigation use, and livestock holdings. Except for the age variable, all our variables of interest conform to expected values. More specifically, Kigali city has the highest reported regional value (5.2), followed by the Eastern province (3.9). Kigali City's higher HDDS is likely because respondents have better access to markets which allows local households to access more diverse foods when compared to other provinces (Warner et al. 2023). Given a lack of resources, youth-headed households having a higher average HDDS is surprising but relevant for potential intervention strategies. We hypothesize that higher levels of education contribute to more diverse consumption and likely reinforces the connection between education and nutritional outcomes. While there is not a large difference, households with children under five years of age have a higher HDDS and could reflect households trying to provide young children with more diverse foods. A central tenet of our research is supported by the rising HDDS score with the percentage level of crops sold and will be discussed later. Distance to markets is negatively correlated, which supports the literature that discusses increasing market access via lower travel times as important for dietary diversity. Land size and number of crops produced also are positively correlated to HDDS, reflecting income and crop choice. Input use such as inorganic fertilizer use indirectly suggests that commercialization increases HDDS. Irrigation is perhaps the most dramatic difference in relative scores and is likely associated with high value crops produced and sold for more diverse consumption. Finally, levels of livestock ownership, including just chickens, all point to more diverse household diets. Overall, virtually all variables we considered perform as expected and suggest that HDDS does reflect implicit proxies for consuming more diverse foods at the household level. The next section breaks down the HDDS to better identify more specific aspects of food consumption.

Table 2: HDDS by selected variables

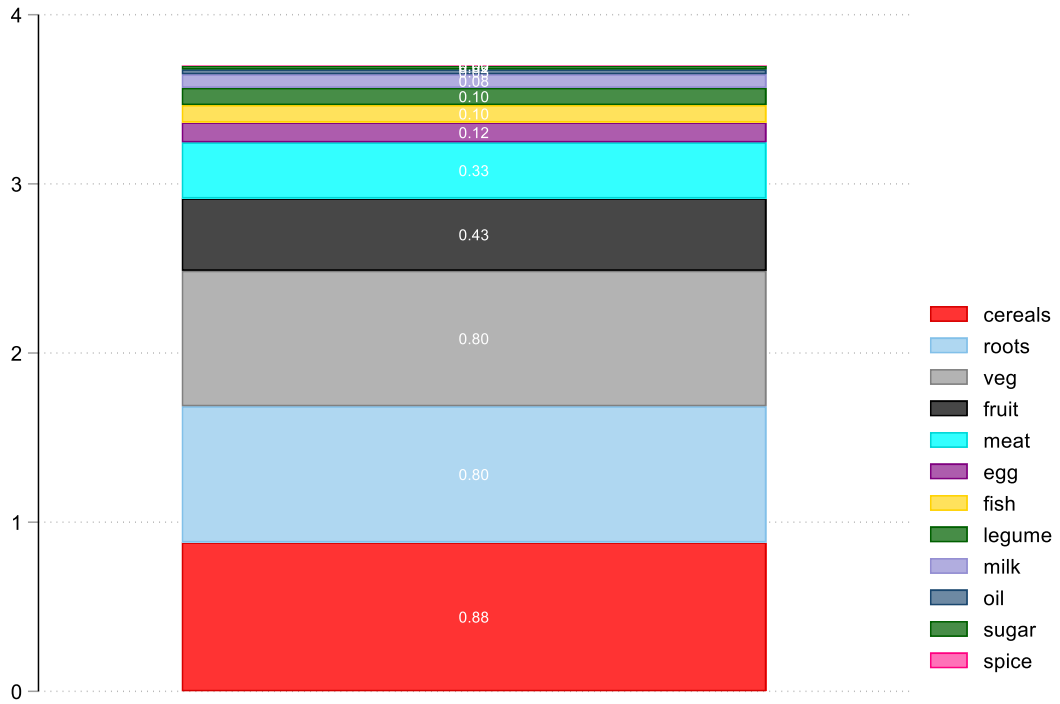
Province Name	Kigali City	5.2
	South	3.7
	West	3.5
	North	3.5
	East	3.9
Head Age	Mature (>=35)	3.7
	Youth (<35)	4.0
Head Gender	Male	3.9
	Female	3.4
Head Education (primary)	Yes	4.2
	No	3.5
Children <5 years	Yes	3.9
	No	3.7
Crop marketed share	0% Sold	3.1
	1-25% Sold	3.8
	25-50% Sold	3.8
	50-75% Sold	4.0
	More than 75% Sold	4.1
Distance to market	30 min or less	3.9
	30-60 min	3.8
	60-120 min	3.7
	> 120 min	3.5
Landholdings	<0.1 ha	3.4
	0.1-0.3 ha	3.7
	0.3-0.5 ha	4.0

