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"Towards multi-functional agro-ecosystems
promoting climate resilient futures"

Asymmetric climate risk and adaptive capacity in Kenyan smallholder systems

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Abstract

Climate adaptation interventions often assume that benefits are symmetric: good and bad years affect households equally. Yet for the most vulnerable smallholders, losses during droughts can be catastrophic while gains during favourable seasons remain modest. This asymmetry is systematically overlooked by mean-based climate impact assessments, leading to maladaptation. We quantify asymmetric climate risk and latent adaptive capacity using survey data from 569 households in Western Kenya, stratified by gender and agro-ecological zone (Lower Midland Zone LMZ, Upper Midland Zone UMZ). We adapt downside beta ( ) and upside beta ( ) from financial economics to climate-yield relationships: measures yield sensitivity during adverse moisture conditions (SPEI-3 DJF negative), during favourable conditions (SPEI-3 DJF positive). Latent adaptive capacity ( ) is estimated using Item Response Theory (IRT) from six climate-smart agriculture practices.

Results reveal a pronounced "climate asymmetry trap" for female-headed households in the LMZ (FHH-LMZ): = –2.10 (95 % CI –2.70, –1.56) versus = 4.55 (95 % CI 2.22, 7.08), yielding an asymmetry ratio (/| |) of only 2.2. By contrast, male-headed households in the LMZ have a ratio of 5.6 – nearly three times more favourable. Low latent capacity ( ) amplifies downside losses by 34 %. For FHH-LMZ, the same drought shock reduces yields more than twice as severely as for more advantaged groups, while wetter conditions bring only half the relative gain.

These findings demonstrate that mean climate-yield elasticities hide catastrophic tails where the most vulnerable live. Equity-calibrated adaptation requires tail-sensitive metrics. We propose -calibrated insurance – payouts triggered by downside risk rather than average loss – and -stratified extension services that match training intensity to measured adaptive capacity. Diagnosing asymmetric risk is a prerequisite for designing climate-resilient, multifunctional agro-ecosystems that leave no one behind.

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