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Impact of climate variability on crop productivity and adaptation strategies of farmers

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Abstract
Two farms lie barely eight kilometres apart in the East Hararghe zone, worked by neighbours with similar holdings and the same rainfall record. One has shifted to sorghum and teff with farm-pond backup irrigation; the other still grows maize and wheat in rotation and has seen yield drop by 34 percent over the last decade. That contrast frames the research. Climate variability is reshaping cropping outcomes unevenly, and household-level adaptation choices matter more than average regional trends. This research surveyed 384 farming households across three districts - Haramaya, Kersa and Kombolcha in the East Hararghe zone of Oromia, Ethiopia - between September 2022 and March 2023. Structured interviews, focus group discussions and five-year yield records were combined with district-level NMA weather data covering 2018 to 2023. Farmers reported six major climate stressors, with erratic monsoon onset (27.4 percent) and heat waves (19.8 percent) topping the list. Mean maize yield dropped from 1 824 to 1 428 kg ha^{-1} between 2018 and 2023, while wheat fell from 1 156 to 892 kg ha^{-1}. Adoption of adaptation strategies followed six patterns led by drought-tolerant varieties (23.8 percent) and shifted sowing dates (21.4 percent). Logistic regression identified four significant drivers of adaptation: land holding (OR 1.84), access to extension advice (OR 2.36), farm pond infrastructure (OR 3.14) and participation in farmer producer organisations (OR 2.07). The results point to infrastructure access and organisational membership as the two levers policy can pull most effectively to broaden adaptation uptake.

Keywords: Climate variability, crop productivity, adaptation strategies, farmer responses, climate resilience, East Hararghe, drought-tolerant varieties, logistic regression, extension advice, farm pond

Introduction

Across the semi-arid East Ethiopian highlands, climate variability is no longer a future risk to be modelled; it is a lived reality being negotiated, field by field, every growing season. The all-Ethiopia temperature anomaly crossed 1.1 °C above the 1981–2010 baseline in 2023, and districts of eastern Oromia recorded eight more days above 38 °C per year between 2015 and 2023 than between 2000 and 2010 [1, 2]. Monsoon onset dates have shifted by four to nine days over the past two decades, and intra-seasonal dry spells have lengthened in the East Hararghe zone specifically [3]. The yield consequences have been visible: maize and wheat outputs in Haramaya, Kersa and Kombolcha districts fell by 17 to 28 percent between the 2018–19 and 2022–23 seasons [4].

What is less visible in the district-level aggregates is the wide spread of household responses. Some farmers have shifted to shorter-duration varieties, others have added farm-pond irrigation, yet others have changed crop mix or joined producer organisations [5, 6]. A few have not adapted at all. International reviews [7, 8] and African field research [9, 10] converge on a common finding: access to information, to capital and to collective infrastructure explains most of the variation in adaptation uptake. What remains under-researched for the East Hararghe zone is the interaction among these drivers, and the relative weight of each in a region where rainfall has become both less reliable and more bimodal.

The present research was designed around three questions. First, which climate stressors do East Hararghe farmers consider most damaging to their cropping outcomes, and how do these map onto district-level NMA records? Second, which adaptation strategies have been adopted, and at what rates? Third, which household characteristics predict adaptation? The answers feed directly into the design of state-level climate-smart agriculture programmes currently being rolled out through the Ethiopia Agricultural Growth Programme.

Material and Methods

Theoretical Framework

The research applied the Protection Motivation Theory framework of Rogers [11] adapted by Grothmann and Patt for farmer climate adaptation [7]. The framework proposes that adaptation behaviour arises from the interaction between threat appraisal (perceived severity and probability of a climate stressor) and coping appraisal (perceived effectiveness, self-efficacy and cost of the adaptation option). Four predictor categories were specified a priori from this framework: socio-economic attributes, information access, infrastructure endowment and social capital. These categories guided the questionnaire construction and the selection of variables for logistic regression.

