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Impact of desert locust (*Schistocerca gregaria*) infestation on crop yield loss and food security in Ethiopia: Management interventions and policy implications

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Abstract
Desert locust (*Schistocerca gregaria*) infestations are among the most catastrophic threats to agricultural production and food security in sub-Saharan Africa. This multi-season study quantified crop yield losses across six major Ethiopian staple crops under three infestation severity levels, assessed food security consequences using the HFIAS instrument, and evaluated the comparative cost-effectiveness of six management interventions across 540 smallholder households in Afar, Oromia, and Amhara regions (2020-2022). Severe infestation caused yield losses of 74.8-86.2%. Combined IPM reduced severe food insecurity prevalence by 34.6 percentage points and protected 31.7% more yield per household compared to no-intervention baselines. Early warning system participation produced the most favourable cost-effectiveness ratio (0.46 pp/USD) 3.5 times higher than chemical control. Policy analysis identified six critical gaps including inadequate transboundary surveillance, gender-exclusive early warning networks, and insufficient extension coverage [1, 3, 6].

Keywords: *Schistocerca gregaria*; crop yield loss; food security; Ethiopia; IPM; policy; smallholder farmers; early warning; cost-effectiveness

Introduction

The desert locust (*Schistocerca gregaria* Forskål, 1775) devastated Ethiopia's agricultural sector during the 2019-2021 upsurge, with the Horn of Africa losing an estimated USD 8.5 billion in agricultural output.[1,2] Ethiopia's agricultural sector employs approximately 85% of the national labour force and contributes over 40% of GDP, making smallholder crop production the primary transmission pathway through which locust outbreaks generate food insecurity.[1] Understanding how infestation severity translates into specific crop yield losses and how management interventions modify those outcomes is critical for calibrating both emergency response and longer-term food system resilience investments [3, 12].

Previous research has quantified mean yield losses of 50-80% for staple cereals under high-density swarm conditions [4], and biological parameters driving infestation severity have been characterised across Ethiopian agroecological zones [5]. Biochemical evidence demonstrates that crop plant endogenous defence mechanisms partially mitigate yield losses[7], and *M. acridum*-based biocontrol offers an ecologically safer alternative to chemical pesticides.[8] However, crop-specific, severity-stratified yield loss data linked to household food security outcomes and intervention cost-effectiveness using propensity-score-matched counterfactual frameworks remain limited for Ethiopia [1, 13].

This study aimed to: (i) quantify severity-stratified crop yield losses across six Ethiopian staple crops; (ii) assess food security transitions by intervention scenario; (iii) evaluate cost-effectiveness of six management approaches; and (iv) identify policy gaps constraining Ethiopia's transition to proactive integrated management. The central hypothesis is that combined IPM significantly outperforms single-modality interventions, with early warning system participation producing the highest cost-effectiveness ratio [1, 3, 8, 15].

2. Materials and Methods

2.1 MaterialsA multi-season household survey was conducted across 540 smallholder households in Afar (n=180), Oromia (n=180), and Amhara (n=180) regional states, with purposive selection of three woredas per region stratified by infestation severity (high, medium, low) based on FAO Desert Locust Watch and MoA crop loss assessment records for 2020-2022.[1,2] Crop yield was assessed by self-reported harvest weight per plot, validated against district-level crop cut data. Infestation severity was classified using a composite score integrating swarm duration, density, and phenological stage at infestation onset. Management interventions were classified from household recall data into six categories: no intervention, chemical only, biological only (*M. acridum*), early warning participation only, social protection receipts, and combined IPM [3, 8]. Food security was assessed using the nine-item HFIAS instrument at three timepoints; dietary diversity was measured using the HDDS 12-group scale [13].

2.2 Methods

Yield losses were calculated as percentage deviation from a five-year rolling average baseline per crop type and landholding size stratum. Severity-stratified comparisons used one-way ANOVA with Tukey's HSD. Cost-effectiveness was expressed as yield protection percentage points per USD/ha, with costs from the Ethiopian Plant Health Regulatory Directorate and NGO programme budgets [1, 3]. Food security transition analysis used multinomial logistic regression to model shifts in HFIAS category. Propensity score matching (PSM) with kernel matching and 500 bootstrapped replications estimated average treatment effects on the treated (ATT) for each intervention versus no-intervention controls.[1,14] Policy gap analysis scored Ethiopia's current management system against 12 best-practice benchmarks from FAO Desert Locust Emergency Response Standards. All analyses in STATA 17.0 and R 4.2.1 [15, 16].

