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Effectiveness of bioacoustics in sorghum for wild boar management: Insights from frontline demonstrations in Sangareddy District

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ABSTRACT

Human-wildlife conflict, particularly crop damage by wild boars (Sus scrofa), poses a significant challenge to agriculture in Telangana, affecting livelihoods and food security. This study was undertaken to assess the effectiveness of frontline demonstrations (FLDs) on the management of wild boar in sorghum cultivation in Sangareddy district, Telangana, during the Rabi seasons of 2023-24 and 2024-25. Demonstrations utilized an integrated pest management (IPM) module incorporating bioacoustics technology, ecological barriers, and indigenous technical knowledge (ITK). Results revealed a yield increase of 20.87% and 20.37% over local checks during 2023-24 and 2024-25, respectively. The pooled Benefit-Cost (B:C) ratio was 2.41 for demonstration plots, indicating economic viability. The technology index averaged 6.41%, indicating the feasibility of the recommended package. Challenges like high device costs, animal habituation, and reliance on community coordination may limit adoption, underscoring the need for subsidies, dynamic calibration, and participatory extension for sustainable use. The study emphasizes the need for continued extension support, capacity building, and policy interventions to enhance the adoption of eco-friendly wildlife management technologies.

Keywords: *Frontline demonstration, wild boar, sorghum, bioacoustics, technology index, extension gap, integrated pest management, ecological barriers, indigenous technical knowledge, eco-friendly.*

Introduction

Human-wildlife conflict over crop damage has been recorded since the advent of agriculture, with recent studies emphasizing its intensification due to habitat encroachment and agricultural expansion [5]. In India, particularly in Telangana, crop damage caused by vertebrate pests like deer, monkeys, rabbits, peacocks, and wild boars (*Sus scrofa*) is a common and recurring issue[4]. Among these, wild boars have emerged as a significant menace to farmers, leading to frequent demands for their removal from crop-growing regions. The menace is notably severe in the rainfed regions of Sangareddy district, where wild boar infestations affect key crops like sorghum, maize, sugarcane, and vegetables.

In the Sangareddy district of Telangana, wild boar infestation has escalated in recent years, contributing to a notable reduction in crop areas. For instance, sorghum, maize cultivation have declined from 72080 acres to 61856 acres and 59197.5 to 20389 acres respectively (Department of Agriculture, Sangareddy, 2025) over the past five years, while cotton area has grown from approximately 390804 continues to face considerable damage. The shift in cropping area is attributed to the observation that wild boars and other wild animals typically avoid cotton crops compared to edible crops. Farmers expressed that, despite lower returns, cultivating cotton ensures at least some income rather than facing complete crop loss.

Farmers have employed Indigenous Technical Knowledge (ITKs) such as tying cloth strips or sarees around field perimeters and maintaining night-time surveillance from raised platforms, *manche* [12]. Despite being culturally embedded, these practices often fail to provide consistent or reliable protection from wild boar incursions. In response, scientific methods for vertebrate pest management have been introduced [1] [2] [10]. These include physical fences, olfactory repellents, and notably bioacoustics deterrents, which employ predator, distress, or alarm calls to repel wild boars and to create an acoustic barrier against crop-raiding species [7]. Studies conducted in Switzerland [6] and other regions have validated the effectiveness of bioacoustics in repelling wild boars.

In response to this persistent challenge, a Frontline Demonstration (FLD) was planned and implemented to bridge the gap between recommended scientific practices and the existing methods adopted by farmers for managing wild boars in sorghum cultivation. The demonstration specifically focused on assessing the effectiveness of the FLD package and promoting the adoption of ecological pest management strategies. The key objective is to mitigate crop yield losses through the promotion of bioacoustics technology for sustainable wild boar management.

Alongside this framework, the present study was undertaken to evaluate the impact of FLDs on ecological wild boar management practices in sorghum-growing areas of Sangareddy district.

