Expectations, Resilience, and Consumption Among Smallholder Farmers

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Abstract

Research on smallholder resilience has largely focused on frameworks and the organisation of indicators, with less attention to how capacities are activated in response to stress. When resilience is understood as capacity, greater focus should be placed on the timing and manner of its mobilisation. This requires empirically decomposing variation in a well-being proxy into persistent between-household differences, shared temporal stressors, and household–time-specific fluctuations, since the relative contribution of these components shapes interpretations of shocks, responses, and capacities. In drought-prone contexts, shared temporal variation is particularly important, expanding the 'shock' domain beyond observed climatic and market events to include household expectations that drive anticipatory behaviour.

Using 18 months of fortnightly data from 73 smallholder households in southern Kenya, we link Primary (time-invariant) and Secondary (time-varying) Capacities with Shocks and food-related Responses. Hierarchical Bayesian multilevel models partition variance in aggregate and component-level reduced Coping Strategies Index (rCSI) measures into between-household, between-time, and within-household contributions, while modelling interactions between shocks and capacities.

Portion-size reduction and meal skipping co-vary primarily with shared temporal stress, whereas consuming less preferred foods and relying on social networks reflect structural household differences and idiosyncratic shocks. Improving meteorological conditions reduce reliance on severe coping strategies, while realised production shortfalls and higher staple prices intensify responses. Irrigation stabilises production under moderate—though not extreme—water stress. Overall, the results show that multilevel variance decomposition clarifies the structural, temporal, and anticipatory dimensions of resilience and should be treated as a prerequisite to resilience assessment.

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1. Introduction

In East Africa, smallholder rain-fed farming underpins livelihoods for millions but they remain highly vulnerable to food insecurity, sensitive to both global price shocks and local climate variability (Giller et al., 2021). While overall regional rainfall is projected to increase, erratic rainfall, droughts, and extreme weather will continue to disrupt production (IPCC, 2022).

Resilience has emerged as a central concept in smallholder development, emphasising households' and farming systems' capacity to absorb, adapt, and transform in response to shocks. Research has operationalised resilience via frameworks aggregating multiple indicators, sometimes linked to well-being and sometimes treated as standalone capacities (Barrett et al., 2021), though no universal framework exists (Constas et al., 2022).

This study advances a resilience framework that disentangles idiosyncratic household experiences from systemic between-time (shared shocks) and structural between-household (persistent differences) correlates of consumption. Rather than conducting a conventional resilience assessment, we empirically interrogate the framework itself. By pooling repeated observations within a single model and incorporating random effects for both households and time, we account for unobserved heterogeneity and shared temporal influences. This approach distinguishes structural and systemic policy-relevant resilience capacities from transient shocks and household-specific fluctuations.

1.1. Inter-temporal Resilience: Expectations and Deliberate Sacrifice

During droughts, food reduction is a common coping strategy (Kabir, 2023), yet such behaviour does not necessarily signal declining resilience. Instead, it may represent deliberate short-term sacrifice aimed at protecting longer-term productive capacity. Where temporary sacrifice is viable, expectations become critical: even when capacities remain intact, expectations shape when assets are mobilised or conserved.

In East Africa, where rainfall follows a bimodal pattern—long rains (March–May) and short rains (October–December)—farmers interpret environmental cues to anticipate seasonal timing and intensity. Rainfall variability is strongly influenced by the migration of the Intertropical Convergence Zone (ITCZ) (Nicholson, 2018), and local forecasting translates associated signals—such as wind shifts, cloud formations, and animal or botanical indicators—into farm-level decisions (Paparrizos et al., 2023). Wind and cloud cues are particularly valued for signalling seasonal transitions (Radeny et al., 2019). These anticipatory processes demonstrate how expectations mediate inter-temporal resilience responses.

1.2. A landscape scale resilience framework

We adopt a landscape-scale, capacity-based view of resilience, focusing on climate-related shocks. Resilience is treated as an emergent property of the social, economic, and environmental system, rather than a trait held by households. Observed household behaviours—such as adjustments to consumption or livelihoods—reflect resilience under prevailing system conditions, rather than resilience itself.

Figure 1 illustrates the framework, distinguishing between slow-changing *Primary Capacities*, medium-term *Secondary Capacities*, and short-term household *Responses* to *shocks*.

