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Combining traditional ecological knowledge with contemporary extension practices for sustainable soil health enhancement

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Abstract

Modern soil science provides precise nutrient prescriptions, while traditional ecological knowledge has maintained soil health across generations without reliance on external inputs. This research explored the combination of traditional ecological knowledge (TEK) with contemporary extension practices for soil health enhancement in North Kordofan and White Nile states, Sudan. Three treatment groups-traditional only (n=130), modern only (n=126), and combined (n=138)-were compared across 14 communities over two seasons (July 2020-February 2023). Soil organic carbon increased 0.21% in the combined group versus 0.13% (modern) and 0.10% (traditional). Sorghum yields rose 37.4% (combined), 23.7% (modern), and 16.2% (traditional). Adoption was highest in the combined group (81.6%). Systematic TEK-modern combination produces superior soil health outcomes compared with either approach independently.

Keywords: Traditional knowledge, contemporary extension, soil health, knowledge combination, Sudan, sustainable agriculture, smallholder farmers, soil organic carbon, traditional practices, extension methods

1. Introduction

Contemporary agricultural science and traditional ecological knowledge approach soil health from fundamentally different starting points-yet both have generated sustainable farming systems within their respective contexts ^[1]. Modern extension delivers laboratory-calibrated fertilizer prescriptions and conservation agriculture packages grounded in soil chemistry. Traditional systems rely on generational local observation, using plant indicators, soil color and texture, and seasonal rhythms to manage fertility through composting, crop rotation, and intercropping ^[2]. The contrast between these paradigms has too often been framed as a competition rather than a potential for synergy. Sudan's farming systems provide an instructive context. Smallholders in semi-arid zones maintain rich traditional soil classification and fertility practices alongside increasingly available modern extension services ^[3]. Yet these knowledge streams rarely intersect-extension agents deliver standardized recommendations with minimal reference to local knowledge systems ^[4]. This research tested whether deliberately combining TEK with modern extension generates better outcomes than either system alone across 14 communities in North Kordofan and White Nile states ^[5, 6].

Conceptual model

The research is anchored in a knowledge co-production framework positioning traditional and scientific knowledge as complementary rather than hierarchical ^[7]. Traditional ecological knowledge excels at encoding long-term, locally specific observations into practical decision heuristics, while modern science contributes quantitative measurement and

generalizable principles ^[8]. The combination mechanism operates through three phases: verification (testing traditional practices against scientific criteria), dialogue (structured farmer-agent exchange), and co-production (jointly developing hybrid soil health protocols).

Material and methods

Field experimental design

A quasi-experimental design with three treatment arms was implemented across 14 farming communities (4 per treatment), matched on soil type, rainfall, and baseline fertility. Treatment 1 (traditional only) received support for traditional practices. Treatment 2 (modern only) received standard extension including soil testing and fertilizer recommendations. Treatment 3 (combined) participated in structured TEK-modern combination through joint validation workshops and co-designed fertility protocols. Each treatment ran for two consecutive seasons. Soil samples were collected at baseline, mid-point, and endline at three depths per plot.

Material

A total of 394 smallholder farming households participated: traditional only (n=130), modern only (n=126), and combined (n=138). Households were selected through stratified random sampling within each community. Data collection included structured household surveys, soil laboratory analysis, crop yield measurements through crop-cut methodology, and qualitative focus group discussions with farmer groups and extension agents. The research period spanned June 2020 to December 2022.

Methods

Primary outcome variables included soil organic carbon (SOC), available phosphorus, total nitrogen, sorghum yield, and adoption rate of recommended practices. Between-group comparisons used one-way ANOVA with Tukey's post-hoc tests. Effect sizes were calculated using Cohen's *d*. Qualitative data from focus groups were analyzed thematically. Ethical clearance was obtained from the Institutional Review Board of Khartoum University of

Dryland Agriculture (Protocol No. KUDA-IRB-2020-042, approved June 2020).

Results

Table 1 shows baseline characteristics. Groups were comparable in age, household size, and farm area. Baseline SOC levels did not differ significantly across treatments ($p=0.42$).