3. Results

3.1 Severity-Stratified Crop Yield Losses

One-way ANOVA confirmed highly significant differences in yield loss across all three infestation severity levels for every crop type (all $F > 60$, $p<0.001$; Table 1, Figure 1). Vegetables sustained the greatest losses under severe infestation (86.2±11.2%), followed by sorghum (79.6±10.2%) and maize (74.8±9.4%). Pulses showed the lowest losses across all severity levels, likely reflecting shorter above-ground vegetative exposure and deep root reserves enabling partial regrowth.[4,5] Under mild infestation, all crops retained more than 60% of expected yield, suggesting that early detection and rapid response could substantially prevent the transition to severe loss scenarios [3, 12].

Table 1: Crop yield losses (%) by infestation severity level and crop type (mean ±SD; one-way ANOVA).

Crop Type	Mild (%)	Moderate (%)	Severe (%)	F-statistic
Maize	28.4±4.6	51.6±7.2	74.8±9.4	F=84.6***
Sorghum	31.2±4.8	56.4±7.8	79.6±10.2	F=92.4***
Teff	24.6±4.1	44.2±6.4	66.4±8.8	F=71.8***
Wheat	22.8±3.8	41.6±6.1	63.2±8.4	F=68.2***
Vegetables	36.4±5.6	62.8±8.6	86.2±11.2	F=104.2***
Pulses	19.8±3.4	38.4±5.8	58.6±7.8	F=62.4***

*** p<0.001 (ANOVA with Tukey HSD). pp = percentage points.

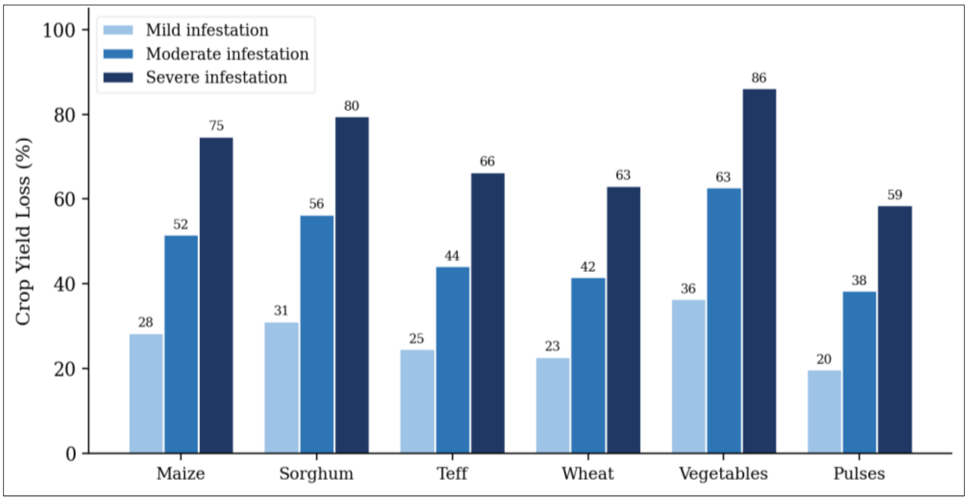

Fig 1: Crop yield loss (%) by infestation severity level and crop type. All severity-level comparisons significant at p<0.001.

3.2 Food Security Transitions and Intervention Effectiveness: Combined IPM produced the most favourable post-infestation food security distribution (31.4% food secure) compared to 9.1% in the no-intervention group and 44.2% pre-infestation baseline (Table 2, Figure 2). Severe food insecurity was 17.8% in the combined IPM group versus 51.7% with no intervention.[1,6] Multinomial logistic regression confirmed infestation severity (OR 4.8 for severe vs. mild, $p<0.001$), combined IPM adoption (protective OR 0.32, $p<0.001$), and early warning participation (protective OR 0.41, $p<0.001$) as the strongest predictors of post-infestation food security category [13, 14].