	0.5-1 ha	4.2
	>=1 ha	4.3
Total Crops Produced	1 to 2	3.4
	3 to 4	3.7
	5 to 6	4.0
	>=7	4.0
Fertilizer Use (inorganic)	Yes	3.9
	No	3.6
Irrigation	Yes	4.4
	No	3.7
Livestock (TLU)	0	3.5
	0 to .5	3.6
	.5 to 1	3.8
	1 to 2	4.1
	>2	4.8
Owns Chickens	No	3.6
	Yes	4.3

Authors' calculations

Figure 3 depicts the HDDS by aggregate food categories. The most consumed food group by rural households is cereals (88% of all households responding), followed by roots and tubers (80%), vegetables (80%), fruits (43%), meats (33%), eggs (12%), fish (10%), legumes (10%), milk (8%) and oil (8%). This is in line with both research by Ruel (2006) in developing countries, and in Rwanda more specifically (NISR 2021). While not capturing overall amounts consumed in the household, the results provide a general overview of the importance of particular food crops in household consumption. It seems important to note that three food crops, cereals, roots and tubers as well as vegetables comprise two-thirds of the typical consumption of households surveyed. Contrasting to previous research, vegetable consumption is noteworthy.

Figure 3. Total HDDS averages by consumption category



Authors' calculations

Table 3 presents gender and age of household head statistical differences between reported consumption of food categories. While male household heads consume more of every category than female heads, only five of the 12 categories are statistically different. In terms of relative overall difference, meat and roots and tubers, are the two largest gendered categories of difference. Reviewing the left part of Table 3, age negatively correlates with household dietary diversity for all but one category. The results indicate that when the household head is less than 35 years old (youth headed), the households have a greater HDDS when compared to mature household heads. More specifically, over half the difference in HDDS between youth and mature headed households (4.0 vs. 3.6, respectively) is comprised of fruit (0.52 vs. 0.4 or 0.12 difference) and legumes (0.087 difference) for a total difference of 0.2 or approximately 50 percent of the total difference.

Table 3: Differences between food groups—Gender and age (youth/mature)

Food group	Male	Female	Difference (Male-Female)	Mature	Youth	Difference (matureyyouth)
Fruits	0.447	.389*	0.059	0.404	.521***	-0.118
Cereals	0.895	.852**	0.043	0.884	0.870	0.013
Vegetables	0.811	0.782	0.030	0.792	.839**	-0.046
Meat, poultry, offal	0.358	.279***	0.08	0.324	0.360	-0.036
Eggs	0.034	.019*	0.015	0.022	.054***	-0.032
Fish and Seafood	0.030	0.011	0.019	0.020	0.034	-0.014
Legumes	0.132	.089***	0.043	0.1	.187***	-0.087
Roots and tubers	0.834	.748***	0.086	0.803	0.81	-0.007
Milk and milk products	0.107	0.091	0.016	0.1	0.111	-0.011
Oils/fats	0.002	0	0.002	0.002	0	0.002
Sugar/honey	0.114	0.081	0.033	0.093	.142***	-0.049
Spices, condiments, beverages	0.093	.055***	0.038	0.079	0.088	-0.009

Authors' calculations; Statistical significance: 90%=*, 95%= **, 99%=***

4.2 Econometric model—Ordered probit

As described in the methodology section, because of the unique characteristics regarding our HDDS dependent variable,[6] and consistent with research literature on the subject, an ordered probit model was determined to be methodologically appropriate. All selected variables of interest in Table 2 were included in the model as independent variables. Unlike Table 2, the purpose of this model is to isolate individual

[6] Given the low response rates after household reported seven consumed food groups, additional values (greater than seven) were rounded down to seven to maintain relatively robust response categories.

impacts while controlling all other relevant variables.[7] In this way we can comment on how relevant variables impact HDDS while holding all others constant.