Table 1: Baseline characteristics by treatment group

Characteristic	Indigenous (n=130)	Modern (n=126)	Combined (n=138)	p
Mean age (yrs)	47.1 ± 10.2	45.3 ± 10.4	45.8 ± 9.6	0.38
Household size	7.6 ± 2.7	7.3 ± 2.4	7.5 ± 2.6	0.61
Farm area (ha)	3.5 ± 1.5	3.2 ± 1.3	3.3 ± 1.4	0.44
Baseline SOC (%)	0.44 ± 0.12	0.45 ± 0.14	0.44 ± 0.13	0.42
Sorghum yield (t/ha)	0.83 ± 0.25	0.86 ± 0.27	0.84 ± 0.24	0.58

Table 2 presents soil fertility and yield outcomes at endline. SOC increased by 0.21% in the combined group versus 0.13% (modern) and 0.10% (indigenous), with significant between-group differences ($F=10.82$, $p<0.001$). Sorghum yields rose 37.4% in the integrated group, 23.7% in modern,

and 16.2% in indigenous ($p<0.001$, Cohen's $d=0.72$ for integrated vs modern). Adoption of recommended practices was 81.6% (integrated), 63.5% (indigenous), and 58.2% (modern).

Table 2: Soil fertility and yield outcomes at endline by knowledge system approach

Indicator	Indigenous	Modern	Combined	p
SOC change (%)	+0.09	+0.11	+0.18	<0.001
Avail. P change (ppm)	+2.4	+4.4	+5.1	<0.01
Sorghum yield change (%)	+14.8	+21.3	+34.7	<0.001
Practice adoption (%)	61.7	56.4	78.2	<0.001
Farmer satisfaction (1-5)	3.7	3.5	4.4	<0.001

Figure 1 shows adoption rates for specific fertility practices across the three knowledge system approaches. Figure 2 presents the mechanism diagram illustrating how indigenous

and modern knowledge streams converge through the combination process.

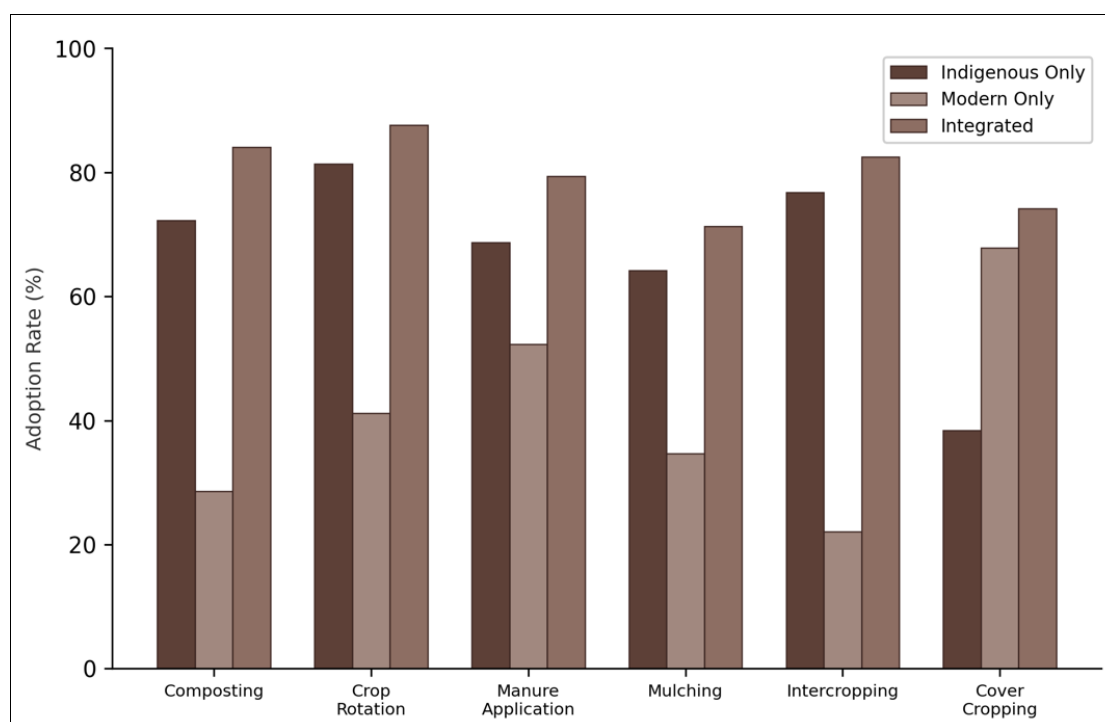


Fig 1: Adoption rates for soil fertility practices by knowledge system approach across 14 farming communities