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Special emphasis was laid on bioacoustics-based repellents, their adoption, and their effectiveness in improving crop yields and promoting sustainable wildlife management through extension approaches. The assessment focuses on yield gains, economic benefits, and the effectiveness of extension methods in encouraging sustainable, community-focused crop protection.

Methodology

Study area and farmers' selection: The present study was undertaken in Lachunayak Thanda (Zaheerabad Mandal) and Nagawar (Raikode Mandal) of Sangareddy district, Telangana, during two consecutive Rabi seasons (2023-24 and 2024-25). These locations were purposively selected due to their proximity to forested hills, which makes them highly vulnerable to wild boar incursions, especially in sorghum cultivation. Based on the severity of crop losses reported by farmers and local extension workers, these two villages were identified in consultation with the DDS Krishi Vigyan Kendra (KVK), Zaheerabad. A total of 12 farmers were selected for participation through a participatory approach, ensuring that the interventions were farmer-centric and context-specific.

Intervention particulars: To assess the impact of integrated wild boar management strategies, Frontline Demonstrations (FLDs) were organized in selected farmer fields. The intervention was designed to compare scientific management practices against conventional practices. Accordingly, two sets of treatments were established:

1. Demonstration plots (2.4 ha/year): These plots implemented a package of integrated ecological pest management practices recommended for wild boar control:

- Safflower border rows (4 rows): Safflower acts as a natural deterrent due to its spiny nature, forming a bio-fence that discourages wild boar entry [9] [10].
- Bioacoustics equipment (Kethi Rakshak): Developed by PJTAU under the All India Network Project on Vertebrate Pest Management, this eco-friendly technology emits predator and distress calls at a fixed sound intensity, creating an acoustic barrier that discourages wild boars from entering fields. The device operates at a constant output of 110 dB, with an effective coverage area of 4 to 5 acres under typical ambient noise conditions (≈42 dB). At 37 dB of ambient noise, the equipment can cover up to 19 acres [16].
- Egg solution spray (20 ml/litre): Sprayed at field borders, this acts as an olfactory repellent due to its decomposing odour, further deterring wild boars.
- Azadirachtin 1500 ppm (5 ml/litre): A botanical insecticide derived from neem used in two sprays at weekly intervals, primarily to manage insect pests but also adding to the repellence.
- Salt spray (10 g/litre): Sprayed in two rounds at weekly intervals; the salty taste reduces the palatability of plants for wild boars.

2. Check plots (2.4 ha/year): These fields followed traditional farmer practices, largely relying on ITKs such as tying sarees or cloth strips around fields and maintaining night vigilance using raised platforms manchans to physically scare away animals.
Although the egg solution spray was included in the recommended demonstration package, many farmers were reluctant to adopt it due to its strong and unpleasant odour. As a result, its impact was not effectively realized or reflected in the outcomes of the present study. This comparative design enabled the evaluation of the efficacy of scientific interventions versus conventional practices under real farming conditions.

Extension activities: A series of extension interventions was carried out to promote awareness, skill development, and adoption of the demonstrated practices. These included:

Table no: 1 Extension activities conducted as part of FLD

Sl No.	Name of activity	No.	Beneficiaries
1.	Training program on wild boar management (On campus)	1	20
2.	Training program on wild boar management (Off campus)	2	42
3.	Regular field visits and interactive farmer meetings	16	35
4.	Method demonstrations on installation of Bioacoustics	2	36
Total			133

The integration of these participatory extension methods was aimed at strengthening the knowledge base of farmers regarding ecological wild boar management, improving technology adoption, and sustaining crop productivity in vulnerable regions.

