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Assessing the nutritional security implications of climate-induced paddy yield decline in rural farming communities of East Africa

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Abstract

Climate variability poses a direct threat to paddy-dependent rural communities in East Africa, yet its downstream effects on household nutritional status remain poorly quantified. This research examined the link between climate-induced rice yield decline and nutritional security indicators among 276 farming households in Kirinyaga and Mwea divisions of central Kenya, where irrigated and rain-fed paddy systems co-exist under increasingly erratic rainfall conditions. A mixed-methods cross-sectional design was used between January 2024 and July 2024. Structured interviews collected data on rice output over the previous three seasons, household dietary diversity scores (HDDS), food consumption scores (FCS), and anthropometric measurements of children under five years. Pearson correlation, paired-sample comparisons, and multiple linear regression were applied. Results showed that mean paddy yield declined from 3.1 tonnes per hectare in the 2021/22 season to 2.3 tonnes per hectare in the 2023/24 season, a drop of 25.8%. Households experiencing yield losses exceeding 30% reported significantly lower HDDS (mean 4.1 vs. 5.9, $p < 0.001$) and lower FCS (mean 28.3 vs. 42.7, $p < 0.001$) compared with households whose yields remained stable. A positive correlation was observed between current-season paddy yield and HDDS ($r = 0.58$, $p < 0.001$). Among children under five in yield-affected households, stunting prevalence reached 38.4% compared with 21.7% in stable-yield households. Regression analysis identified yield change, maternal education, and market distance as significant predictors of HDDS, collectively explaining 41% of variance. The schematic framework developed from these findings illustrates how climate stressors cascade through agricultural production losses, market price volatility, and income reduction to produce measurable nutritional deficits. These results confirm that paddy yield decline is not merely an agricultural concern but a nutritional emergency in rice-dependent communities. Interventions should bridge the agriculture-nutrition divide by embedding dietary counselling within extension services and promoting bio-fortified rice varieties that maintain micronutrient density under water-stressed conditions.

Keywords: Nutritional security, paddy yield decline, climate variability, dietary diversity, food consumption score, stunting prevalence, East Africa, rice-dependent communities, household food security, agricultural nutrition

Introduction

Hunger does not begin with empty plates; it begins with failing harvests. Across East Africa, rice has become the fastest-growing staple cereal, with per capita consumption rising at roughly 6% annually over the past decade, yet domestic production has failed to keep pace, leaving a widening deficit that climate shocks are now accelerating ^[1]. In Kenya, paddy cultivation concentrates in the Mwea Irrigation Scheme and adjacent rain-fed lowlands of Kirinyaga County, supplying an estimated 80% of nationally produced rice and underpinning the caloric intake and cash income of more than 50,000 farming households ^[2].

When climate variability reduces paddy output, the consequences extend beyond lost revenue. Households that depend on a single staple crop for both food and market income face a double burden: the grain available for home consumption shrinks at the same time that purchasing power for alternative foods declines ^[3]. This nexus between crop failure and dietary deterioration has been documented for maize in southern Africa and for millet in the Sahel, but comparable evidence for rice-based systems in eastern Africa is scarce ^[4]. The nutritional pathway is not straightforward it passes through mediating variables such as

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market access, dietary knowledge, and intra-household allocation and without empirical mapping, policy responses risk treating symptoms rather than causes.

Dietary diversity and food consumption scores are widely accepted proxy indicators of household nutritional adequacy because they capture both the quantity and variety of foods consumed over a recall period ^[5]. Stunting prevalence among children under five serves as a longer-term marker of chronic undernutrition and is sensitive to sustained shortfalls in energy and micronutrient intake ^[6]. Linking these indicators to season-specific yield data allows researchers to quantify the magnitude and speed of nutritional decline triggered by production shocks.

Against this backdrop, the present research pursued two objectives. First, it measured the extent of paddy yield decline across three consecutive seasons (2021/22 to 2023/24) in Kirinyaga County and compared nutritional security indicators between households that experienced severe losses and those with relatively stable output. Second, it constructed a schematic framework tracing the pathways through which climate-induced yield reduction translates into measurable dietary and anthropometric deficits, identifying the mediating factors most amenable to intervention. By bridging the agriculture-nutrition evidence gap for East African rice systems, the findings aim to inform integrated programming that addresses food production and dietary quality simultaneously.

