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RESEARCH ARTICLE

Unraveling the paradox of child growth in Tanzania's breadbasket regions: impact of household food production

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KEYWORDS

Stunting, crop production, dietary diversity, working status

HIGHLIGHTS

- Growth of children in breadbasket regions is more likely to be impaired than in non-breadbasket regions.
- Higher crop production reduces the risk of stunting in non-breadbasket regions, but not in breadbasket regions.
- Higher crop production contributes to improved height-for-age in non-breadbasket regions, but not in breadbasket regions.
- Increased crop production is associated with greater household dietary diversity in non-breadbasket regions.

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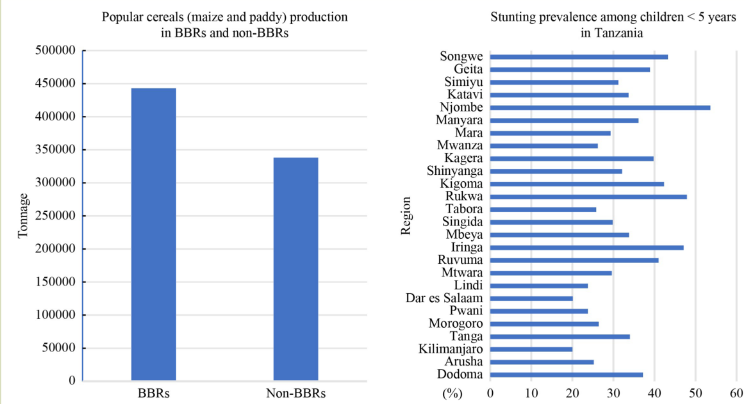
GRAPHICAL ABSTRACT



Motivation of the paper: BBRs have higher production but also higher prevalence of stunted children than non-BBRs.
Findings: Higher crop production correlates with lower risks of stunting and improved height-for-age (HAZ) in non-BBRs, mainly due to greater household dietary diversity (HDDS).

ABSTRACT

Tanzania's food supply relies heavily on crop production from its breadbasket regions (BBRs). Despite their central role in national agriculture, the 2018 National Nutrition Survey revealed a troubling paradox: five of the regions with the highest rates of child stunting and severe malnutrition are located within these BBRs. This paper investigates the underlying causes of this paradox. Using data from the 2017–2018 National Household Budget Survey, the 2020–2021 National Integrated Labor Force Survey, and the 2020–2021 National Panel Survey, instrumental variable probit models were used to assess the impact of household crop production on children's growth status. The findings confirm that children in BBRs are more likely to experience stunting than those in non-BBRs. Overall, higher crop production is associated with a lower risk of stunting and improved height-for-age z-scores. However, these benefits appear more pronounced in non-BBRs than in BBRs. Further analysis shows a positive relationship between increased crop production and household dietary diversity, although this relationship is also weaker in BBRs. These results indicate that factors beyond food availability, such as dietary practices and household-level conditions, may contribute to the observed paradox, highlighting the need for more nuanced policy discussions.

1 Introduction

Tanzania's economy is predominantly based on agriculture. The agricultural sector contributes about 31% to Tanzania's GDP and supports the livelihoods of about 75% of the population[1,2]. Notably, 80% of Tanzania's crop production is focused on food, underscoring the subsistence-oriented nature of its agriculture[2]. Despite Tanzania's vast agricultural potential, variations in climate and topography have made certain regions particularly well-suited for crop production, especially grain cultivation. Eight of Tanzania's 26 administrative regions, Ruvuma, Rukwa, Mbeya, Iringa, Njombe, Songwe, Morogoro and Katavi, are recognized as Tanzania's breadbasket regions (BBRs) due to their significant contribution to food production. According to a previous study[1], between 2007 and 2010, these regions together accounted for over 38% of Tanzania's maize production, with maize being the most commonly consumed cereal in the country. By 2023, the top three regions among these had been identified as the leading grain-producing areas[3].

However, a paradox emerges when examining the relationship between crop production and nutrition in Tanzania. While increasing crop production is generally regarded as essential for improving nutrition, particularly in developing countries where undernutrition and malnutrition are prevalent, the situation in Tanzania is more complex. The 2018 National Nutrition Survey revealed that five regions with the highest rates of child stunting and severe malnutrition, Njombe, Rukwa, Iringa, Songwe and Ruvuma, are all located within the BBRs[4]. This finding contradicts earlier studies indicating a direct correlation between higher crop production and improved nutritional outcomes. Research in Tanzania has generally found a positive association between crop production and household nutrition[5–8]. Similar findings have been reported in studies from other countries, including Malawi[9], Bangladesh[10,11] and Nigeria[12], along with broader cross-country analyses[13,14], all of which highlight positive links between agricultural production and nutritional quality.

However, other studies caution that while such relationships may exist, they are neither universally applicable nor straightforward. Some studies[15–18] have indicated that these associations are more nuanced. In Tanzania, the paradox of high crop production coexisting with high malnutrition rates has largely been identified through descriptive statistics. Unfortunately, such statistics often oversimplify the data, masking underlying causes. This underscores the need for a more detailed analysis to fully understand the complex relationship between crop production and nutrition. It is therefore crucial, particularly for policymaking, to determine whether the descriptive findings from Tanzania's surveys accurately reflect real-world dynamics or merely simplify a far more complex situation.