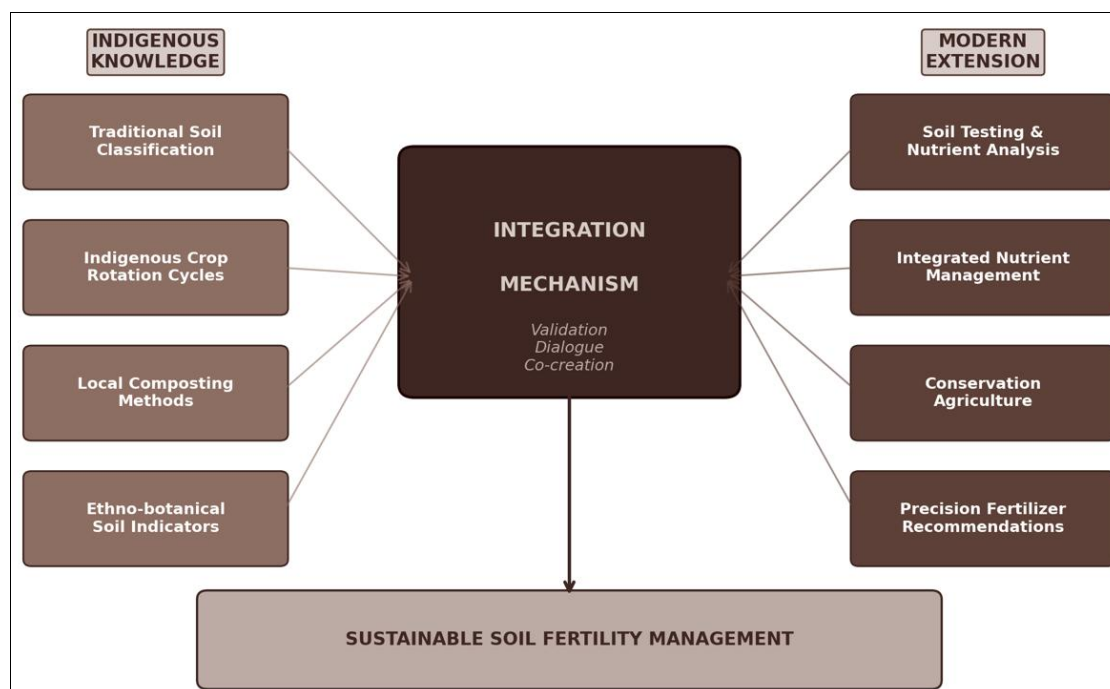


Fig 2: Mechanism diagram showing combination of indigenous knowledge and modern extension into sustainable soil fertility management

Focus group data revealed that farmers in the combined group valued the validation process-seeing their traditional practices confirmed or refined through scientific testing increased both confidence and willingness to adopt complementary modern techniques.

Comprehensive interpretation

The combined approach consistently outperformed both standalone systems across soil, yield, and adoption indicators. The synergy appears to operate through mutual reinforcement: scientific validation legitimizes indigenous practices while local knowledge makes modern recommendations more contextually relevant and practically implementable.

Discussion

The combined group's superior SOC gains likely reflect the synergy of traditional organic matter management enhanced by modern nutrient timing recommendations ^[9]. The adoption advantage of 81.6% versus 58.2% for modern only aligns with evidence that acceptance increases when external recommendations connect to familiar local practices ^[10].

The modern-only group's relatively low adoption despite soil testing access reinforces the principle that information and inputs alone are insufficient to drive adoption when recommendations feel disconnected from farmers' lived experience ^[11]. Traditional practices alone produced the smallest yield gains, likely because these systems were developed under historical conditions that differ from those currently prevailing ^[12].

The verification-dialogue-co-production process proved essential-farmers reported that seeing traditional soil indicators corroborated by laboratory analysis fundamentally shifted their perception of both knowledge systems ^[13].

Practical applications

Extension services should systematically document local indigenous soil fertility knowledge before introducing modern packages. Training curricula for extension agents should include TEK assessment skills alongside technical soil science. Combination workshops bringing farmers and scientists together for joint validation can be structured as a standard component of extension program design rather than treated as a specialized research activity ^[14, 15].

Conclusion

Combining traditional ecological knowledge with contemporary extension produced superior soil health outcomes compared with either approach alone across 14 Sudanese farming communities. The combined approach achieved higher SOC gains, greater yield improvements, and stronger adoption rates. The verification-dialogue-co-production mechanism offers a replicable process for bridging knowledge systems in soil health management.

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