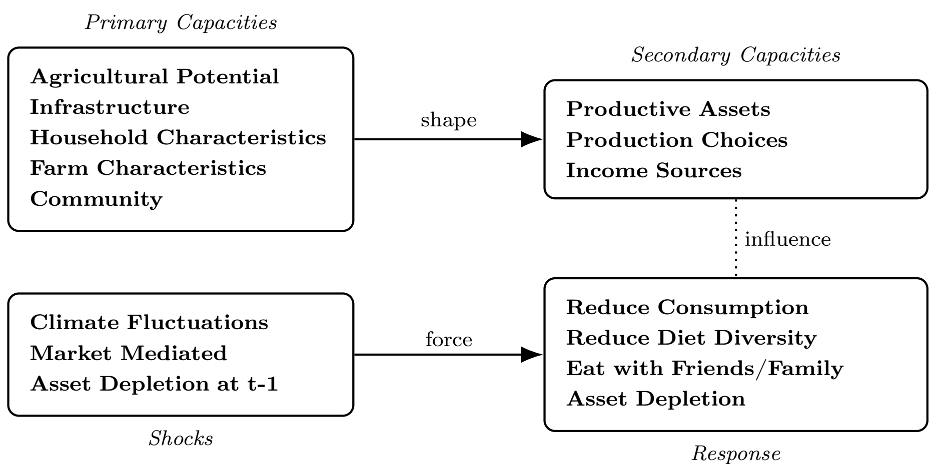

Figure 1: Resilience framework linking slow- and fast-changing contexts to household strategies and coping responses.

Primary Capacities are largely exogenous, slow-changing features that which shape opportunities available to households. *Secondary Capacities* represent household positioning that leverages primary capacities. These adjust more slowly than immediate responses but remain under household agency. *Shocks* impose pressure on livelihoods and consumption, to which households deploy *Responses*—short-term, high-frequency behavioural adjustments—to manage these shocks.

A key feature of the framework is feedback between responses and secondary capacities. Choices that preserve assets may buffer households in the short term, whereas repeated asset-depleting responses can erode capacities over time, influencing future vulnerability and resilience.

2. Methodology

2.1. Study Site

The study forms part of the EU-funded ESSA project (Earth Observation and Environmental Sensing for Climate-Smart Sustainable Agropastoral Ecosystem Transformation in East Africa) and was conducted between November 2022 and May 2024. The period followed severe flooding and coincided with a prolonged drought (2021–2024), providing a context of sustained climatic stress.

The site lies within the transition zone between the Taita Hills and Tsavo National Park in southern Kenya. The landscape comprises shrublands, grasslands, and acacia woodlands supporting mixed crop–livestock smallholder systems. Agricultural potential is constrained by short growing seasons (<150 days) and predominantly nutrient-poor Rhodic Ferralsols, with more fertile soils occurring locally. Infrastructure and electrification are spatially uneven, clustering in favourable areas, while most households rely on boreholes or rivers for water. Farms typically span 1–5 hectares, livestock holdings are modest, tenure security is high, and off-farm income opportunities are limited and generally low-skilled.

2.2. Data

The analysis draws on 73 households across 18 villages in Mwachabo and Maktau. High-frequency household surveys were conducted fortnightly over 18 months (36 rounds), generating panel data on consumption responses and time-varying capacities. Time-invariant indicators were collected through an in-depth baseline survey. Meteorological and biophysical variables were derived from remote sensing products aligned temporally with survey rounds. Additional geospatial data (e.g., soil characteristics, infrastructure, night lights, road density) were used to characterise structural conditions.

2.2.1. Response Indicators

Household responses are measured using the reduced Coping Strategies Index (rCSI), which captures short-term food-related coping behaviours over the previous seven days. The index records the frequency of: (1) eating less preferred foods, (2) eating with friends or relatives, (3) reducing portion sizes, (4) reducing adult intake for children, and (5) skipping meals. The weighted aggregate score (range 0–56) reflects both frequency and severity. Component-level models allow differentiation between types of coping behaviour.

2.2.2. Shock Indicators

Shocks are conceptualised broadly and grouped into four domains:

- **Expectations via meteorological observations:** wind direction and speed, rainfall, temperature variance, cloud cover and depth. These proxy environmental signals used to form anticipatory expectations rather than only realised production impacts.
- **Production shocks:** root-zone soil moisture and vegetation productivity (NDVI), capturing biophysical constraints on output.
- **Staple food and fodder prices:** household-reported maize and fodder prices, representing market shocks.

Biophysical indicators were spatially aggregated within 10 km buffers around households and temporally smoothed to align with survey windows (14-day or 90-day averages depending on the variable).