This study sought to resolve the paradox between crop production and child stunting in Tanzania by examining the impact of household food production on children's growth. Specifically, it investigated how household crop production affects child growth status, accounting for regional differences between families residing in breadbasket and non-breadbasket regions. Additionally, the study examined two potential mechanisms: the influence of household dietary quality and the employment status of mothers. The research had two main objectives. First, it aimed to rigorously assess whether the paradox observed in the national nutrition survey, concerning the differential impact of crop production on child growth in BBRs versus non-BBRs, is statistically significant. Second, it sought to explore possible explanations for this paradox, if they arose from the survey data or from the statistical analysis conducted in this study.

The remainder of this paper is structured as follows: Section 2 outlines the materials and methods employed; Section 3 presents the results; Section 4 discusses the findings; and the final section concludes with implications for policy-making.

2 Material and methods

2.1 Data sources

We used secondary data obtained from the National Bureau of Statistics of Tanzania, specifically drawing information from three separate surveys. The use of multiple surveys was necessary due to the difficulty of capturing all relevant variables within a single data set. The 2020–2021 Tanzania Panel Survey served as the primary data set for empirically examining the differential impact of crop production on children's growth status between BBRs and non-BBRs. This panel survey provided two key indicators of child growth: stunting and height-for-age z-scores (HAZ). Stunting was recorded as a binary variable, where a value of 1 indicates stunting and 0 indicates its absence. HAZ was categorized into four levels: severe, moderate, mild and healthy. Additionally, the data set included information on household crop production, reported in kilograms for the season preceding the survey.

However, since the 2020–2021 Panel Survey has not included data on household dietary diversity scores (HDDS), so we supplemented it with the 2017–2018 Household Budget Survey. This survey was used to evaluate HDDS as a potential explanatory factor for the observed paradox. It provided detailed information on the variety of foods consumed by households over a 7-day period, which is used to compute the HDDS. To address the absence of data on working hours in the other two surveys, we also incorporated the 2020 Integrated Labor Force Survey. This data set allowed us to examine a second mechanism, the time mothers spend away from home, as it relates to children's growth outcomes.

To address potential inconsistencies arising from the use of different surveys, we relied on the 2020–2021 Tanzania Panel Survey as the core data set for analyzing the differential impact of crop production on stunting and HAZ between BBRs and non-BBRs. The other two surveys were used only to supplement variables not available in the panel data. To ensure comparability, we selected households that match the socioeconomic and demographic characteristics of those in the panel data set. We also adopt standardized and harmonized definitions for key variables, including crop production, child growth indicators and dietary diversity. In addition, we conducted robustness checks by comparing household characteristics across data sets to confirm there are no systematic differences that could bias our findings. We verify that key demographic and economic indicators (e.g., household size, income and education levels) are consistent across data sets, thereby mitigating concerns about sample incompatibility.

2.2 Estimation techniques

In the first part of the study, we used the propensity score matching (PSM) technique to examine differences in children's growth status and crop production between BBRs and non-BBRs. As given in Eq. (1), we controlled for household income and size, the gender and age of the household head, and an urban residence dummy. Subsequently, we empirically analyzed the relationship between household crop production and children's growth status, using two measures: stunting and HAZ. A key challenge in estimating Eq. (2) is the potential endogeneity bias arising from mutual causality between child growth status and household crop production decisions. For example, households may increase food production in response to child undernutrition. To address this potential bias, we used instrumental variable (IV) probit models.

When estimating stunting, we used land ownership status (specifically, whether the household owns planted land) as an instrumental variable for crop production. For HAZ, which was categorized into four levels, we apply the two-stage residual inclusion (2SRI) method, following approaches used in prior studies[10,19]. Land ownership qualifies as a valid instrument for two main reasons. First, after controlling for other household characteristics such as income and size, land ownership was not expected to directly influence children's growth outcomes, satisfying the exogeneity condition. Second, since crop production is heavily dependent on access to land, the relevance condition was also fulfilled.

Accordingly, in our empirical analysis, we used IV probit models to examine the relationship between crop production and stunting. For HAZ, we used the 2SRI approach to assess how crop production relates to children's overall growth status.

The specific model specifications for PSM are:

$$\tau_{ATT} = E(\tau|D=1, P(X)) = E[Y(1)|D = 1, P(X)] - E[Y(0)|D=1, P(X)] \quad (1)$$

where, τ_{ATT} is an average treatment effect on the treated, $D = 1$ is BBRs, $Y(1)$ and $Y(0)$ are children's growth status and crop production when $D = 1$ and $D = 0$ at given matching variables X, respectively.

The probit model can be specified as:

$$P(Growth_i = 1) = F(\gamma_0 + \gamma_1 Pr_i + \gamma_2 BBR + \gamma_3 Pr \times BBR + \gamma_4 X_i + \varepsilon_i) \quad (2)$$

where, $Growth_i$ is a binary variable representing the growth status of a child in the i^{th} household; Pr_i is crop production, measured as the total quantity produced; BRR captures the five regions identified as having higher rates of poor child growth in the national nutrition survey; X_i is a vector of control variables, including the child's age, household income and size, gender and age of the household head, an urban dummy, and the marital status of the household head; ε_i is the error term.