Data collection and analysis: Data were systematically collected from both demonstration and check plots on the following parameters: grain yield (q/ha), input costs (₹/ha), gross returns (₹/ha), net returns (₹/ha) and benefit-cost (B:C) ratio. Descriptive statistics including means and standard deviations were calculated for key variables. Data were analysed using paired t-tests to compare demonstration and check plots for grain yield, net income, and B:C ratio after normality checks using the Shapiro-Wilk test on the differences between demo and check plots for each of the above mentioned parameters and year. Effect sizes were computed using Cohen's d to assess practical significance. The analysis was performed using MS Excel and SPSS version 22. Additionally, the impact of extension interventions (training programmes, demonstrations, and field visits) on farmer knowledge and adoption behaviour was also assessed as extension gap, technology gap, and technology index. The following standard formulas were employed for quantitative analysis as suggested by[14].

- Extension Gap (q/ha) = Yield of Demonstration -Yield of Local Check
- Technology Gap (q/ha) = Potential Yield - Yield of Demonstration
- Technology Index (%) = [(Potential Yield - Demonstration Yield) / Potential Yield] x 100
- Benefit - Cost Ratio (B:C) = Gross Returns / Cost of Cultivation

Where the potential yield of sorghum was considered as 30 q/ha based on regional agronomic recommendations.

Results

The Frontline Demonstration (FLD) conducted in two wild boar-prone villages of Sangareddy district effectively validated the role of integrated pest management strategies especially the use of bioacoustics deterrent devices in mitigating crop losses in sorghum cultivation. A total of 153 farmers participated and benefited from a series of extension interventions including on- and off-campus trainings, method demonstrations, and field visits conducted by DDS Krishi Vigyan Kendra (KVK). These activities played a pivotal role in building awareness about the behavioural patterns of wild boars, crop susceptibility, and the advantages of scientific interventions over conventional practices.

Grain yield improvements

The grain yield under demonstration plots was significantly higher than that of check plots in both years of study. In the 2023-24 season, the demo plots recorded a yield of 27.50 q/ha compared to 22.75 q/ha in check plots, translating to a 20.87% increase. Similarly, during 2024 - 25, the yield increase was 20.37%, with demo plots achieving 28.65 q/ha compared to 23.80 q/ha in check plots. These yield enhancements are directly attributable to the use of integrated ecological practices, including bioacoustics, azadirachtin, safflower border crop, and salt and egg-based sprays [7]. The consistent yield improvements across two seasons demonstrate the technical feasibility and practical utility of these methods under field conditions.

Table no. 2: Economics of wild boar management in sorghum

Parameter	Season	Demo (Mean ± SD)	Check (Mean ± SD)	t Statistic	p – value*	Cohen's d
Grain yield	2023-24	27.50 ± 1.61 q/ha	22.75 ± 0.43 q/ha	10.73	0.0001	4.38
	2024-25	28.65 ± 1.03 q/ha	23.80 ± 0.89 q/ha	12.86	<0.0001	5.26
Cost of investment	2023-24	48,124.70 ± ₹1,015.83	₹46,750.03 ± ₹759.22	4.47	0.0069	1.82
	2024-25	₹53,375.31 ± ₹1,710.96	₹50,119.70 ± ₹1,210.79	6.24	0.0016	2.55
Gross income	2023-24	₹1,18,249.67 ± ₹1,518.39	₹97,824.71 ± ₹3,115.17	11.58	0.0001	4.72
	2024-25	₹1,26,060.26 ± ₹4,562.91	₹1,04,720.07 ± ₹5,148.55	6.30	0.0015	2.58
Net income	2023-24	₹70,125 ± 1,961	₹51,075 ± 2,573	11.93	0.0001	4.86
	2024-25	₹72,685 ± 5,075	₹54,600 ± 4,848	5.83	0.0019	2.38
B:C ratio	2023-24	2.46 ± 0.07	2.09 ± 0.05	-	-	-
	2024-25	2.36 ± 0.12	2.09 ± 0.10			

**t statistic is significant at the 0.05 level (2 –tailed)*

The paired t-test results demonstrated statistically significant differences between the demonstration (demo) and check plots across all key parameters in both 2023-24 and 2024-25 seasons. Grain yield showed a highly significant increase in demo plots compared to check plots in both years (t = 10.73, p = 0.0001 in 2023-24; t = 12.86, p < 0.0001 in 2024-25). Correspondingly, the large effect sizes (Cohen's d = 4.38 and 5.26, respectively) indicated a very strong practical impact of the demonstrated interventions on yield.