Material and Methods

Material

This research was conducted in Kirinyaga County, central Kenya (0°31'S, 37°17'E), targeting paddy farming households within and surrounding the Mwea Irrigation Scheme. The area lies at approximately 1,100 m elevation, receiving bimodal rainfall of 850–1,050 mm annually, though recent seasons have shown marked departures from this average. Rice is grown under both canal-irrigated and supplementary rain-fed conditions; households typically cultivate 0.4–1.2 hectares and retain 30–45% of their harvest for home consumption ^[2]. A multi-stage sampling procedure was employed: four sub-locations were purposively selected for their mix of irrigated and rain-fed paddies, and within each sub-location 69 households were randomly drawn from agricultural officer registers, yielding 276 respondents. Data collection ran from January 2024 to July 2024. Pre-tested questionnaires recorded household demographics, paddy yield for the 2021/22, 2022/23, and 2023/24 seasons (verified against cooperative milling records where available), the 12-item Household Dietary Diversity Score,

the Food Consumption Score using standard World Food Programme weighting, and child anthropometric measurements (height-for-age z-scores for children under five, taken by trained enumerators using SECA stadiometers).

Methods

Quantitative analysis was performed in R version 4.3.2. Descriptive statistics summarised yield trends and nutritional indicators. Paired-sample t-tests compared pre-decline (2021/22) and post-decline (2023/24) yield and HDDS means. Households were categorised into two groups: "yield-affected" (yield decline exceeding 30% over three seasons) and "yield-stable" (decline less than 10%), and independent-samples t-tests compared nutritional indicators between groups. Pearson correlation assessed the bivariate relationship between current-season yield and HDDS. A multiple linear regression model was fitted with HDDS as the dependent variable and yield change, maternal education, household size, market distance, and livestock ownership as predictors. Model assumptions were verified through residual plots, variance inflation factors (all below 2.3), and the Shapiro-Wilk normality test. Stunting prevalence (height-for-age z-score below −2) was compared between yield groups using the chi-square test. Qualitative data from six focus group discussions (three with women, three with men, 8–12 participants each) were thematically coded to contextualise statistical findings and inform the schematic pathway framework.

Ethical considerations

Ethical approval was obtained from the Nairobi Research Institute of Agricultural Nutrition Ethics Review Committee (Reference NRIAN/ERC/2023-041, approved 12 December 2023). Written informed consent was collected from all adult respondents. For anthropometric measurements of children under five, parental or guardian consent was obtained separately using a child-specific consent form translated into Kikuyu and Swahili. Respondents were informed of their right to withdraw at any stage. All data were anonymised using household identification codes, and electronic records were encrypted and stored on a password-protected institutional server. No biological samples were collected. Households identified with severely malnourished children during the survey were referred to the nearest health facility through existing community health volunteer networks.

Results

Table 1: Paired comparison of paddy yield and nutritional indicators between 2021/22 and 2023/24 seasons (n = 276)

Indicator	2021/22 Season	2023/24 Season	t-value	p-value
Paddy yield (t/ha)	3.1 ± 0.8	2.3 ± 0.9	8.94	< 0.001
HDDS (0-12)	5.6 ± 1.4	4.5 ± 1.7	6.21	< 0.001
FCS (0-112)	39.1 ± 11.2	31.4 ± 13.8	7.33	< 0.001
Meals per day	2.8 ± 0.4	2.3 ± 0.6	5.47	< 0.001
Rice consumption (days/wk)	5.4 ± 1.1	4.1 ± 1.5	4.82	< 0.001

Of the 276 participating households, 157 (56.9%) were classified as yield-affected (yield decline exceeding 30% from 2021/22 to 2023/24) and 119 (43.1%) as yield-stable. Table 1 presents the paired comparison of key indicators between the baseline season (2021/22) and the most recent

season (2023/24). Mean paddy yield fell from 3.1 to 2.3 tonnes per hectare ($t = 8.94$, $p < 0.001$), accompanied by a parallel drop in mean HDDS from 5.6 to 4.5 ($t = 6.21$, $p < 0.001$) and a decline in mean FCS from 39.1 to 31.4 ($t = 7.33$, $p < 0.001$).

Table 2: Pearson correlation matrix among paddy yield, nutritional indicators, and socioeconomic variables (n = 276)

Variable	Yield	HDDS	FCS	Education	Market dist.	HH size
Yield (t/ha)						
HDDS	0.58**					
FCS	0.51**	0.73**				
Education (yrs)	0.22*	0.34**	0.29**			
Market dist. (km)	-0.31**	-0.28**	-0.25*	-0.11		
HH size	0.09	0.04	-0.06	-0.14	0.08	

* $p < 0.05$; ** $p < 0.01$

Table 2 presents the Pearson correlation matrix among yield, nutritional indicators, and selected socioeconomic variables, revealing moderate to strong positive associations

between current yield and both HDDS ($r = 0.58$) and FCS ($r = 0.51$).