Overall, the model performed well with a large majority of variables conforming to expected signs and statistical significance. A key variable of interest, crop commercialization was positive and statistically significant and is consistent with most literature. As expected, landholdings, livestock and relative asset holdings were all positive contributors to dietary diversity. Crop management decisions were mixed, with irrigation strongly positive but inorganic fertilizer use and number of crops produced were positive but not statistically significant while irrigation is both strongly positive and statistically significant. Infrastructure, represented by travel distance to a marketplace, was negative and significant. In terms of demographics, youth-headed households consume more dietary diverse foods. Those households with at least one child less than five years old also had greater dietary diversity and it should be noted that these households were not just youth-designated but equally distributed across youth and mature designations. Somewhat disappointingly, female headed households consumed less diverse foods, but this may be a consequence of their relative age. Importantly, female heads that sold more crops consumed more diverse foods.

Table 4: Ordered logit results

VARIABLES	(1) HH Dietary Diversity Score
HHH Women	-0.104
HHH Women*Crop Sales (%)	0.004**
HHH Youth	0.186***
HHH Education (years)	0.0506***
HH Child under 5	0.141***
Number of Crops Produced	0.00887
Irrigation	0.277***
Inorganic fertilizer	0.00653
Dist. To Market (mins.)	-0.00133***
2nd quartile HH asset (1st quartile omitted)	0.132*
3rd quartile HH asset	0.312***
4th quartile HH asset	0.414***
Top quartile HH asset	0.580***
Crop Sales (%)	0.00310***
Landholdings (ha)	0.116**
Livestock (TLU)	0.106***
Owns Chickens	0.143**
Diagnostics	
Village_id	1.77e-09
cut1	-1.246***
cut2	-0.0714
cut3	0.748***
cut4	1.408***
cut5	1.968***

[7] The coefficients are presented in raw form and are not adjusted for direct interpretation (ie. odds ratios), therefore the direction and statistical significance of the coefficient are relevant, but the values are not directly interpretable.

cut6	2.379***
Observations	1,723

Authors' calculations, *** p<0.01, ** p<0.05, * p<0.1

5. DISCUSSION

This research paper evaluates the effect of commercialization on nutritional outcomes of Rwandan smallholder farmers with an emphasis on gender and youth headed households. The results of this study clearly demonstrate the positive role of commercialization has regarding household dietary diversity and supports much of the commercialization literature that indicates the positive correlation with dietary diversity.

5.1 Household head characteristics

Somewhat disappointedly, female headed households exhibit a negative, but statistically insignificant, relationship with household dietary diversity when compared to their male counterparts. However, unlike male headed households the results also suggest that female-headed households' level of commercialization exhibits a positive and significant correlation with household dietary diversity. This suggests that female-headed households, by participating in commercial activities, may have access to additional income, which they are more likely to spend on enhancing the quality and diversity of their diet. This finding aligns with Obisesan and Awolala (2021), who observed that female-headed households, when they have income, tend to prioritize spending on high-quality foods. This also reinforces the idea that women, when empowered with financial resources, may allocate funds in ways that positively affect household nutrition and food security.

Youth-headed households exhibit a positive and statistically significant relationship with household dietary diversity compared to mature-headed households. This relationship is likely influenced by several factors, including education. The survey data reveal that youth-headed households tend to be better educated than mature-headed households (Warner et al. 2023). Education plays a crucial role in improving knowledge about nutrition, leading to a greater emphasis on nutrient-dense foods. Educated households are more likely to diversify their crop production, recognizing the importance of incorporating a variety of fruits, vegetables, and grains into their diets. Furthermore, access to off-farm employment opportunities allows youth-headed households to earn additional income, which can be used to purchase a wider range of foods. These findings align with previous research that found that as age increases, household dietary diversity scores (HDDS) tend to decrease. Our results emphasize that youth, often considered a disadvantaged group, can improve their household nutrition significantly when provided with educational and economic support.

The education level of the household head is statistically significant in improving household dietary diversity. This relationship may be attributed to the fact that more educated household heads are often more knowledgeable about nutrition and healthier food choices. Additionally, they may have better access to diverse food sources, either through increased financial means or enhanced awareness of where and how to obtain a variety of foods. These findings are consistent with the research of Bandyopadhyay et al. (2012), Taruvinga et al. (2013), Jones et al. (2014), Koppmair et al. (2016), Ahiman et al. (2021), and Sinyolo et al. (2021), all of which suggest a positive link between education and improved household

dietary diversity. This highlights the critical role education plays in enhancing the quality and variety of food consumed by households.