The cost of investment, although slightly higher in demo plots, was different in both seasons. However, the returns justified the investment, as shown by the substantial increases in gross and net incomes. Gross income in demo plots was greater than in check plots in both years, reinforcing the economic viability of the intervention. Similarly, net income differences were also demonstrating the financial advantage of adopting integrated wild boar management strategies, including bioacoustics. Overall, the statistical evidence affirms that the technological interventions had a robust and meaningful impact on productivity and profitability under real-world farming conditions.

Table 2 illustrates that the Benefit - Cost (B:C) ratio was also favourable in the demonstration plots. The pooled B:C ratio was 2.41 for demo plots and 2.04 for check plots. Notably, the net income for demo plots during 2023-24 was ₹70,125/ha compared to ₹51,075/ha in check plots, and in 2024-25 it was ₹72,685/ha versus ₹54,600/ha. These findings indicate a clear economic advantage for farmers adopting the improved package of practices. While the cost of investment was slightly higher in the demo plots due to the inclusion of bioacoustics equipment and eco-friendly sprays, the return on investment more than compensated for this, confirming the economic viability and scalability of the intervention.

Table no. 3: Technology gap, Extension gap and Technology index of Wild boar Management in Sorghum

Year	Technology gap (q/ha)	Extension gap (q/ha)	Technology index
2023-2024	2.50	4.75	8.30
2024-2025	1.35	4.85	4.50
Average	1.92	4.80	6.41

Technology gap

The technology gap, defined as the difference between potential yield (30 q/ha) and the demo plot yield, was 2.50 q/ha in 2023-24 and 1.35 q/ha in 2024-25. The average technology gap across both years was 1.92 q/ha. This relatively narrow and declining gap suggests that the demonstration technology was closely aligned with the optimal agronomic potential and well-accepted by the farmers. The improvement in 2024-25 reflects not only better farmer compliance and understanding but also the refinement of field-level implementation, possibly aided by previous season learnings.

Extension gap

The extension gap, i.e., the difference in yield between demonstration and check plots, was 4.75 q/ha and 4.85 q/ha for the two respective years. The average extension gap of 4.80 q/ha highlights the substantial yield advantage gained through the adoption of scientifically validated practices over conventional practices. This finding underscores the importance of continuous extension education and farmer engagement in promoting new technologies. Given that check plots relied on methods like tying sarees or night-time guarding practices with limited deterrence impact, the observed yield difference is a strong case for scaling up modern, eco-friendly deterrent systems.

Technology Index

The technology index, which reflects the feasibility of the recommended technology under farmers' field conditions, was 8.30% in 2023-24 and 4.50% in 2024-25, averaging 6.41% across the two seasons. A relatively lower technology index indicates greater effectiveness and adaptability of the demonstrated technologies in actual field settings. The declining trend also points to increased farmer confidence, likely facilitated by hands-on demonstrations, community engagement, and observed yield benefits.

Discussion

While the frontline demonstrations showcased the effectiveness of integrated wild boar management, especially through the use of bioacoustics and ecological deterrents, the long-term sustainability, scalability, and adaptability of these interventions demand critical scrutiny. The promising yield gains and favourable cost-benefit ratios, though encouraging, may not fully translate into broader farming systems unless the underlying structural barriers are addressed. Studies show that wildlife rapidly habituate to unvaried sound deterrents within weeks [8], and deterrent effectiveness is often context-dependent. The high capital investment required for bioacoustics equipment remains a formidable hurdle for many resource-poor farmers. Without institutional credit, subsidy mechanisms, or FPO-based models for shared access, the adoption of such technologies may remain confined to pilot projects and donor-funded programs. Moreover, scientific literature warns of behavioural habituation in wild animals to recurring auditory deterrents if not dynamically altered [15] [3] implying that static deployment of bioacoustics could eventually lose efficacy, necessitating periodic calibration and species-specific acoustic variation.