The covariates were included to enhance the comprehensiveness of our analysis, ensuring that we account for all plausible explanations behind the observed paradox. From a theoretical standpoint, these variables represent hypothesized pathways discussed in the literature[20–22], and remain essential to understanding child growth dynamics in Tanzania's breadbasket regions.

We also included an interaction term between crop production and BBR status to capture the heterogeneous impact of production on children's health outcomes across BBRs and non-BBRs. Economic theory, particularly agricultural household models[23], suggests that household production decisions affect both consumption and health outcomes through income effects and own-production effects. These effects are unlikely to be homogeneous across regions, especially where structural and institutional contexts differ.

In Tanzania, BBRs vary markedly from non-BBRs in terms of agricultural intensity, production scale and crop specialization. Households in BBRs often engage in higher levels of production and are more market-integrated. As a result, food production may not translate into improved household consumption, particularly when much of the harvest is commercialized. This aligns with agricultural transformation theory, which posits that increases in production, especially in market-oriented regions, do not automatically yield better nutrition outcomes. This disconnect may arise from commercialization, limited dietary diversity, and intra-household food allocation dynamics. If the sum of γ_1 and γ_3 is less than γ_1, and statistically significant, consistent with findings from the national nutrition survey, then a deeper investigation is warranted to explain the coexistence of food abundance and poor child growth in BBRs.

We developed two hypotheses to explore this paradox. First, economic trade-offs may be at play: increased crop production may require women, typically the primary caregivers, to spend more time away from home on economic activities. Prior research emphasizes that time is a critical determinant of nutritional outcomes, closely linked to food preparation and caregiving[24–27]. Second, we hypothesize that increased crop production may reduce household dietary diversity scores, as commercialization and specialization may drive households to cultivate fewer food types for home consumption in favor of market-oriented crops.

To test these hypotheses, we examined whether increases in crop production are associated with (1) longer working hours for women away from home in BBRs, and (2) lower HDDS. It is important to note that dietary diversity can be measured at the individual or household level, each offering distinct interpretive insights. For this study, we used HDDS due to data availability. The recall period for HDDS varies across studies, from 24-h recall[28,29] to 7-day recall periods[30,31]. Therefore, we adopted a 7-day recall period, which better captures day-to-day variation in household food consumption[14]. HDDS is computed based on 10 food groups: cereals; legumes, nuts and seeds; tubers and roots; meat; fish and other seafood; eggs; milk and milk products; fruits; vegetables; and cooking oils.

To test our hypotheses, we used instrumental variable regression models. Specifically, we applied a Poisson IV regression model for Eq. (3) and a standard IV regression model for Eq. (4). Poisson regression is appropriate for count data, making it suitable for modeling HDDS in Eq. (3). To focus on women's working hours, Eq. (4) was estimated using a subsample of adult women. These equations are:

$$HDDS_i = \alpha_0 + \alpha_1 Pr_i + \alpha_2 Pr_i \times BBR + \alpha_3 BBR + \alpha_4 Z_i + \varepsilon_i \quad (3)$$

$$Hours_i = \beta_0 + \beta_1 Pr_i + \beta_2 Pr_i \times BBR + \beta_3 BBR + \beta_4 M_i + \mu_i \quad (4)$$

where, Z_i and M_i are a set of covariates, including household size, the age and education level of the household head and an urban dummy variable.

Additional controls in the HDDS model included household income, the gender of the household head, and dummy variables indicating the availability of a kitchen and ownership of a refrigerator for food preservation. For the working-hours model, additional controls included possession of production skills, a dummy variable for involvement in commercial agriculture, the disability and residence status of the household head, perceived benefits of the activity being performed and access to credit within the last 12 months.

In the HDDS model, if α_2<0, this implies that as crop production increases in BBRs, dietary diversity is lower compared to non-BBRs. Similarly, in the working-hours model, if β_2<0, it indicates that increases in production in BBRs are associated with individuals, particularly women, spending more time away from home than in non-BBRs, potentially impacting childcare negatively. To assess whether BBRs experience a greater impact, we compare the interaction coefficients between models estimated separately for BBRs and non-BBRs. Also, to address potential heteroskedasticity, all models are estimated using robust standard errors. Notably, the working-hours model is estimated using a sub-sample consisting only of women.

3 Results

3.1 Descriptive statistics

Table 1 presents the descriptive statistics of the variables used in this study, highlighting notable differences between BBRs and non-BBRs. Children residing in BBRs were more likely to have experienced stunting compared to those in non-BBRs. Also, the HAZ scores of children in BBRs were significantly lower than those of children in non-BBRs. Since HAZ was measured as a categorical variable, with higher values indicating better growth outcomes, the lower HAZ in BBRs aligns with the higher stunting rates observed. This finding is consistent with data from the national nutrition survey, which also reported a higher prevalence of poor child growth in these regions.