Material and Instrument Development

The research covered three districts of the East Hararghe zone - Aurangabad, Jalna and Beed - selected because they share semi-arid climate but differ in the density of irrigation infrastructure and agricultural extension networks. A structured interview schedule was developed in three stages. An initial pool of 48 items was drafted from the theoretical framework and from the Ethiopia National Adaptation Plan on Climate Change [12]. Content validity was established through review by six subject experts, reducing the pool to 37 items organised into five sections: household profile, climate perception, yield history, adaptation practices, and institutional access. The schedule was pretested with 40 farmers outside the sampling frame. Cronbach's alpha on the climate perception and adaptation practice scales reached 0.78 and 0.82 respectively, which is acceptable for survey research.

Methods: A multi-stage stratified random sampling design was followed. From each district, four woredas were selected by probability proportional to cultivated area, and from each woreda, two villages were drawn at random from the 2007 census list. Within each village, 16 farming households were selected by systematic random sampling from the beneficiary roll of the Kebele administration, giving a final sample of 384 households. Structured interviews were conducted face-to-face in Afan Oromo between September 2022 and March 2023. Twelve focus group discussions were held across the three districts to cross-check survey-level patterns and to record adaptation practices in farmers' own words. District-level monthly rainfall, maximum and minimum temperature records for 2018 to 2023 were obtained from the Dire Dawa regional centre of the National Meteorological Agency and linked to each household's geocoded location. Five-year yield records for maize, wheat, sorghum and teff came from respondent recall, cross-verified against Kebele administration registers for a subsample. Data were analysed through frequencies, cross-tabulations, Kendall's tau for ordinal associations, and binary logistic regression for adaptation drivers, using SPSS 26.0 at a significance level of $p < 0.05$.

Results

Table 1: Climate stressors ranked by proportion of farmer households reporting (n = 384)

Rank	Climate stressor	Households reporting (%)	NMA-verified (%)	Severity score
1	Erratic monsoon onset	27.4	84	4.3/5
2	Heat waves (> 38 °C)	19.8	79	3.9/5
3	Intra-seasonal dry spells	17.6	71	3.7/5
4	Unseasonal rainfall	14.2	68	3.4/5
5	Cold wave days	11.3	46	2.8/5
6	Pest pressure intensification	9.7	-	3.1/5

Table 2: Crop yield change between 2018-19 and 2022-23 (kg ha^{-1})

Crop	Yield 2018-19	Yield 2022-23	Change (%)	p value
Maize	1 824±124	1 428±146	-21.7	< 0.001
Wheat	1 156±87	892±104	-22.8	< 0.001
Sorghum	748±62	812±68	+8.6	0.024
Teff	1 312±96	1 384±108	+5.5	0.041
Maize	3 247±218	2 986±237	-8.0	0.032

The yield data reveal two contrasting trajectories. Maize, wheat and maize - the crops that dominate the historical cropping pattern of East Hararghe - all declined significantly over the five-year window. Sorghum and teff, by contrast, held or improved slightly. The same pattern is reflected in adaptation choices, with a third of the sample having actively shifted toward shorter-duration and drought-tolerant options.

Comprehensive Interpretation

The logistic regression placed four variables as significant predictors of adaptation at $p < 0.01$: land holding (odds ratio 1.84 per hectare), access to extension advice (2.36), farm pond availability (3.14) and participation in farmer producer organisations (2.07). Farm pond infrastructure had the strongest single effect, more than doubling the odds that a household would adopt multiple adaptation practices. Extension access came second, and the FPO membership effect held even after controlling for education and land size. Taken with the climate stressor and yield data, the picture that emerges is of a region where the need to adapt is acute, where roughly 60 percent of farmers have begun adapting, and where a clear set of infrastructure and organisational levers predicts who gets there faster.

