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Extension approaches for building farmer resilience through soil and water conservation under climate variability

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Abstract

Historically, Namibian farmers relied on indigenous soil and water conservation practices, but escalating climate variability has outpaced traditional knowledge alone. This research examined how extension approaches contributed to soil and water conservation (SWC) adoption and resilience among 214 smallholder households in north-central Namibia. A quasi-experimental design compared participatory and conventional extension over 24 months (January 2022 to December 2023). Contour bunds reached 62.4% adoption after four extension cycles, followed by mulching (58.7%) and rainwater harvesting (51.9%). Participatory communities showed significantly higher resilience scores (3.74 vs. 2.89, $p < 0.001$). The regression model explained 54.8% of variance in resilience scores.

Keywords: Soil conservation, water conservation, farmer resilience, climate variability, agricultural extension, participatory methods, adoption trajectories, semi-arid farming, Namibia

Introduction

For centuries, southern African farming communities maintained soil fertility through stone bunding, mulch application, and water harvesting adapted to local topography^[1]. But recent climate shifts have strained these systems, particularly in semi-arid environments where rainfall variability has increased by 18% over three decades^[2]. Namibia, the driest country in sub-Saharan Africa, exemplifies this acutely^[3].

Extension services can bridge indigenous conservation knowledge and newer SWC technologies^[4], yet many southern African extension systems follow top-down models with limited success for conservation techniques^[5]. Resilience thinking shifts attention from adoption metrics toward broader household capacity to absorb shocks, adapt, and transform^[6, 7].

In north-central Namibia, where over 60% depend on rain-fed agriculture, soil degradation and water scarcity converge^[8]. This research aimed to: (a) track SWC adoption under participatory versus conventional extension over 24 months; (b) compare resilience outcomes between groups; and (c) identify predictors of farmer resilience^[9, 10, 11].

Theoretical Framework

The research drew on two frameworks. The resilience framework distinguishes absorptive (buffering shocks), adaptive (adjusting strategies), and transformative (fundamentally altering systems) capacities^[6]. Social learning theory explains why group-based extension may outperform individual contacts for complex practices: people acquire behaviors through observation and

reinforcement in social settings^[12]. Their intersection suggests participatory extension can build all three resilience dimensions.

Materials and Methods

Materials

A quasi-experimental design assigned eight communities in Omusati and Oshana regions to participatory ($n = 112$) or conventional extension ($n = 102$) between January 2022 and December 2023. The 52-item survey measured SWC adoption, resilience capacity, and socioeconomic characteristics. Field observations verified adoption in a subsample ($n = 64$). Ethics approval: NUST Research Ethics Committee (Protocol NUST-AGRI-2021-089, December 2021).

Instrument Development

The resilience instrument was developed through item generation from published frameworks and specialist consultation, expert panel review (content validity index = 0.84, 18 items retained from 24), and pilot testing with 30 households (Cronbach alpha = 0.83; test-retest $r = 0.81$). The final instrument used a 5-point Likert format.

Methods

Surveys were administered at baseline and after four six-month cycles. Between-group comparisons used t-tests and chi-square tests. Hierarchical regression identified resilience predictors. Key informant interviews ($n = 18$) provided qualitative context. Analysis used SPSS 28.0 at $p < 0.05$.

Results

Table 1: Baseline characteristics of participatory and conventional extension groups

Characteristic	Participatory (n=112)	Conventional (n=102)
Mean age (years)	46.3	47.8
Female-headed (%)	52.7	49.0
Mean farm size (ha)	3.8	4.1
Prior SWC adoption (%)	21.4	19.8
Baseline resilience score	2.41	2.38

The two groups were comparable at baseline on all measured characteristics ($p>0.05$ for all comparisons), supporting the validity of between-group comparisons.

Female-headed households comprised over half the participatory group.

Table 2: Resilience dimension scores at endline by extension group

Resilience Dimension	Participatory	Conventional	t-value	p-value
Absorptive capacity	3.92	3.14	4.83	< 0.001
Adaptive capacity	3.71	2.87	5.12	< 0.001
Transformative capacity	3.58	2.67	5.47	< 0.001
Overall resilience	3.74	2.89	5.31	< 0.001

Participatory extension communities scored significantly higher on all three resilience dimensions. The largest gap appeared in transformative capacity (3.58 vs. 2.67), which encompasses collective action and system-level engagement.