In addition, the level of crop production in BBRs exceeded that of non-BBRs. Among the predictor variables, significant differences are observed between the two regions in most cases. For example, children in BBRs tend to be older, and their families are generally wealthier but smaller in size. BBRs also had a higher proportion of female-headed households, with many located in more urbanized settings. In these regions, mothers are more commonly responsible for fetching water.

3.2 Differences in children’s growth status and crop production between BBRs and non-BBRs

Table 1 indicates that children residing in BBRs were more likely to have experienced stunting and have lower HAZ scores. We observe a significant disparity in children’s growth status between the two regions. To determine whether this variation can be attributed to individual and household-level heterogeneity, we used a PSM approach. This method uses individual and household characteristics as matching variables to compare children’s growth outcomes across regions. As shown in Table 2, our results revealed that children in BBRs

Table 1 Descriptive statistics

Variable	BBR		Non-BBR		Difference
	Mean	S.D.	Mean	S.D.	
Stunting (ratio)	0.442	0.019	0.334	0.006	0.107***
HAZ	2.77	0.041	2.93	0.013	−0.156***
Production (kg)	923	61.3	799	13.5	124*
Child_Age	32.1	0.675	29.3	0.203	2.86***
log(HHIncome)	11.1	0.023	11.0	0.008	0.138***
hhSize	6.60	0.099	8.86	0.055	−2.26***
HHAge	18.9	0.662	18.4	0.206	0.528
FHHs	0.226	0.016	0.194	0.005	0.033**
Urban	0.190	0.015	0.109	0.004	0.080***
PersonWater	0.096	0.012	0.055	0.003	0.041***
Firewood	0.901	0.012	0.895	0.004	0.005
Observations	654		6706		7360

Note: HAZ, height-for-age on four-point scale (1, severe; 2, moderate; 3, mild; and 4, healthy); ***, ** and * are statistical significance at $p < 0.01$, $p < 0.05$ and $p < 0.1$, respectively; Child_Age is measured in months; log(HHIncome), log per capita household income; hhSize, household size; HHAge, age of household head; FHHs, gender of household head; Urban, urban dummy; PersonWater, adult women participating in water-fetching activities; and Firewood, main cooking fuel is firewood. S.D. refers to standard deviation.

Table 2 Differences in children’s growth status and crop production between BBRs and non-BBRs-PSM

Item	BBRs	Non-BBRs	ATT	Std.Err.
Stunting (ratio)	0.442	0.347	0.095***	0.030
HAZ	2.77	2.86	−0.085	0.066
Production (kg)	923	597.504	326.226***	75.9

Note: *** indicates $p < 0.01$.

continue to face a significantly higher risk of stunting compared to their counterparts in non-BBRs. However, the difference in HAZ scores was no longer statistically significant after matching.

Also, crop production in BBRs is about 50% higher than in non-BBRs. While previous studies have demonstrated a strong link between food production and improved child growth in developing countries, our findings show that despite higher levels of crop production in BBRs, children's growth outcomes remained significantly poorer.

3.3 Impact of crop production on stunting risk of children

To examine the relationship between crop production and children's growth status, we used instrumental variable (IV) probit models. We used stunting and HAZ as indicators of child growth and designate them as the dependent variables. The rationale for using the IV probit model was based on the results of the Wald test of exogeneity. The test yielded a $\chi^2(2)$ of 8.66 ($p = 0.01$), leading to the rejection of the null hypothesis of no significant difference between the probit and IV probit estimates. This result confirms the presence of endogeneity, implying that estimates from the standard probit model may be biased. Therefore, we relied on the IV probit model in our analysis.

To further assess the strength and validity of our instruments, we conducted both the Anderson-Rubin (AR) and Wald tests. The AR test evaluates whether the instrument is strongly correlated with the endogenous regressor, a key condition for valid parameter identification in structural equations[32]. It tests the null hypothesis that the instrument is either weak or invalid, i.e., it lacks sufficient correlation with the endogenous variable.

In contrast, the Wald test examines whether the coefficient of the endogenous variable is statistically different from zero. In the context of weak instruments, it indirectly assesses instrument strength by testing the significance of the IV-based estimate. The null hypothesis of the Wald test states that the endogenous regressor has no effect on the dependent variable or that the instrument is weak.

As shown in Table 3, the results from both the AR and Wald tests rejected their respective null hypotheses, indicating that the chosen instrument, land ownership, is strongly correlated with the endogenous variable and satisfies the relevance condition for IV estimation.

Table 4 presents the IV probit results on the relationship between crop yield and children's stunting status. The interaction term between household crop production and BBR status had a statistically significant marginal effect of 1.18 at the 5% significance level. This indicates that the influence of crop production on child stunting is significantly more positive (i.e., less beneficial or even adverse) in BBRs than in non-BBRs.

Economically, while an increase in household crop production is generally expected to reduce the risk of stunting, this beneficial effect appears to be attenuated, or even reversed, in BBRs. In other words, BBR status moderates the relationship between crop production and nutrition, likely due to structural characteristics of these regions. BBRs are potentially more commercially driven, with households often selling a large share of their agricultural output instead of consuming it directly. This commercialization may undermine the nutritional benefits of self-produced food, particularly if the resulting income is not used to purchase a diverse array of nutrient-rich foods.

