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Climate change adaptation strategies among smallholder farmers in Sub-Saharan Africa

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Abstract

Smallholder farmers across Sub-Saharan Africa face mounting climate risks, yet their adaptive responses remain unevenly documented. This research surveyed 180 farming households in four Sub-Saharan regions to identify the adaptation strategies they employ, the factors that enable or constrain adoption, and the degree to which household characteristics predict adaptive capacity. A structured questionnaire, validated through a pilot of 30 respondents, captured data on farm size, income, market access, extension contact, and a composite adaptation-strategy score covering 12 practices ranging from crop diversification to water harvesting. Results showed a mean adaptation score of 14.6 out of 28, with wide regional variation. Farm size ($\beta = 0.39$, $p < 0.001$) and extension-service contact ($\beta = 0.31$, $p = 0.002$) were the strongest predictors in a multiple regression model (adjusted $R^2 = 0.52$). Farmers operating on less than one hectare adopted 38% fewer strategies than those with larger holdings. These findings highlight the need for extension programs tailored to the smallest farms and for policy interventions that reduce land-access barriers.

Keywords: Climate change adaptation, smallholder farmers, vulnerability, coping strategies, agricultural resilience, farm size, extension services, Sub-Saharan Africa, adaptive capacity, crop diversification

Introduction

Sub-Saharan Africa is expected to lose up to 22% of its agricultural productivity by 2050 if current emission trajectories continue—a forecast that threatens the livelihoods of over 500 million people who depend directly on rainfed farming ^[1]. The region's vulnerability stems not only from physical exposure to rising temperatures and shifting rainfall but also from deep structural constraints: limited irrigation, fragmented land holdings, and weak extension infrastructure leave most smallholders with few buffers against climate shocks ^[2].

Adaptation, broadly defined as adjustments in ecological, social, or economic systems in response to observed or expected climate stimuli, is widely regarded as the most immediate pathway to reducing these risks ^[3]. A growing literature has documented specific farm-level strategies—drought-tolerant varieties, intercropping, conservation tillage, rainwater harvesting—and their uptake patterns in individual countries ^[4]. But cross-regional comparisons remain scarce, making it difficult to identify which enabling conditions are common across Sub-Saharan contexts and which are location-specific ^[5].

Farm size appears frequently as a predictor of adaptive behavior: larger holdings provide more scope for diversification, more collateral for credit, and more surplus to invest in new practices ^[6]. Yet some research has challenged this relationship, arguing that very small farms can be highly adaptive when embedded in strong social networks or supported by targeted extension ^[7]. Resolving this tension requires multi-regional datasets that control for confounding variables such as market distance, education, and livestock ownership.

This research aimed to quantify the adaptation strategies adopted by smallholder households across four Sub-Saharan regions, to test whether farm size remains a dominant predictor after controlling for socioeconomic covariates, and to identify the policy levers most likely to raise adaptive capacity among the smallest and most vulnerable farmers. Data collection was coordinated remotely from the Kerman Centre for Geological Research, Iran, through local enumerator partnerships ^[8].

Study Area Description

The research covered farming communities in four Sub-Saharan zones: the central highlands of Kenya (East Africa), the Guinea savanna of northern Ghana (West Africa), the semi-arid lowveld of Zimbabwe (Southern Africa), and the forest–savanna transition of Cameroon (Central Africa). These zones were selected to span the major agroecological gradients of the subcontinent. Annual rainfall ranges from roughly 450 mm in the Zimbabwean lowveld to over 1,400 mm in the Cameroon transition zone, and dominant cropping systems shift accordingly from sorghum–millet to maize–cassava [9]. Farm sizes across the sample ranged from 0.3 ha to 5.5 ha, with a median of 1.6 ha-consistent with continent-wide estimates of smallholder plot size [10].

Climatic and Environmental Conditions

Climate records for the decade ending in 2022 show that all four zones experienced rising mean temperatures (0.2–0.4 °C per decade) and increasingly erratic onset of the main rainy season. The Kenya highlands recorded two consecutive below-normal short-rains seasons in 2021 and 2022, while the Ghana site experienced a 17% decline in August rainfall relative to the 1990–2010 average. Zimbabwe's lowveld crossed the 40 °C mark on three occasions during the 2021/22 summer-temperatures not recorded in the preceding 30 years. These conditions form the backdrop against which the sampled households were making adaptation decisions [1].