5.2 Household demographics

Table 4 indicates that households with children under five tend to have statistically significant higher dietary diversity scores. This may be because families with young children are more likely to prioritize a varied diet to meet their nutritional needs, as children in this age group require a broader range of nutrients for healthy growth, development, and immune function. Parents may be more conscious of providing a well-rounded diet to support cognitive development, physical growth, and overall health. Additionally, the presence of young children may drive families to seek out diverse food options to fulfill the recommended dietary requirements for early childhood. This aligns with research by Lungaho et al. (2015) and Weatherspoon et al. (2019), who found that children who consume a variety of foods are less likely to experience stunting. While these findings underscore the importance of dietary diversity for early childhood health, it is also important to consider that other factors, such as socio-economic status, access to healthcare, and parental education, may further influence dietary choices and overall child nutrition. Therefore, promoting access to diverse, nutritious foods, particularly for households with young children, remains a critical area for policy intervention and support.

5.3 Agricultural factors

The results indicate that the number of crops produced does not have a statistically significant effect on dietary diversity. This may be due to factors such as food shortages resulting from inadequate farm production, reduced household income, and higher food prices during the lean season. These challenges can limit a household's ability to access a diverse range of foods, even when crop production diversity is relatively high. This finding is consistent with previous research, including that of Matita et al. (2021), who suggest that seasonal fluctuations and production limitations may have a more substantial impact on dietary diversity than the quantity of crops produced.

The findings revealed a positive and statistically significant association between irrigation practices and improved dietary diversity. The implementation of irrigation systems has been shown to enhance the consistency of crop production, which can lead to a broader range of foods available to households. Irrigation also supports commercialization by boosting yields through year-round cultivation and crop diversification, providing a reliable water source to sustain crop yields. As a result, households can sell surplus crops, generating income that enables them to purchase a wider variety of foods. These findings align with research by Jebessa et al. (2019), Moyo and Machethe (2016), Taruvinga et al. (2013), and Passarelli et al. (2018), which also highlight the positive impact of irrigation on agricultural productivity and dietary diversity.

Use of inorganic fertilizer did not have a statistically significant effect on dietary diversity despite its potential to boost production. This suggests that other factors may be contributing to its impact on dietary diversity, beyond just the boost in crop yields. This finding contrasts with the results of Koppmair et al. (2016), who suggested that the use of chemical fertilizers is important for dietary diversity. They argued that by increasing crop yields, fertilizers enable surplus production to be sold, which can generate income to purchase more nutrient-dense food.

Distance to the market has been statistically significant in improving household dietary diversity, with increased distance to the market being associated with a slight decrease in dietary diversity. Households located farther from markets may face limited access to diverse foods, which could result in a lower dietary diversity score. These findings align with research which indicates that market access (ie. infrastructure) plays a crucial role in allowing farmers to sell their produce and purchase a wider variety of foods for improved household nutrition.

5.4 Household assets and livelihoods

The ownership of non-farm assets is significantly associated with improved household dietary diversity. This suggests that wealthier households, particularly those in the 3rd and 4th quartiles, as well as the top quartile, are more likely to have greater dietary diversity. This may be because they have better access to financial resources, which allows them to purchase a broader range of foods. Additionally, ownership of non-farm assets often enables households to invest in agriculture-related inputs and technologies, boosting both their income and their ability to diversify food sources through commercial production. These assets can also help households withstand economic shocks and food price fluctuations, further enhancing food security. These findings are consistent with research by Amao et al. (2023) and Bandyopadhyay et al. (2021), which also found that asset ownership is positively associated with improved household dietary diversity.

5.5 Landholdings and livestock

Landholding size was statistically significantly associated with improved dietary diversity, suggesting that larger landholdings are linked to higher dietary diversity. Households with more land may have the capacity to grow a wider variety of crops, which directly contributes to a more diverse and nutritious diet. In addition to growing diverse crops for household consumption, larger landholdings can provide surplus produce that can be sold in local markets, generating additional income that allows households to purchase a broader range of foods and enhancing dietary diversity. This is consistent with the findings of Kabir et al. (2022) which indicate that land size affects household dietary diversity.

Livestock ownership, including the ownership of chickens, was statistically significantly associated with improved household dietary diversity. This suggests that owning livestock positively influences dietary diversity by providing access to protein-rich animal products such as milk, eggs, and meat. Additionally, the sale of these products can generate income, which households can use to purchase a broader variety of foods, further enhancing dietary diversity. This aligns with findings from Mannaf and Uddin (2012), Taruvinga et al. (2013), and Murendo et al. (2018), which also highlighted the positive impact of livestock ownership on household dietary diversity.