Additionally, households in BBRs may face competing demands on caregiver time due to the labor-intensive nature of farming. This may reduce the time available for childcare and feeding. These two possible explanations are examined in greater depth in the next section of this paper. Also, the findings indicate that the overall likelihood of children experiencing stunting is higher in BBRs than in non-BBRs. The analysis also revealed a negative and statistically significant association between crop yield and the probability of stunting. Specifically, marginal effects suggest that, in the total sample, a 100% increase in crop yield is associated with a 164% reduction in the probability of stunting. However, regionally

Table 3 Testing for weak instrument

Test	Statistic	*P*-value
AR	$Chi^2(1) = 8.51$	$Prob > Chi^2 = 0.00$
Wald	$Chi^2(1) = 6.38$	$Prob > Chi^2 = 0.01$

Table 4 Impact of crop production on children's stunting risk

Variable	Total sample		BBR		non-BBR	
	dy/dx	Std.Err.	dy/dx	Std.Err.	dy/dx	Std.Err.
BBR	6.17**	2.95				
log(Production)×BBR	1.18**	0.531				
log(Production)	–1.04**	0.526	0.126	0.121	–1.82***	0.698
Child_Age	0.010***	0.002	0.005	0.004	0.007**	0.003
log(HHIncome)	0.103	0.133	–0.030	0.146	0.437*	0.228
HHSize	0.124*	0.064	–0.057	0.036	0.213**	0.083
HHHAge	–0.004	0.004	0.003	0.005	–0.005	0.004
HHHGender	0.030	0.062	0.223	0.189	–0.039	0.153
Marital	0.281*	0.162	–0.124	0.187	0.407**	0.176
Urban	–0.633**	0.252	–0.083	0.188	–1.27***	0.451
observations	7360		654		6706	
Wald test of exogeneity	8.66**		0.87		9.33***	

Note: Dependent variable being stunting dummy with 1 for stunting and 0 otherwise; BBR, breadbasket regions; and ***, ** and * indicate $p < 0.01$, $p < 0.05$ and $p < 0.1$, respectively.

disaggregated effects showed that in BBRs, a 100% increase in crop yield leads to a 13.2% increase in the probability of stunting, while in non-BBRs it results in a 104% reduction.

This weaker reduction in stunting in BBRs may explain the higher prevalence of poor child growth in those regions relative to non-BBRs. When analyzing subsamples, the negative relationship between crop yields and stunting remains strong and statistically significant in non-BBRs, but is not statistically significant in BBRs. These findings reinforce the paradox observed in the national nutrition survey. The results are consistent with previous studies conducted in Nigeria[15], a cross-country study[16] and prior research in Tanzania[33]. Among the control variables, child age, household size, and the marital status of the household head are positively associated with the risk of stunting.

3.4 Robustness test: results from HAZ

The results for HAZ, obtained from the 2SRI model, are presented in Table 5. These results are consistent with those of the IV probit model used to estimate stunting. First, the findings indicate that an increase in crop yield was associated with a higher probability of children attaining a healthy HAZ score. Specifically, the results suggest that increased crop production significantly reduced the likelihood of children

Table 5 Impact of crop production on children's HAZ: results from ordered probit model

Variable		Total sample		BBR		non-BBR	
		dy/dx	Std.Err	dy/dx	Std.Err	dy/dx	Std.Err
BBR	Severe	0.110	0.238				
	Moderate	0.072	0.156				
	Mild	0.015	0.032				
	Health	–0.197	0.426				
log(Production) × BBR	Severe	–0.009	0.042				
	Moderate	–0.006	0.028				
	Mild	–0.001	0.006				
	Health	0.016	0.075				

(Continued)