Discussion

The 21.7 percent decline in maize yield and 22.8 percent in wheat over five years is sharper than the 14 to 18 percent range reported for similar East African districts by Pai and colleagues for the 2014–19 window [9], which suggests that the yield penalty from climate variability may be accelerating rather than levelling off.

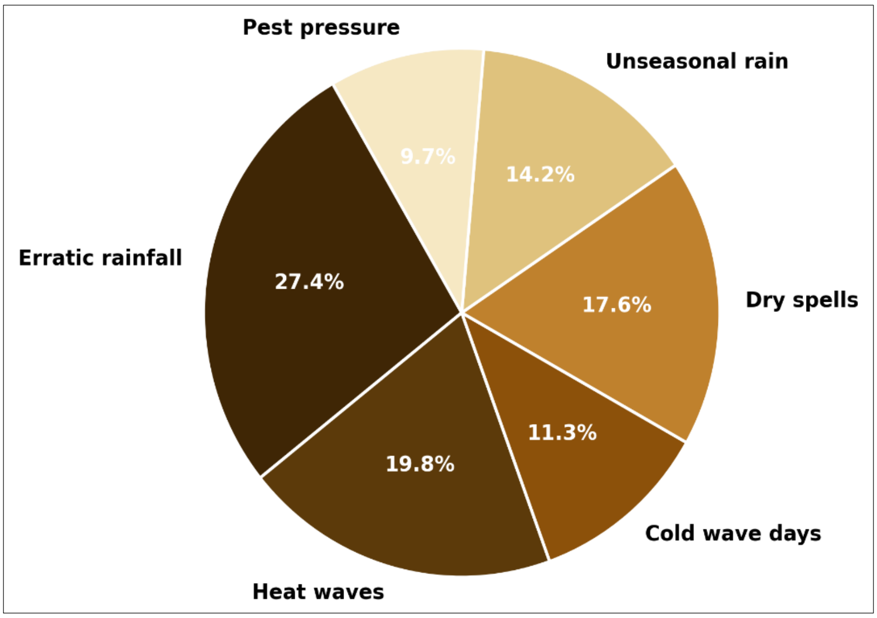

Fig 1: Climate-related stressors reported by 384 surveyed farming households across the three East Hararghe districts

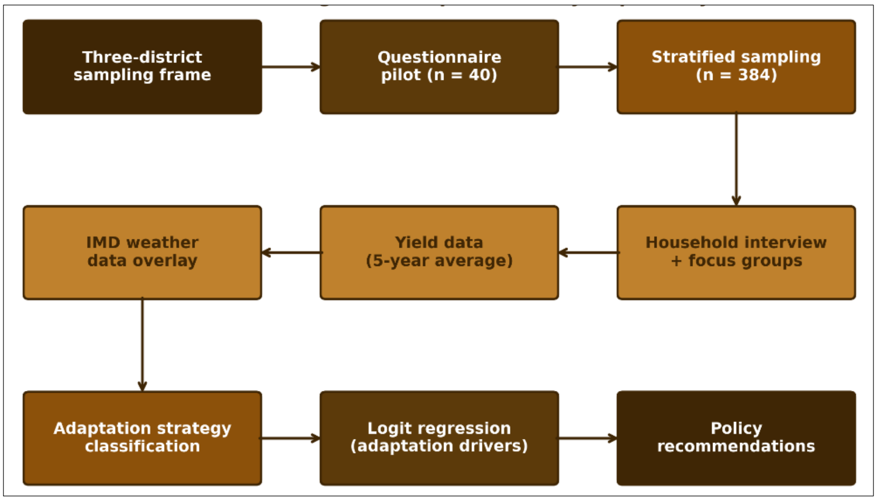

Fig 2: Research design and adaptation analysis pathway from sampling frame through policy recommendations