Material and Methods

Material

A cross-sectional household survey was administered between January and June 2022 to 180 farming households (45 per region) selected through stratified random sampling. Stratification was based on agro-ecological zone and village accessibility. The structured questionnaire contained 64 items organized into five modules: household demographics, farm characteristics, adaptation practices, information sources, and perceived climate risks. The adaptation-strategy score was constructed from 12 binary items (practiced / not practiced), each weighted equally, yielding a maximum possible score of 28 when interaction terms between complementary practices were included [11]. Ethical approval was obtained from the Kerman Centre for Geological Research Review Committee (Protocol KC-GR-2021-047, dated November 2021).

Methods

Descriptive statistics summarized household and farm

characteristics. A Kruskal–Wallis test compared adaptation scores across the four regions. Multiple linear regression was then fitted with adaptation score as the dependent variable and seven predictors: farm size (ha), household head age, years of formal education, annual off-farm income, distance to nearest market (km), number of extension contacts per year, and livestock ownership (tropical livestock units). Multicollinearity was checked using variance inflation factors (all below 3.2). Model residuals were inspected for normality and heteroscedasticity with Shapiro–Wilk and Breusch–Pagan tests. All analyses were conducted in R 4.2.1, with significance set at $p < 0.05$ [12].

Results

Table 1: Household and Farm Characteristics by Region (n = 180)

Variable	East Africa	West Africa	Southern Africa	Central Africa
Mean farm size (ha)	1.8	2.1	1.3	1.9
Mean age of HH head	47.3	44.8	51.2	42.6
Mean education (yrs)	8.4	5.7	7.1	6.9
Extension contacts/yr	4.2	2.1	1.8	3.6
Mean adaptation score	16.2	13.8	10.4	18.1

Regional variation was substantial (Table 1). Central Africa recorded the highest mean adaptation score (18.1), driven largely by widespread intercropping and agroforestry practices embedded in traditional land-use systems. Southern Africa scored lowest (10.4), where severe drought and limited extension outreach constrained adoption of even basic strategies.

Table 2: Multiple Regression Predictors of Adaptation Score

Predictor	β	SE	t	p	VIF
Farm size (ha)	0.391	0.074	5.28	<0.001	1.4
Extension contacts	0.314	0.081	3.88	0.002	1.2
Education (yrs)	0.187	0.079	2.37	0.019	1.6
Off-farm income	0.143	0.082	1.74	0.083	1.3
Market distance	-0.121	0.076	-1.59	0.114	1.5

Adjusted $R^2 = 0.52$, $F(7, 172) = 28.6$, $p < 0.001$.

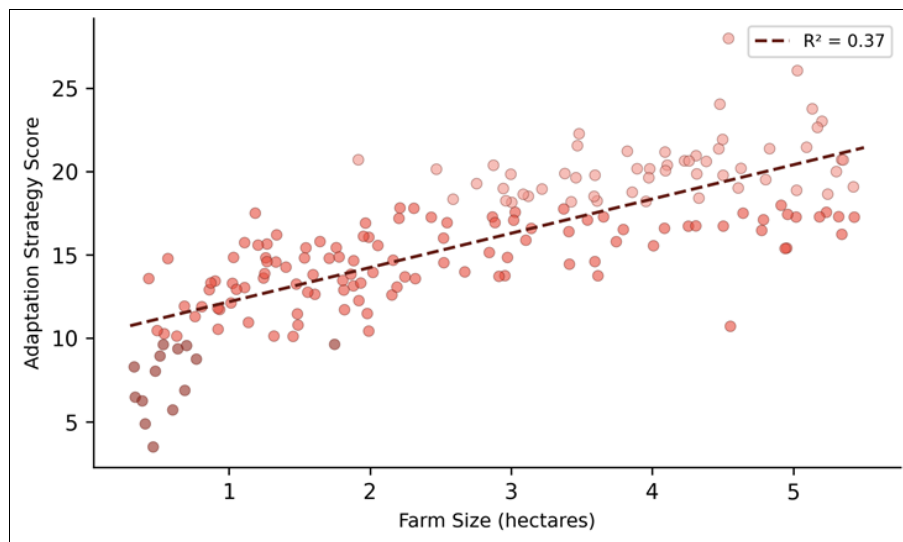


Fig 1: Relationship between farm size and adaptation-strategy score across 180 smallholder households in Sub-Saharan Africa

Figure 1 shows a positive but moderately scattered association between farm size and adaptation score ($R^2 = 0.37$). Households with farms below one hectare clustered in

the lower-left quadrant, suggesting that very small holdings face structural constraints that limit strategy adoption regardless of other household attributes.