Variable		Total sample		BBR		non-BBR	
		dy/dx	Std.Err	dy/dx	Std.Err	dy/dx	Std.Err
log(Production)	Severe	-0.090^{***}	0.024	−0.147	0.275	-0.087^{***}	0.019
	Moderate	-0.059^{***}	0.016	−0.195	0.361	-0.054^{***}	0.012
	Mild	-0.012^{***}	0.004	0.028	0.053	-0.012^{***}	0.003
	Health	0.162^{***}	0.043	0.314	0.583	0.154^{***}	0.033
log(HHIncome)	Severe	0.013^{***}	0.011	0.076	0.094	0.023^{**}	0.011
	Moderate	0.009^{***}	0.007	0.101	0.122	0.015^{**}	0.007
	Mild	0.002^{**}	0.001	−0.015	0.019	0.003^{**}	0.002
	Health	-0.023^{***}	0.019	−0.162	0.198	-0.041^{**}	0.019
Child_Age	Severe	0.002^{***}	0.000	0.001^{**}	0.001	0.002^{***}	0.000
	Moderate	0.001^{***}	0.000	0.002^{**}	0.001	0.001^{***}	0.000
	Mild	0.000^{***}	0.000	-0.000^{*}	0.000	0.000^{***}	0.000
	Health	-0.003^{***}	0.000	-0.003^{**}	0.001	-0.003^{***}	0.000
HHHAge	Severe	−0.000	0.000	0.000	0.001	-0.001^{*}	0.000
	Moderate	−0.000	0.000	0.000	0.002	-0.000^{*}	0.000
	Mild	−0.000	0.000	−0.000	0.000	-0.000^{*}	0.000
	Health	0.001	0.001	−0.000	0.003	0.001^{*}	0.001
HHSize	Severe	0.010^{***}	0.003	0.012	0.033	0.009^{***}	0.003
	Moderate	0.007^{***}	0.002	0.016	0.043	0.006^{***}	0.002
	Mild	0.001^{***}	0.000	−0.002	0.006	0.001^{***}	0.000
	Health	-0.018^{***}	0.006	−0.025	0.069	-0.016^{***}	0.005
HHHGender	Severe	0.006	0.008	0.021	0.063	0.025^{**}	0.012
	Moderate	0.004	0.005	0.028	0.084	0.016^{**}	0.007
	Mild	0.001	0.001	−0.004	0.012	0.003^{**}	0.002
	Health	−0.010	0.014	−0.044	0.135	-0.044^{**}	0.020
Marital	Severe	0.026^{**}	0.010	0.029	0.061	0.032^{***}	0.010
	Moderate	0.017^{***}	0.007	0.039	0.080	0.020^{***}	0.006
	Mild	0.003^{***}	0.001	−0.006	0.012	0.004^{***}	0.002
	Health	-0.046^{***}	0.018	−0.063	0.130	-0.056^{***}	0.018
Urban	Severe	-0.046^{***}	0.015	−0.084	0.110	-0.053^{***}	0.016
	Moderate	-0.030^{***}	0.010	−0.111	0.142	-0.033^{***}	0.010
	Mild	-0.006^{***}	0.002	0.016	0.022	-0.007^{***}	0.003
	Health	0.081^{***}	0.027	0.179	0.231	0.093^{***}	0.029

Note: Dependent variable being HAZ, height-for-age on four-point scale (1, severe; 2, moderate; 3, mild; and 4, healthy); BBRs, breadbasket regions; and ***, ** and * indicate $p < 0.01$, $p < 0.05$ and $p < 0.1$, respectively.

falling into the severe, moderate and mild malnutrition categories, while increasing the probability of being in the healthy category. A 100% increase in crop yield was associated with a 9.0% reduction in the probability of severe malnutrition, a 5.9% reduction in moderate malnutrition and a 1.2% reduction in mild malnutrition. Conversely, it increased the probability of a child being in good nutritional health by 16.2%.

The marginal effects of the interaction term between crop production and BBR status followed a similar trend as the main effects, negative for all malnutrition levels and positive for healthy status. However, none of these interaction effects were statistically significant. This lack of significance indicates that the positive impact of crop production on children's HAZ scores did not differ meaningfully between BBRs and non-BBRs. In other words, despite expectations that households in BBRs, due to better agroecological conditions, would experience greater nutritional benefits from increased crop production, the results do not support this. The lack of significant interaction terms indicates that being located in a breadbasket region neither amplifies nor diminishes the effect of crop production on child nutritional outcomes, at least within the framework of this model.

In addition, child age, household size, marital status of the household and female-headed households was negatively associated with a healthy HAZ score. In contrast, household income, urban residence, and the age of the household head were positively associated with healthier HAZ outcomes.

3.5 Potential mechanisms for BBRs and growth of unhealthy children

The findings of this study align with the national nutrition survey, which indicates that children in BBRs are more prone to growth impairments than those in non-BBRs. To investigate this paradox, we explored whether the number of hours women spend working away from home may be a contributing factor. The core hypothesis posits that higher crop production in BBRs may compel women to engage more actively in out-of-home economic activities. As a result, the time available for household care and child nutrition management is reduced. To test this hypothesis, we used an instrumental variable (IV) regression approach. A key concern is the potential simultaneity between farm production and women's working hours. From one perspective, increased farm yields may enhance household food security and income, reducing the need for women to seek off-farm employment. From another, longer hours spent by women in external work may reduce their availability for farm labor, thereby affecting yields. This endogeneity issue would render ordinary least squares estimates biased and inconsistent.

To address this, we used farm ownership (a binary variable indicating whether the household owns or rents the farm) as an instrument for farm production. Theoretically, farm ownership is strongly associated with production levels but is unlikely to directly affect women's working hours, thus making it a suitable instrument. The validity of the IV approach over ordinary least squares was confirmed through endogeneity tests. Specifically, Durbin's score (Chi-square) test yielded a statistic of 7.22 (p = 0.03) and the Wu-Hausman F-test returned an F-statistic of 25.3 (p = 0.00). Since both p-values are below the 5% threshold, we reject the null hypothesis of exogeneity, thereby confirming that farm production is endogenous and justifying the use of IV regression. Consequently, the IV estimates can be considered to provide more consistent and reliable insights into the causal relationship between farm production and women's working hours.

We estimated a system of three equations. In the first model, using the full sample and including an interaction term between crop yields and BBR status, we assessed whether higher yields in BBRs were associated with increased time women spend working outside the home. However, as shown in Table 6, the marginal effect of this interaction term was not statistically significant. This finding does not support our hypothesis: higher crop yields in BBRs did not significantly increase women's out-of-home working hours compared to non-BBRs. Thus, agricultural productivity in BBRs does not appear to have driven women's time away from the home. To explore regional heterogeneity, we estimated the model separately for BBRs and non-BBRs. In BBRs, the marginal effect of crop yield was negative but not statistically significant, suggesting that higher agricultural production may slightly reduce women's time spent away from home, possibly due to improved food security and income, but the evidence is inconclusive.