2.2.3. Secondary Capacity (Time-Varying)

Secondary capacities capture operational decisions and adaptive resources that may change over time, including:

- **Production choices:** irrigation use, crop diversity.
- **Productive assets:** crop storage, livestock holdings.
- **Income sources:** binary indicators of the household's primary income (agricultural, salaried, remittances, mining, small business, transport services, natural resource extraction, etc.).

Secondary capacities operationalise how primary conditions are translated into adaptive strategies.

2.2.4. Primary Capacity (Time-Varying)

Primary capacities capture structural characteristics unlikely to change over the study period. These include:

- **Agricultural Potential:** agro-ecological zone, soil-type.
- **Infrastructure:** night-light, road density, distance to town.
- **Household Characteristics:** demographics, education, tenure security.
- **Farm Characteristics:** land size, water conservation investment.
- **Community:** village, group membership.

These indicators represent the structural foundation shaping exposure and adaptive potential.

2.3. Modelling Strategy

2.3.1. Null Model

A baseline model partitions variance into:

- Between-household differences
- Between-time (shared temporal) variation
- Within-household residual variation

Formally:

$$Y_{it} = \beta_0 + u_t + u_i + \epsilon_{it} \tag{1}$$

where u_t captures time-specific shocks common to all households, u_i captures persistent household differences, and ϵ_{it} represents idiosyncratic variation.

2.3.2. Reference Model

The reference model introduces shocks, secondary capacities (SC), primary capacities (PC), and their interactions:

$$Y_{it} = \beta_0 + \text{Shocks}_{it} + \text{SC}_{it} + \text{PC}_i + (\text{Shocks}_{it} \times \text{SC}_{it}) + u_t + u_i + \epsilon_{it} \qquad (2)$$

Interactions test whether secondary capacities condition the effect of shocks on household responses (e.g., irrigation moderating soil moisture stress; income sources moderating price shocks).

2.3.3. Distributions

- Aggregate rCSI (bounded, overdispersed count) is modelled using a negative binomial likelihood with a log link.
- Component-level rCSI measures (0–7 day counts) are modelled using binomial likelihoods with a logit link.

3. Results

3.1. Responses

The use of rCSI coping strategies declined over time, initially at a gradual pace and later more sharply (see Figure 2). The exception is rCSI2—Eat with Friends—which remained relatively stable and even showed a modest increase.

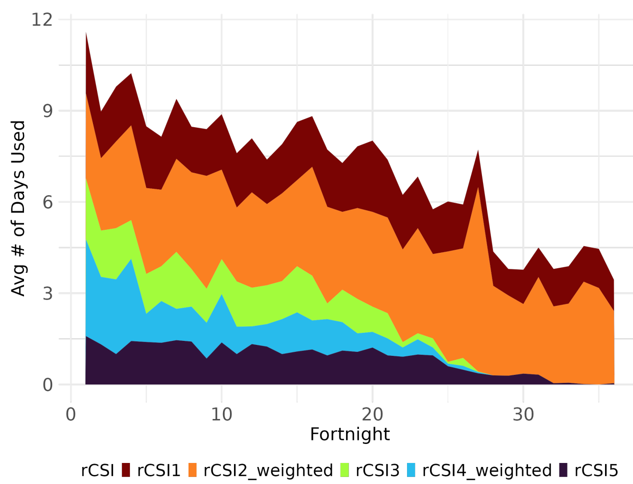

Figure 2: Use of rCSI Coping Strategies per Fortnight

3.2. Variance Decomposition: Household and Temporal Effects

Table 1 shows that portion-size reduction strategies (rCSI3–4) are primarily driven by shared, system-level shocks, whereas reliance on social networks (rCSI2) reflects structural household differences. Individual dietary compromises (rCSI1) is highly responsive to household-specific idiosyncratic events. Adding covariates substantially reduces the share of unexplained variance attributable to between-time factors, with residual variation increasingly concentrated within households.

Metric	rCSI	rCSI1	rCSI2	rCSI3	rCSI4	rCSI5
Null Model						
Between-time variance (%)	13	2	2	61	39	29
Between-household variance (%)	42	15	41	21	33	39
Within-household variance (%)	45	83	57	18	28	32
Reference Model						
Between-time variance (%)	3	<1	3	42	8	9
Between-household variance (%)	31	12	33	25	44	50
Within-household variance (%)	66	87	64	33	48	41

Table 1: Variance decomposition (ICCs) for Null and Reference rCSI models. *Null model results show raw variance: portion-size strategies (rCSI3–4) are driven by shared shocks, social strategies (rCSI2) and aggregate rCSI by persistent household differences, and rCSI1 by household-specific variation. Reference model results show that adding covariates reduces between-time variance, with residual variation increasingly concentrated within households.*

3.2.1. Important Shocks, Secondary Capacities & Interactions

Table 2 reports coefficients for all shock indicators and their interactions with household capacities. Three key patterns emerge. First, rCSI3 and rCSI4 (portion-size reduction strategies) are consistently correlated with meteorological indicators, with improved agricultural conditions linked to lower use of these coping strategies. Second, production shocks increase aggregate rCSI use, particularly via rCSI1 and rCSI4. Third, higher feed and food prices are associated with increased overall coping strategy use.