6. CONCLUSION AND RECOMMENDATIONS

Even though Rwanda still grapples with nutrition related issues, a lot has been accomplished over the past two decades for supporting a healthier population. This paper explores the effects of crop commercialization on nutritional outcomes of Rwandan smallholder farmers, with a focus on women and youth headed households. The goal is to enable policy makers to better identify potential strategies for greater household dietary diversity, particularly among more vulnerable rural households.

The results indicated that the rural smallholder farmers diet is predominantly based on cereals, roots and tubers as well as vegetables which comprise two-thirds of the indicated consumption categories of the households surveyed. Diversity scores were highest for Kigali City province (5.2) as compared to other provinces (all below 4), but all values are relatively low, which we attribute, in part, to both economic shocks and the fact that data collection was undertaken during the pre-harvest period between October and November 2022. It is important to emphasize that while absolute values may be lower than average annual values found in other surveys, the relative values are useful to demonstrate differences in access to various food groups.

This research finds that the key determinants that statistically influence household dietary diversity are age and educational attainment of the household head, the presence of children under five, crop sales, travel time to markets, household non-farm assets, irrigation, land holdings, and livestock ownership. Of interest is that female headed households, relative to their male counterparts, appear to respond more significantly to consuming more diverse foods when they market additional crops. This appears to be an important venue for additional research.

These findings have important policy implications as they indicated that during lean season the household dietary diversity of rural households is low. Given these challenges, policy interventions aimed at improving food security should consider not only increasing agricultural productivity but also:

- **Addressing broader economic factors, such as income support, and price stabilization** to ensure that households can access a more diverse and nutritious diet throughout the year.

- **Targeting special groups such as female headed households and mature headed households** this will yield positive results in improving their household dietary diversity through nutrition education by shedding light on the benefits of diversifying their food choices which would help reduce reliance on staple crops and can help in emphasizing the importance of balanced diets, meal planning and making nutritious choices on a limited budget.

- **Nutrition education interventions** for boosting the demand for healthy foods and while reducing the demand for unhealthy options. Making national food-based dietary guidelines available in local languages and accessible across all platforms will guide individuals, informing public health strategies and fostering a healthier, more sustainable food environment.

- **Introducing nutrition education into school's curriculum**: This will equip children with valuable knowledge about nutrition as they grow up, fostering greater awareness of the importance of healthy eating habits. Research results have shown that youth-headed households, being more educated, have higher dietary diversity when compared to mature headed households. Therefore, by providing nutrition education at a young age, children can develop enhanced ability to discern and make informed dietary choices, ultimately leading to improved overall health outcomes.

- **Implementation of women empowerment strategies,** this will not only improve individual health and nutrition but also will yield broader social and economic benefits

- **Facilitating market linkages and investing in market and road infrastructure** for smallholders who are confronted with longer distances to reach markets for selling their diverse produce and purchasing diverse foods would make a significant difference.

- **Improved transportation and market access** can enhance the economic viability of diversified farming systems and ensure that farmers have access to a broader range of nutritious foods.

- **Promoting agripreneurship among youth-headed households,** whose primary challenge is land scarcity, can lead to positive outcomes in improving food security, income generation and economic empowerment.
- **The introduction of vertical farming** could be encouraged, particularly among youth and female-headed households who often have limited land. Vertical farming offers a viable solution by utilizing vertical space, allowing for year-round food production irrespective of seasonal constraints. This approach not only maximizes productivity in limited spaces but also empowers marginalized groups such as female-headed households by providing them with sustainable means of food production and economic independence.
- **Encouraging investment in small livestock**. Livestock improves dietary diversity with obvious access to animal sourced foods, including eggs. More research is needed regarding how livestock specifically enhances nutrition, but this preliminary evidence is positive.
- **Expansion of irrigation infrastructure** can lead to significant improvements as it plays a crucial role in commercialization. By providing a reliable water source, it helps reduce household risk and creates opportunities for producing higher value crops for sale. This, in turn, raises income and access to more diverse foods.