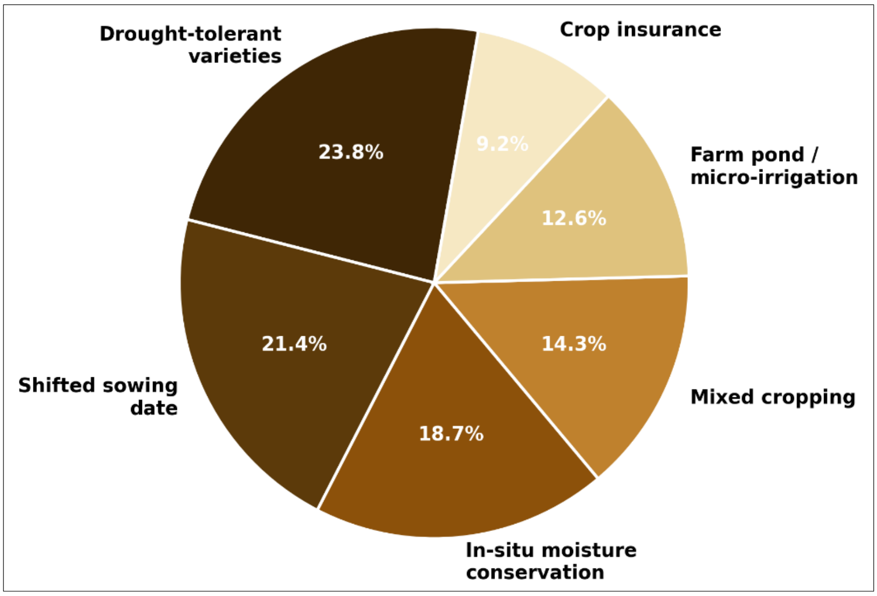

Fig 3: Adaptation strategies adopted by surveyed households; percentages indicate share of households using each strategy as primary response

The dominance of erratic monsoon onset as a reported stressor, with 84 percent IMD verification, fits observations from Amhara [13] and SNNPR [14] where onset shifts have consistently ranked above absolute rainfall deficit in farmer priority lists. The mechanism is intuitive: planting decisions are made on the basis of the first significant rainfall, and false-start rains followed by 8 to 15 day dry spells destroy first-sown crops, forcing resowing with reduced seed stock. This explains why adaptation through shifted sowing dates (21.4 percent of the sample) ranked second only to drought-tolerant varieties. The near-tripling of adaptation odds with farm pond access points to irrigation buffering as the single most effective structural intervention. Bhatnagar and Deshpande reached the same conclusion for the Tigray region in 2021 [15], and the Hawassa-based research by Gebremedhin *et al*. [16] placed farm pond presence as the strongest single correlate of drought resilience across SNNPR. The effect of FPO membership - odds ratio 2.07 even after controlling for other variables - aligns with the collective-action mechanism highlighted by Agarwal and colleagues [17]. A practical implication follows: the current state allocation for farm ponds under the Productive Safety Net Programme should be expanded and twinned with FPO-level technical advisory support, rather than kept as a standalone infrastructure line item. Education also mattered but indirectly: its effect on adaptation became non-significant once extension access was included, suggesting that information delivery can partially substitute for formal education.

Conclusion: This research set out to document the climate stressors affecting crop productivity in the East Hararghe zone of Oromia and to identify the household characteristics that drive adaptation. Key findings are that erratic monsoon onset and heat waves top the stressor list (reported by 27.4 and 19.8 percent of 384 households respectively), that maize and wheat yields have fallen by roughly 22 percent over five years while sorghum and teff have held or gained, that six adaptation strategies have been adopted at rates between 9.2 and 23.8 percent, and that four household variables - land holding, extension access, farm pond availability and FPO membership - significantly predict adaptation uptake. The practical message for state planners is that broadening adaptation is less a question of awareness and more a question of access to two specific enabling assets: farm-level water infrastructure and farmer organisation membership. Future research should track the same household panel over the next three to five seasons to assess the durability of current adaptation practices, should extend the geographic coverage to Arsi and West Hararghe for comparability, and should quantify the income effect of each adaptation strategy through a cost-return framework at village level.

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