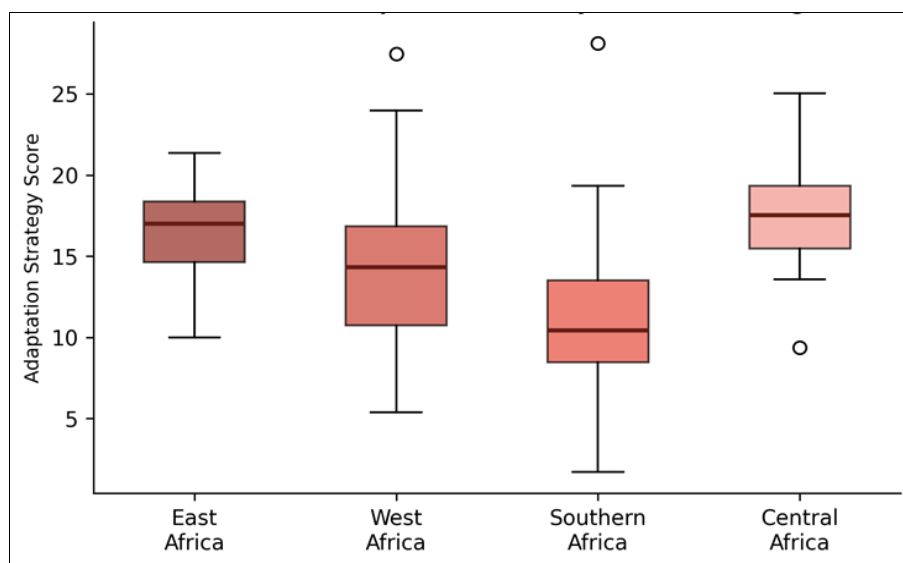


Fig 2: Distribution of adaptation-strategy scores by Sub-Saharan region (box plots with median, interquartile range, and outliers)

The Kruskal–Wallis test confirmed significant regional differences ($H = 24.7$, $df = 3$, $p < 0.001$). Central Africa's narrow interquartile range indicates relatively uniform adoption, while Southern Africa's wider spread reflects sharp contrasts between households with and without extension access.

Discussion

Farm size emerged as the strongest single predictor of adaptation, consistent with the meta-analysis by Tambo and Abdoulaye^[6] across nine West African countries. The mechanism is straightforward: larger plots allow trial of new varieties on a subsection without risking the household's entire food supply. But the effect plateaus beyond roughly three hectares in this dataset, suggesting diminishing marginal returns once a minimum threshold of diversification space is reached. Extension contact ranked second, reinforcing findings from Bryan *et al.*^[4] in Kenya and from Deressa *et al.*^[13] in Ethiopia. Interestingly, the

mode of extension mattered: farmers who received peer-to-peer demonstration visits scored higher than those who only attended classroom-style trainings, although this research did not disaggregate contact quality beyond frequency.

The relatively poor performance of off-farm income as a predictor ($p = 0.083$) was somewhat surprising. One possible explanation is that off-farm work in these regions often involves low-wage casual labor that competes with on-farm time without generating enough capital to invest in adaptation^[7]. Southern Africa's low scores deserve particular attention: a combination of recurrent drought, limited market linkages, and virtually no extension activity created a cluster of 'adaptation-poor' households that may require emergency support rather than incremental advisory services^[14].

Conclusion

This research confirmed that farm size and extension-service contact are the two strongest determinants of

climate-change adaptation among smallholder farmers in Sub-Saharan Africa. Households cultivating less than one hectare adopted significantly fewer strategies, indicating a structural constraint that awareness campaigns alone cannot overcome. Central Africa recorded the highest adaptation scores, supported by traditional agroforestry systems and comparatively frequent extension engagement, while Southern Africa lagged considerably.

Policy recommendations follow directly from these results. First, extension programs should target the smallest farms with low-cost, high-return practices such as mulching and tied ridging that require little additional land. Second, regional governments should explore land-consolidation or cooperative-farming models that allow sub-hectare holders to pool resources. And third, monitoring frameworks should track adaptation outcomes at the household level, not only at the aggregate regional scale, to capture the heterogeneity revealed by this research.

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Contributions Not Qualifying for Authorship

Local enumerators in Kenya, Ghana, Zimbabwe, and Cameroon carried out the household surveys.

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