Conversely, in non-BBRs, the marginal effect was positive but also not statistically significant. This may indicate a weak tendency for increased agricultural production to create economic opportunities that draw women away from the home. However, the absence of statistical significance prevents firm conclusions. Overall, these findings suggest that the number of hours women spend working away from home is unlikely to explain the paradoxical coexistence of high agricultural production and poor child growth outcomes in BBRs.

Another possible explanation for the paradoxical finding of higher stunting rates and poor HAZ scores among children in Tanzania's BBRs relates to household dietary diversity. We hypothesized that higher levels of crop production in BBRs may, paradoxically, lead to lower HDDS. This may be driven by increased specialization and commercialization of agriculture. As households become more commercially oriented, focusing on the cultivation of specific cash crops, they may deprioritize

Table 6 IV regression results for the impact of production on out-home mothers' working hours

Variable	Total sample		BBRs		non-BBRs	
	Coefficients	Std.Err	Coefficients	Std.Err	Coefficients	Std.Err
BBR	−9.73	8.97				
Log(Production) × BBR	0.857	0.783				
log(Production)	−0.933	0.720	−0.456	0.283	33.4	1140
log(HHIncome)	3.14	4.09	−0.070	0.084	3.00	104
log(Age)	−0.026	0.297	−0.639	0.434	−15.9	532
HHSize	0.037	0.034	0.114**	0.048	−1.18	40.1
Year_School	0.036	0.036	0.039	0.044	−1.78	60.8
Marital	0.086	0.118	0.129	0.203	−0.250	11.3
Urban	−0.091	0.150	0.009	0.241	−0.102	5.03
Observations	950		126		824	

Note: *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$; the estimation focused exclusively on female subsamples in both BBRs and non-BBRs to capture gender-specific working hours.

the production and consumption of a wide variety of food items essential for a balanced diet. Such dietary patterns can negatively affect children's nutritional outcomes, offering a plausible explanation for the paradox.

To test this hypothesis, we used an IV-Poisson regression model rather than the standard Poisson regression, due to concerns about potential endogeneity. Such endogeneity arises from a possible bidirectional relationship between household crop production (measured by yield) and HDDS. On one side, higher crop production may improve dietary diversity by increasing food availability. On the other, households with more diverse dietary preferences may choose to cultivate a wider range of crops. Ignoring this simultaneity may lead to biased and inconsistent estimates. To address this issue, we use farm ownership (a binary variable equal to 1 if the household owns the farm and 0 if it rents) as an instrumental variable. Farm ownership affects a household production capacity but, after controlling for socioeconomic factors, is plausibly exogenous to HDDS. It thus satisfies both the relevance and exclusion criteria for a valid instrument.

The results, as shown in Table 7, indicate a notable divergence in marginal effects between the standard Poisson and IV-Poisson regression models, confirming the presence of endogeneity. The significant shift in marginal estimates after instrumenting highlights the importance of accounting for the bidirectional relationship. Since HDDS is a count variable, the Poisson regression is appropriate for this estimation. We conducted three sets of estimations, on the full sample and separately for BBRs and non-BBRs. For the full sample, we included an interaction term between crop yield and BBR status. A negative and statistically significant coefficient on this interaction term would support the hypothesis that crop yield in BBRs is associated with lower dietary diversity. The results confirmed this: the interaction term is negative and significant at the 10% level, indicating that rising crop yields in BBRs are linked to less diverse household diets relative to non-BBRs. Although modestly significant, this result offers compelling preliminary evidence that commercialization and crop specialization in BBRs may have contributed to nutritional deficiencies.

The subsample analyses provided further insight. In both BBRs and non-BBRs, the marginal effects of crop production on HDDS were positive, indicating that increased yields generally improve dietary diversity. However, the strength and significance of this relationship differed by region. In non-BBRs, the effect is statistically significant, indicating that higher crop yields could have led to more diverse diets and, likely, improved nutritional outcomes. In contrast, in BBRs, the marginal effect, though positive, was not statistically significant. This supports the earlier interaction effect and implies that agricultural productivity in BBRs had not meaningfully enhance dietary diversity. This may be due to commercialization (with households selling rather than consuming diverse foods), market access limitations or cultural food preferences that restricted dietary diversity, even in highly productive regions.