As Rwanda increasingly adopts food systems thinking, intersectoral connections need greater research emphasis, including a deeper understanding of how to improve agriculture production and nutritional outcomes. Our statistical and econometric models indicate potential pathways for improving dietary diversity with small-holder rural producers. Policies that increase household income such as:

- **Investing in higher value crops and adopting improved variety seeds** will yield positive results in increasing profitability and productivity.
- **Improved linkages between agriculture and nutrition** could also be emphasized through production and consumption of nutritional crops such as biofortified crops and it is assumed that the less commercialized households at risk of having low dietary diversity would be able to access the nutrient dense foods directly from farms. Moreover, households who rely on the market can also access these biofortified foods from farmers, as they are high-yielding varieties, as well as drought and heat resistant. This ensures broader availability and accessibility of nutritious options for a wider population.
- **The promotion and consumption of fortified foods** will help in delivering essential nutrients particularly to vulnerable populations.

Future research should also focus on assessing household dietary diversity during the harvest season to explore how seasonal variations affect dietary patterns.

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8. ANNEXES

8.1 annex 1: List of 12 groups and the food contained within each group.

Food Groups	Foods within the Food Group (at least one consumed value=1)	Points
Cereals	Kawunga, rice, porridge, chapati, bread, or macaroni, sosoma, sorghum porridge, millet porridge, or maize on the cob, macaroni for children	1 (Yes)
Roots and tubers	Irish potato, cassava, white sweet potato, or banana cassava ugali, yam, or plantain	1
Vegetables	Carrots, pumpkin, or sweet potatoes that are orange inside, green amaranth, sukuma wiki, pumpkin leaves, cassava leaves, or spinach, Bean leaves, pumpkin leaves, sweet potato leaves, or yam leaves, tomatoes, cabbage, eggplant, or green pepper, cucumber, beetroot, mushrooms, or cauliflower	1
Fruits	Ripe mango, ripe papaya, tamarillo, or passionfruit, orange, mandarin, or grapefruit, Banana, avocado, guava, watermelon, pineapple	1
Meat, poultry, and offal	Sausages, beef, goat, offal, or sheep, pork or rabbit, chicken, or duck	1
Eggs	Eggs	1
Fish and seafood	Fish, dried fish, or sardines	1
Pulses/legumes/nuts	Beans, soybeans, peas, or lentils, groundnuts, groundnut sauce, sunflower seeds, or macadamia nuts	1
Milk/milk products	Cheese, ikivuguto or yogurt, milk, tea with milk, or powdered milk	1
Oils/fats	Fried chicken, burgers, or pizza, mandazi, samosa, chips, fried sweet potato, or fried whole fish	1

Sugar/honey	Cakes or sweet biscuits, bonbon, chocolates, juice or ice cream, Tea with sugar or coffee with sugar	1
Spices, condiments, and beverages	Crisps, Fanta, or energy drinks like Red Bull	1
Total points		12

(Swindale & Bilinsky 2006)

8.2 Annex 2: Dietary diversity questionnaire

	[code dietdiversity_vl]	Yesterday during the day or at night, did you eat or drink whether at home or outside the home any of the following: [**ITEM**] **[code: yesno_vl]**
	M4E_Q00	**M4E_Q1**
1	Kawunga, rice, porridge, chapati, bread, or macaroni	
2	Sosoma, sorghum porridge, millet porridge, or maize on the cob	
3	Irish potato, cassava, white sweet potato or banana cassava ugali, yam, or plantain	
4	Beans, soybeans, peas, or lentils	
5	Carrots, pumpkin, or sweet potatoes that are orange inside	
6	Green amaranth, sukuma wiki, pumpkin leaves, cassava leaves, or spinach	
7	Bean leaves, pumpkin leaves, sweet potato leaves, or yam leaves	
8	Tomatoes, cabbage, eggplant, or green pepper	
9	Cucumber, beetroot, mushrooms, or cauliflower	
10	Ripe mango, ripe papaya, tamarillo, or passionfruit	
11	Orange, mandarin, or grapefruit	
12	Banana, avocado, guava, watermelon, pineapple	
13	Cakes or sweet biscuits	
14	Bonbon, chocolates, or ice cream	
15	Eggs	
16	Cheese	
17	Ikivuguto or yogurt	
18	Sausages	
19	Beef, goat, offal, or sheep	
20	Pork or rabbit	
21	Chicken or duck	
22	Fish, dried fish, or sardines	
23	Groundnuts, Gnut sauce, sunflower seeds, or macadamia nuts	
24	Crisps	
25	Macaroni for children	
26	Mandaazi, samosa, chips, fried sweet potato, or fried whole fish	
27	Milk, tea with milk, or powdered milk	
28	Tea with sugar or coffee with sugar	
29	Juice	
30	Fanta, or energy drinks like Red Bull	
31	Fried chicken, burgers or pizza	

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