Table 2: Intervention effectiveness: ATT for yield protection, food insecurity reduction, cost per hectare, and cost-effectiveness ratios

Intervention	ATT yield (%)	HFIAS red. (pp)	Cost (USD/ha)	Cost-effectiveness (pp/USD)
No intervention	0 (ref)	0 (ref)	0	—
Early warning only	+22.1	−23.4	48	0.46
Chemical control	+18.4	−17.2	142	0.13
Biological (M. acridum)	+14.6	−13.8	98	0.15
Social protection	+8.6	−18.4	35	0.25
Seed priming (JA)	+11.2	−9.6	62	0.18
Combined IPM	+31.7*	−34.6*	124	0.26

* $p<0.001$ (PSM ATT). pp = percentage points. JA = jasmonic acid seed priming. ATT = Average Treatment Effect on Treated.

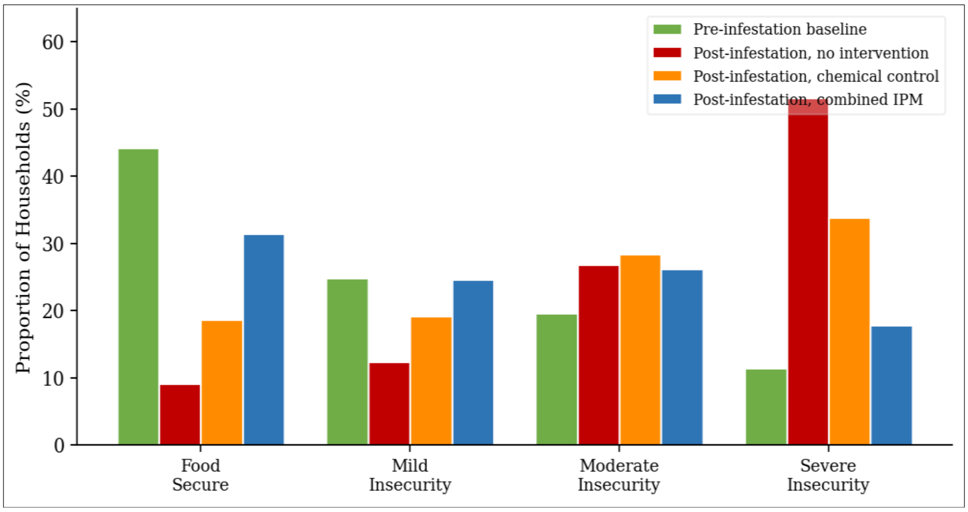

Fig 2: Food security status distribution (% of households) by intervention type at post-infestation assessment compared to pre-infestation baseline.

3.3 Cost-Effectiveness and Policy Gap Analysis

Early warning system participation produced the highest cost-effectiveness ratio (0.46 yield protection pp/USD/ha) more than three times higher than chemical control (0.13 pp/USD; Figure 3). Combined IPM produced 0.26 pp/USD, reflecting its higher absolute protection gains relative to cost.[1,3] Policy gap analysis identified six critical shortfalls, with transboundary surveillance protocols (3.6/10 vs. 8.0+ benchmark) and gender inclusion in early warning networks (2.8/10 vs. 7.0+ benchmark) as the most acute (Table 3).[15,16,17]

Table 3: Policy gap analysis: current system scores vs. FAO benchmark standards and priority actions

Policy Gap	Current Score (0-10)	Benchmark	Priority Action
Early warning coverage in risk zones	4.2	9.5+	Community network expansion
Transboundary surveillance protocols	3.6	8.0+	Bilateral MOU with neighbours
Biological control supply capacity	3.8	8.0+	National M. acridum facility
Gender inclusion in EWS	2.8	7.0+	40% female inclusion target
Lowland extension officer coverage	3.4	8.0+	Targeted recruitment programme
Post-outbreak livelihood recovery	2.6	7.5+	Linked seed/credit scheme