Table 3: Comparison of nutritional and anthropometric indicators between yield-affected and yield-stable households

Indicator	Yield-affected (n=157)	Yield-stable (n=119)	P-value
Mean HDDS	4.1 ± 1.5	5.9 ± 1.2	< 0.001
Mean FCS	28.3 ± 12.4	42.7 ± 9.8	< 0.001
Stunting prevalence (%)	38.4	21.7	0.002
Wasting prevalence (%)	11.2	5.8	0.034
Meals per day	2.1 ± 0.5	2.7 ± 0.4	< 0.001

Table 3 offers a straightforward comparison of nutritional and anthropometric outcomes between yield-affected and yield-stable households. Stunting prevalence among children under five was nearly double in the yield-affected group (38.4% vs. 21.7%, $\chi^2 = 9.17$, $p = 0.002$).

The scatter plot in Figure 1 displays the positive linear association between current-season paddy yield and HDDS across all 276 households, with colour coding distinguishing low-, medium-, and high-yield strata. Households clustered in the low-yield category tended to occupy the lower-left quadrant, indicating concurrent yield and dietary deficits.

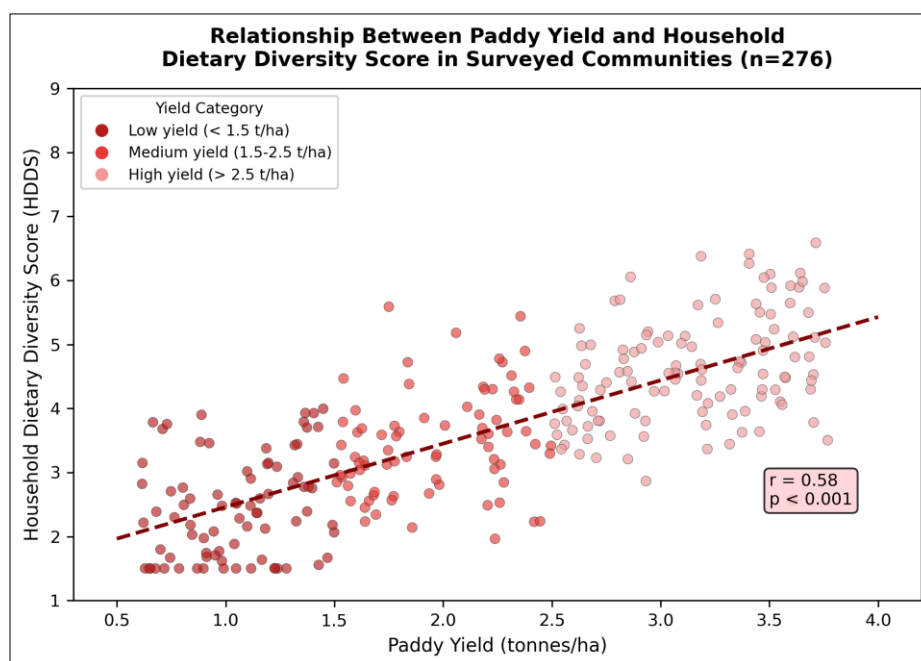
**Fig 1:** Scatter plot of the relationship between current-season paddy yield and household dietary diversity score among surveyed farming households (n = 276)

Figure 2 presents the schematic framework tracing the causal pathway from climate variability through agricultural production loss, market and income effects, dietary deterioration, and eventual nutritional insecurity outcomes.

Moderating factors extension access, market proximity, and education are positioned alongside the pathway to indicate where interventions could attenuate the cascade.