Interactions indicate that higher soil moisture combined with irrigation reduces coping strategy use. Livestock-dependent households face greater vulnerability to fodder-price shocks, while the effect of maize-price shocks varies by income source.

Indicator	rCSI	rCSI1	rCSI2	rCSI3	rCSI4	rCSI5
Observed Meteorological Signals						
Northerly Wind	-1.11 [-8.32, 4.64]	2.02 [-3.62, 11.47]	28.08 [-0.89, 75.76]	20.85 [-12.43, 93.84]	-69.30 [-82.57, -50.53]	-19.82 [-47.34, 6.88]
Wind Speed	1.22 [-2.38, 7.26]	0.97 [-2.73, 6.15]	-0.29 [-8.52, 7.95]	-8.67 [-30.61, 6.93]	15.84 [-7.85, 61.30]	57.21 [24.92, 96.20]

Indicator	rCSI	rCSI1	rCSI2	rCSI3	rCSI4	rCSI5
Cloud Cover	-1.65 [-8.92, 2.86]	0.43 [-4.56, 6.24]	-13.82 [-27.50, -0.11]	-55.32 [-68.54, -38.57]	8.63 [-16.98, 50.76]	3.18 [-12.80, 25.67]
Cloud Depth	0.28 [-2.67, 4.06]	0.89 [-2.31, 5.18]	1.28 [-4.37, 9.26]	28.98 [9.64, 50.41]	23.70 [0.10, 50.72]	-6.17 [-17.17, 2.66]
Cloud Height	4.44 [-0.07, 9.98]	-0.26 [-3.74, 3.03]	6.29 [-1.33, 17.33]	47.69 [28.59, 68.30]	22.75 [0.47, 48.24]	4.25 [-5.28, 17.61]
Rainfall	-0.02 [-4.42, 4.47]	0.25 [-3.86, 5.20]	2.06 [-5.75, 13.64]	-10.59 [-38.30, 8.70]	-63.78 [-78.52, -43.99]	11.11 [-7.36, 43.53]
Temp Var	-1.43 [-10.41, 4.72]	1.18 [-4.79, 9.12]	0.88 [-13.21, 17.61]	-20.02 [-54.94, 8.21]	-79.62 [-90.01, -64.13]	-14.50 [-43.24, 11.08]
Production Shocks						
RZ Soil Moisture	-2.46 [-10.80, 2.88]	-9.54 [-16.79, -0.48]	18.20 [-1.69, 49.94]	-3.72 [-37.84, 30.63]	-51.33 [-73.40, -16.20]	-16.49 [-44.36, 8.01]
RZ Soil Moisture:Irrigate	-22.24 [-41.51, 0.02]	-37.05 [-58.15, -3.35]	-0.21 [-17.99, 19.17]	-42.21 [-78.13, 6.23]	15.65 [-40.18, 139.54]	1.49 [-33.87, 47.69]
NDVI	-11.06 [-17.42, -3.25]	-1.73 [-9.05, 2.91]	-3.42 [-14.62, 3.86]	-52.73 [-63.80, -39.07]	-51.63 [-66.87, -31.45]	-19.62 [-34.87, -1.02]
NDVI:Crop Diversity	1.42 [-0.91, 4.80]	7.55 [3.38, 11.72]	6.72 [0.95, 12.41]	3.65 [-4.47, 15.61]	-3.77 [-16.23, 6.52]	-30.11 [-35.47, -24.67]
Market Shocks						
Fodder Price	3.11 [-0.44, 7.81]	-4.12 [-8.61, 0.05]	13.97 [5.31, 22.91]	33.46 [12.48, 56.77]	-4.81 [-18.96, 7.04]	13.77 [1.98, 25.69]
Fodder Price:Cattle Stock	0.23 [-1.50, 2.24]	0.41 [-1.68, 2.98]	2.22 [-0.76, 6.23]	6.67 [-0.60, 16.16]	-1.93 [-8.37, 3.49]	-12.63 [-16.74, -8.43]
Fodder Price:Shoat Stock	3.04 [0.09, 6.19]	4.00 [0.35, 7.63]	2.90 [-0.65, 7.57]	0.62 [-4.40, 6.31]	-1.09 [-9.39, 6.54]	0.22 [-4.36, 5.32]
Maize Price	15.00 [7.89, 22.15]	33.93 [24.54, 44.26]	-8.85 [-16.88, -0.14]	22.06 [-3.51, 61.01]	43.34 [-1.43, 110.02]	4.09 [-9.31, 22.84]
Maize Price:Small Kiosk	-5.84 [-15.46, 1.16]	-24.54 [-33.62, -14.26]	27.27 [10.24, 45.40]	3.89 [-20.83, 43.25]	75.79 [-18.69, 452.85]	-30.01 [-50.36, -1.02]
Maize Price:Remittances	3.92 [-2.07, 14.30]	-16.16 [-25.68, -4.44]	24.57 [8.65, 41.29]	18.59 [-10.44, 85.90]	129.63 [-1.56, 397.61]	167.08 [94.92, 256.05]
Maize Price:Agriculture	-9.51 [-19.78, 0.26]	-33.38 [-41.24, -24.71]	1.38 [-7.43, 13.10]	-1.02 [-36.33, 41.10]	38.73 [-20.76, 234.50]	196.22 [62.92, 414.37]