In combination, these results offer a plausible explanation for the nutritional paradox observed in BBRs. In non-BBRs, higher crop production generally enhances dietary diversity and

Table 7 Poisson IV regression results for the impact of production on household dietary diversity (HDDS)

Variable	Ordinary poisson		IV-poisson regression (d*y*/d*x*)					
	Total sample		Total sample		BBRs		Non-BBRs	
	Coefficient	Std.Err	Coefficient	Std.Err	Coefficient	Std.Err	Coefficient	Std.Err
BBR	0.033	0.034	−0.623**	0.269				
Log(Production) × BBR	0.018**	0.007	−0.128*	0.074				
log(Production)	0.039**	0.016	0.639***	0.120	0.124	0.212	0.665***	0.144
log(HHIncome)	0.215***	0.018	0.190***	0.027	0.210***	0.033	0.192***	0.026
HHSize	−0.028***	0.004	−0.054***	0.006	−0.004	0.010	−0.062***	0.008
HHGender	0.018	0.028	0.010	0.034	0.041	0.061	0.008	0.039
Marital	0.015	0.030	−0.008	0.037	−0.024	0.076	−0.015	0.041
Year_School	0.009**	0.003	0.014***	0.004	0.024***	0.007	0.016***	0.005
HHHage	−0.002***	0.001	−0.004***	0.001	−0.002	0.002	−0.003***	0.001
Urban	0.082***	0.026	0.303***	0.058	0.128	0.100	0.417***	0.083
Constant	−2.48***	0.201						
Observations	7460				654		6706	

Note: *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$.

nutritional outcomes. As noted in previous studies[34,35], smallholder farmers in less-productive, non-BBR regions often rely more heavily on market purchases due to lower food self-sufficiency. In such contexts, increased yields can raise household income through market sales, enabling the purchase of a wider variety of foods and thereby improving dietary diversity. Conversely, BBRs are typically more commercially oriented, with households specializing in the production of a few staple crops. Despite higher overall production, this specialization may reduce dietary diversity. Greater market integration in BBRs often promotes cash crop cultivation, leading households to prioritize sales and non-food expenditures over diverse food consumption.

Previous studies have documented a weakened or even negative relationship between crop production and dietary diversity in high-production areas, primarily due to commercialization effects[14,36]. Our findings are consistent with this pattern: the positive impact of crop yields on dietary diversity is more pronounced in non-BBRs than in BBRs. These results underscore the importance of contextual factors in shaping the relationship between agricultural production and dietary outcomes.

4 Discussion

This study highlights a troubling paradox in Tanzania's BBRs. Despite their critical role in national food production, children in BBRs exhibit worse growth outcomes, particularly higher stunting rates, than those in non-BBRs. These findings are consistent with prior region-specific studies[37,38].

To investigate potential mechanisms, we examined whether maternal out-of-home working hours mediate this relationship. Contrary to expectations, crop production did not significantly influence the number of hours mothers spend working outside the home in either BBRs or non-BBRs. This may be attributed to the commercial nature of agriculture in BBRs, where higher yields do not necessarily demand increased maternal labor. This result aligns with some studies indicating that women's economic participation does not always compromise childcare[39–42], but contrasts with others that link higher stunting to children of farming mothers[43], possibly due to differing methodological scopes or regional contexts.

We also tested the hypothesis that higher crop production reduces HDDS due to agricultural specialization. While the results show a significant positive correlation between crop production and HDDS in non-BBRs, this relationship was not statistically significant in BBRs. This finding contrasts with studies reporting an inverse relationship between production and nutrition in highly commercialized agricultural settings[15,16,33,35]. The analysis of control variables provides additional insights into the determinants of child growth. Larger household sizes are associated with poorer nutritional outcomes, likely due to resource dilution effects[44]. Similarly, children in households where mothers are responsible for fetching water are more prone to stunting, echoing previous findings linking long water-fetching distances to malnutrition[45]. Importantly, female-headed households and urban residence are positively associated with healthier child growth outcomes.

In summary, the coexistence of high agricultural productivity and poor child growth in BBRs indicates that increasing food production alone is insufficient to improve children's nutritional outcomes. Addressing broader socioeconomic determinants, such as water access, household composition, and women's caregiving capacity, is crucial. Targeted community development and nutrition-sensitive interventions are urgently needed to ensure equitable improvements in child health.

5 Conclusions

This study highlights a paradoxical relationship between crop production and child growth outcomes in Tanzania's BBRs. Although these regions are vital to the national food supply, children in BBRs had poorer growth outcomes, particularly higher stunting rates, compared to those in non-BBRs. While increased crop production is generally associated with improved child nutrition, this positive effect is statistically significant only in non-BBRs.

The findings also challenge the assumption that agricultural work reduces the time mothers can devote to childcare. We find no significant impact of crop production on maternal working hours in either BBRs or non-BBRs. Additionally, in BBRs, HDDS does not show a significant relationship with crop production, further complicating the link between agricultural productivity and child health.

These results underscore the complex interplay of factors shaping child nutrition in high-production regions. They indicate that policies should go beyond increasing food production to also address broader socioeconomic challenges that affect child well-being. When promoting agriculture toward specialization and marketization, it should be noted that in poor areas, the underdevelopment of food markets may lead to regional-level food shortages. Specialization (or monoculture) will further affect the dietary diversity of specialized farmers, thereby impacting their dietary quality. This is an issue that policymakers need to focus on. Importantly, the study was unable to explore other potential pathways underlying the crop-nutrition paradox. Future research should aim to fill this gap using targeted surveys and more comprehensive data.

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Compliance with ethics guidelines

Mosses Lufuke and Xu Tian declare that they have no conflicts of interest or financial conflicts to disclose. This article does not contain any studies with human or animal subjects performed by any of the authors.

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