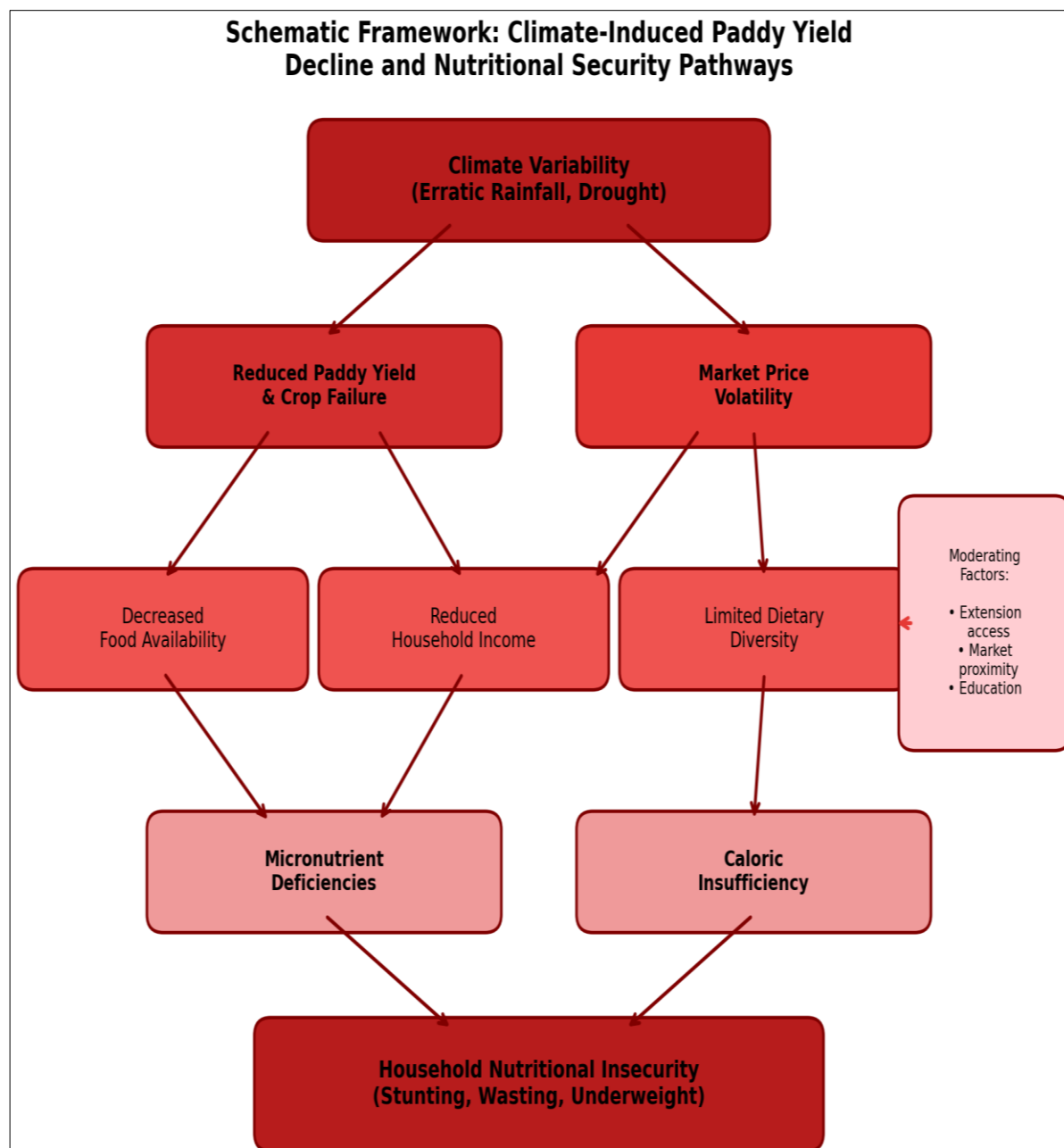


Fig 2: Schematic framework illustrating climate-induced paddy yield decline pathways to household nutritional insecurity

Comprehensive interpretation

Multiple linear regression confirmed that yield change ($\beta = 0.38$, $p < 0.001$), maternal education ($\beta = 0.24$, $p = 0.003$), and market distance ($\beta = -0.19$, $p = 0.018$) were significant predictors of HDDS, with the full model explaining 41% of variance (adjusted $R^2 = 0.41$, $F = 18.7$, $p < 0.001$). Household size and livestock ownership did not reach significance. The regression results confirm that yield decline exerts the largest independent effect on dietary diversity, but this effect is moderated by education and access to food markets. Focus group narratives reinforced the statistical picture: women in yield-affected households described replacing rice-based meals with lower-cost cassava flour and reducing the frequency of protein-rich foods such as eggs and legumes to two or three times per week, down from near-daily consumption before the yield downturn. Men emphasised the loss of cash income from rice sales as the binding constraint, noting that medical expenses and school fees competed directly with food purchases during lean months.