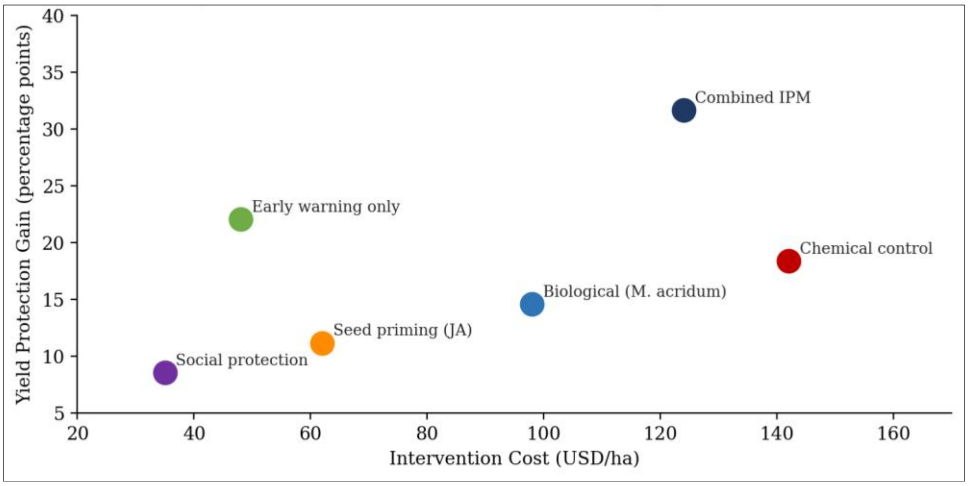

Fig 3: Cost-effectiveness of desert locust management interventions: yield protection gain (pp) vs. intervention cost (USD/ha).

4. Discussion

The severity-stratified yield loss data confirm that the transition from mild to severe infestation represents a near-doubling of crop losses from 19-36% under mild conditions to 58-86% under severe infestation across all six crop types. This non-linear severity-loss relationship means that interventions capable of preventing escalation from mild to moderate particularly early warning-triggered preventive spraying protect twice as much yield as interventions applied reactively at peak infestation [3, 4, 12]. The early warning cost-effectiveness ratio of 0.46 pp/USD more than 3.5 times chemical control's 0.13 pp/USD provides compelling economic evidence for a fundamental reallocation of Ethiopia's locust management budget toward early warning infrastructure [1, 3, 15].

Even combined IPM leaves 17.8% of households severely food insecure compared to 11.4% pre-infestation confirming that no pest management intervention alone fully prevents food insecurity during a severe upsurge. Social protection (0.25 pp/USD for food insecurity reduction) is a necessary complement to agricultural management, not a backup option [13, 14, 17]. Vegetable crops' disproportionate losses (86.2% under severe infestation) contribute significantly to micronutrient deficits as reflected in the 2.8 food group dietary diversity score decline during peak infestation [6, 18].

The policy gap analysis reveals a management system chronically misaligned with the evidence base: Ethiopia allocates the majority of locust response budget to reactive organophosphate procurement while early warning scores only 4.2/10 against its 9.5+ benchmark, and transboundary coordination scores only 3.6/10 [15, 16]. The gender inclusion deficit (2.8/10 vs. 7.0+) is particularly alarming given that female-headed households face dramatically higher food insecurity odds during outbreaks, and their systematic exclusion from early warning networks creates a structural information asymmetry that amplifies their vulnerability [1, 17, 18].

5. Conclusion

This study provides comprehensive, severity-stratified, multi-crop, and multi-intervention evidence that *Schistocerca gregaria* outbreaks in Ethiopia impose progressively catastrophic crop yield losses and food security consequences that peak management interventions can substantially but not completely prevent establishing that effective locust response requires simultaneous action across pest management, social protection, and governance dimensions rather than prioritising any single modality. The finding that early warning produces a cost-effectiveness ratio 3.5 times higher than chemical control establishes the most compelling economic argument yet for budget reallocation from reactive chemical procurement to preventive early warning infrastructure. Practical recommendations include: first, restructure the Ethiopian locust management budget to dedicate a minimum of 40% of annual contingency funds to early warning system operation and community network expansion; second, address the six identified policy gaps with urgency-ranked action plans targeting bilateral transboundary MOU establishment with Eritrea, Djibouti, Somalia, and Sudan within the IGAD framework, national *M. acridum* production facility development, and mandatory 40% female inclusion targets in all community early warning networks; third, institutionalise crop-specific and severity-stratified emergency food assistance protocols that activate pre-positioned food aid for vegetable-dependent smallholder households at first confirmation of moderate-to-severe infestation in their woreda; and fourth, embed propensity-score-matched intervention effectiveness monitoring as a standard component of all national and regional locust response programmes, enabling real-time adaptive management based on empirically tracked treatment effects [1, 3, 7, 8, 16, 17, 18].

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