Table 2: Posterior summaries of time-varying predictors for the rCSI models. *Columns rCSI1–rCSI5 show predicted probability changes for each coping strategy; rCSI shows percent change in the aggregate outcome. Credible intervals are shown below point estimates. Predictors are grouped by domain (weather, crop and livestock production, incomes, food prices, expenditures, festivals), highlighting temporal dynamics and household heterogeneity in coping behaviours.*

4. Discussion

This study examines household food security using multilevel variance decomposition across three levels—between-time, between-household, and within-household—based on 18 months of fortnightly data for 73 households. This decomposition provides an empirical lens for interrogating resilience frameworks, linking time sensitive and insensitive capacities, shocks, and coping responses.

4.1. Structural and idiosyncratic drivers of rCSI components

Portion size reductions and meal skipping (rCSI3–5) are concentrated in between-time variation, indicating reactive responses to shared shocks rather than structural disadvantage. In contrast, dietary compromise (rCSI1) and social reliance strategies (rCSI2) show stronger within-household and between-household variation, highlighting sensitivity to idiosyncratic shocks, such as meidcal bills, and structural capacities such as community cohesion and infrastructure.

4.2. Shocks and capacity interactions

Between-time variation captures realised and anticipated shocks. Meteorological improvements correlate with reduce use of severe coping, suggesting that anticipatory expectations may meaningfully influence household decision-making. Production shocks correlate with rCSI use, particularly rCSI2 and rCSI5, reflecting constrained food availability and income. Secondary Capacities, such as irrigation or off-farm income, moderate these effects, stabilising outcomes under moderate stress but providing limited protection during severe shocks.

Market-mediated shocks show heterogeneous effects. Higher fodder prices increase dietary compromise, while maize price spikes elevate rCSI2, rCSI3, and rCSI5. Households with stable non-agricultural income sources experience attenuated responses, indicating partial insulation from price fluctuations. Price shocks reflect complex pathways, combining environmental conditions, local market dynamics, and broader regional factors, highlighting the need for careful interpretation.

4.3. Implications for resilience assessment

Operationalising resilience assessments requires clarity in the target of assessment—idiosyncratic versus landscape-scale shocks—and careful consideration of model structure. Primary Capacities may be more appropriately measured as static household characteristics, while Secondary Capacities may interact dynamically with both realised and anticipatory shocks. Explicit modelling of inter-temporal linkages is essential, as past Responses and asset-depleting strategies constrain current coping potential.

5. Conclusion

By decomposing variance in rCSI components, this study demonstrates that coping behaviours are differentially shaped by structural and dynamic capacities, covariate shocks, and idiosyncratic household conditions. Anticipatory perceptions of environmental and market conditions function as effective shocks themselves, prompting proactive behavioural adjustments. For resilience assessments, distinguishing between realised versus perceived shocks, and between structural and dynamic capacities, is critical. Hierarchical modelling of high-frequency panel data, combined with proxies for persistent capacities, enables robust inference about the structural and temporal drivers of household resilience and should be considered a pre-requisite of resilience assessment.

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