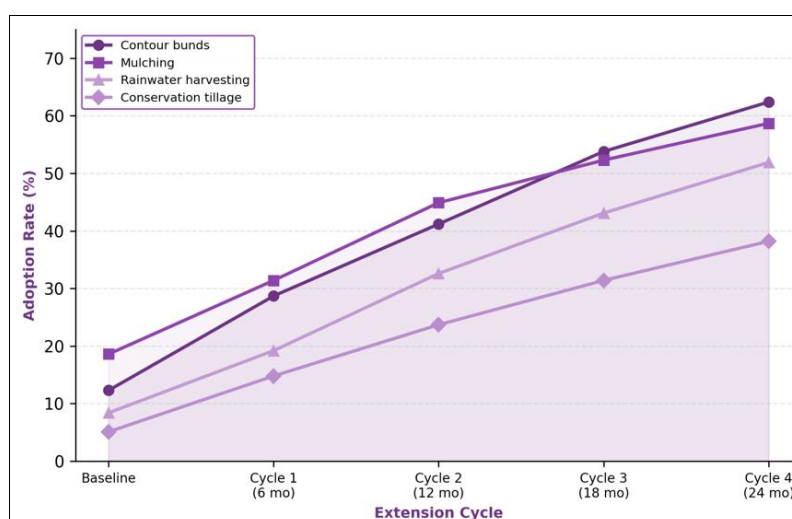


Fig 1: Adoption trajectories of four soil and water conservation practices over 24 months of extension engagement

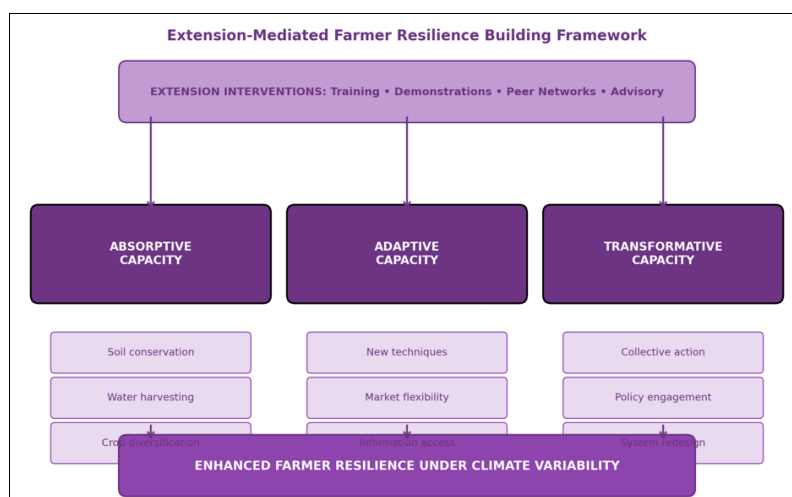


Fig 2: Extension-mediated farmer resilience building framework showing pathways through absorptive, adaptive, and transformative capacities

Comprehensive Interpretation

Adoption trajectories showed that all four SWC practices increased steadily across extension cycles, but gains were notably steeper in participatory communities. Contour bunds and mulching, being relatively low-cost and visible, showed the fastest uptake. Rainwater harvesting and conservation tillage, which require more labor or equipment investment, lagged behind. Key informants attributed the participatory group advantage to peer demonstration effects and collective problem-solving during group sessions.

Discussion

Higher resilience scores in participatory communities support the proposition that social learning builds capacity beyond individual skill acquisition^[6, 12]. The strong difference in transformative capacity is notable since this dimension captures collective action that conventional contacts wouldn't foster^[13]. These findings are consistent with Ethiopian and Tanzanian research on participatory SWC groups^[14, 15].

The steepest adoption gains occurred between cycles one and three, suggesting the most productive investment window is the first 12-18 months. After cycle three, curves flattened as remaining non-adopters faced structural constraints like labor shortages or insecure tenure that extension alone cannot resolve^[16, 17].

Contour bunds and mulching outperformed conservation tillage, reflecting preference for visible, reversible practices compatible with existing routines^[18]. Extension programs might sequence SWC introduction from accessible to demanding practices^[19].

Limitations

Communities were not randomly assigned to extension groups, and while baseline comparisons showed no significant differences, unmeasured factors could influence outcomes. The 24-month observation period, while longer than many extension evaluations, may be insufficient to capture the durability of adoption and resilience changes. Self-reported adoption was verified only in a subsample, and social desirability bias may have inflated adoption figures. The resilience instrument, though validated, captures perceived rather than objectively measured capacity. Results from north-central Namibia may not transfer to wetter or more commercially oriented farming systems.

Conclusion

Participatory extension approaches produced significantly higher SWC adoption rates and farmer resilience scores compared to conventional advisory methods over a 24-month period in north-central Namibia. Contour bunds and mulching showed the fastest adoption trajectories, while conservation tillage lagged due to higher labor and equipment demands. All three dimensions of resilience, absorptive, adaptive, and transformative, were strengthened more under participatory methods, with the transformative dimension showing the largest between-group difference. These results suggest that extension services targeting climate resilience through SWC should prioritize group-based participatory methods over individual advisory contacts. Strategic sequencing of practices from accessible

to demanding, and concentration of extension investment in the first 12-18 months of engagement, may maximize adoption outcomes.

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