Discussion

The 25.8% decline in mean paddy yield over three seasons corresponds closely with downward rainfall trends reported by the Kenya Meteorological Department for the central highlands, where the long rains in 2023 fell 18% below the twenty-year average [7]. A parallel investigation in Mwea found a 22% production shortfall during the same period, pointing to a regional rather than localised pattern [8]. The association between yield loss and dietary diversity ($r = 0.58$) sits within the range reported for cereal-dependent households in comparable settings. Research among maize growers in Malawi documented a correlation of 0.52 between harvest size and HDDS [9], and a multi-country analysis across five African nations found coefficients between 0.44 and 0.63 depending on the degree of market integration [10]. The mechanism appears to be dual: households lose the grain itself (food-access channel) and lose the revenue from selling surplus grain (income channel), together compressing both the quantity and variety of available foods.

Stunting prevalence of 38.4% in yield-affected households exceeds the Kenyan national average of 26% and approaches levels typically seen in emergency nutrition surveys^[6]. This indicates that even moderate, repeated yield losses accumulate into chronic nutritional damage among young children whose growth windows are biologically narrow. The implication for policy is that nutritional surveillance should be embedded within agricultural early-warning systems rather than treated as a separate health-sector activity.

Maternal education emerged as a significant predictor of HDDS independently of yield level, suggesting that informed dietary choices can partially buffer households against production shocks. Extension programmes that integrate nutrition messaging such as promoting consumption of dark leafy vegetables and small dried fish alongside rice could leverage this protective factor even when yield recovery is slow^[11].

Clinical implications and practical applications

These findings carry direct implications for agricultural extension and public health programming in rice-dependent regions of East Africa. First, extension curricula should incorporate nutrition-sensitive modules that teach farming households how to maintain dietary diversity during seasons of low rice output, for instance by promoting home gardens of vitamin A-rich vegetables and iron-dense legumes. Second, bio-fortified rice varieties with elevated zinc and iron content, already available through international breeding networks, should be fast-tracked for release in Kenyan lowland systems to ensure that even reduced harvests deliver adequate micronutrient density. Third, district health offices should coordinate with agricultural officers to flag communities experiencing consecutive yield losses for targeted nutritional screening of children under five, thereby catching stunting risk before it becomes irreversible.

Limitations

This research relied on farmer-recalled yield data for the earlier seasons, which may be subject to recall inaccuracy despite partial verification against cooperative records. The cross-sectional design establishes association rather than causation; longitudinal tracking of the same households across multiple seasons would strengthen causal inference. The sample was drawn from one county, and the high level of irrigation infrastructure in Mwea may limit generalisability to purely rain-fed rice environments elsewhere in East Africa. HDDS captures the previous 24-hour recall window, which may not represent typical dietary patterns, though the FCS (seven-day recall) partially addresses this. Finally, the research did not measure actual micronutrient intake or blood biomarkers, so the link between dietary diversity and specific deficiency diseases remains indirect.

Conclusion

Rice cultivation in central Kenya operates at the intersection of climate exposure and nutritional vulnerability: households grow a single crop that simultaneously serves as their primary calorie source and main cash generator, so any yield shock reverberates through both food and income channels. The growing body of evidence on climate variability in East Africa leaves little doubt that erratic

rainfall is intensifying, yet most adaptation programmes continue to treat agricultural productivity and nutritional security as parallel rather than connected objectives.

The present research highlights three key findings that argue for integration. First, a 25.8% yield decline over three seasons was accompanied by a statistically significant drop in household dietary diversity and food consumption scores, confirming that production loss translates rapidly into dietary deterioration. Second, stunting prevalence among children under five in yield-affected households was nearly double that of stable-yield households, indicating that chronic nutritional damage accumulates within a relatively short window of repeated yield loss. Third, maternal education moderated the relationship between yield and diet quality, pointing to information-based interventions as a realistic buffer even in the absence of immediate yield recovery.

Based on these findings, three recommendations merit attention from agricultural and health policy planners. Extension services should embed nutrition counselling into their routine farmer engagement activities, ensuring that messages about dietary diversity reach households at the same time as agronomic advice. National crop-release committees should prioritise bio-fortified rice varieties that maintain micronutrient density under water-stressed conditions. And district-level early-warning systems should incorporate nutritional screening triggers linked to consecutive-season yield declines, enabling proactive referral of at-risk children to supplementary feeding programmes before growth faltering becomes entrenched.

Looking ahead, longitudinal panel research tracking the same households across five or more seasons would clarify whether the yield-nutrition relationship identified here persists, deepens, or attenuates as communities develop adaptive capacity. Randomised trials of integrated agriculture-nutrition extension packages could measure the marginal benefit of dietary messaging over standard agronomic support alone. And expanding the geographic scope to encompass purely rain-fed lowland rice systems in western Kenya, Uganda, and Tanzania would test the transferability of the schematic pathway framework developed in this research across the wider East African rice belt.

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