One significant constraint identified during the study was the high initial cost of the bioacoustics device, which may deter small and marginal farmers from adopting it individually. This challenge was effectively mitigated by introducing a community-shared model, where one device covered up to 6 acres, reducing per capita cost and promoting equitable access. Such collective approaches not only improved the affordability but also enhanced social cohesion in technology adoption, a key principle in participatory extension methodologies.

Furthermore, the success of such interventions hinges on collective responsibility and community-level coordination which, although ideal in theory, are often undermined by fragmented landholdings, sociocultural divisions, and lack of cohesive farmer institutions in many rural areas. Another limitation lies in the narrow ecological and temporal scope of most demonstrations [13]. While the FLD was successful in Sangareddy's semi-arid tracts during two Rabi seasons, ecological variability, wild boar population density, crop cycles, and topographical differences across regions may influence outcomes substantially requiring multi-seasonal, cross-regional trials before generalizing results. Most importantly, the issue of wild boar damage is not just an agronomic or technological challenge; it is a socio-political and policy vacuum, where wildlife regulations, agricultural compensation policies, and extension mechanisms operate in silos. The absence of convergence between agricultural, forestry, and rural development departments significantly weakens the institutional response to crop depredation. Meanwhile, while PMFBY now allows wildlife-damage cover, uptake at the state level remains inconsistent [11]. To enhance farmer resilience, wildlife-induced crop damage especially by species like wild boars, needs to be explicitly included under existing crop insurance schemes. This would provide financial protection and incentivize the adoption of sustainable deterrent practices.

In this context, while FLDs offer a valuable entry point into participatory technology dissemination, a multidimensional strategy is essential, combining scientific innovation, context-specific extension models, and policy support, including subsidies, landscape-level risk mapping, and real-time advisory services. Only then can such ecological interventions mature from localized success stories into scalable, sustainable, and socially inclusive solutions to the growing problem of wild boar-related crop losses.

Conclusion

The present study highlights the significant potential of integrated wildlife management approaches, particularly the application of bioacoustics deterrents, safflower border rows, and natural repellents in mitigating wild boar damage in sorghum cultivation. The two-year Frontline Demonstration (FLD) program conducted in the forest-adjacent villages of Sangareddy district revealed consistently higher grain yields, better economic returns, and significantly improved cost-benefit ratios in demonstration plots compared to traditional farmer practices. Statistical analyses reinforced the significance of these outcomes, with high effect sizes and low technology indices indicating both practical relevance and strong field-level performance.

Importantly, the interventions were not only effective but also farmer-friendly when introduced through participatory extension methodologies. Farmers' feedback and adoption trends underscore the need for continued awareness generation, capacity-building, and infrastructural support to scale the technology sustainably. While the cost of bioacoustics equipment remains a barrier, community-level deployment and targeted subsidies could play a transformative role in broadening adoption.

Overall, the study reaffirms that scientifically validated, ecologically grounded, and socially acceptable management strategies when disseminated through effective extension mechanisms can serve as sustainable solutions to persistent human wildlife conflicts in agriculture. The findings contribute to the growing body of evidence supporting adaptive, knowledge-based interventions for promoting climate-resilient and wildlife-compatible farming systems.

Future Scope

The present study establishes the potential of bioacoustics-based interventions as an eco-friendly and economically viable strategy for managing wild boar damage in sorghum cultivation. However, future research should focus on long-term and multi-location trials across diverse agro-ecological zones to validate scalability and adaptability under varying conditions. Dynamic calibration of bioacoustics devices, integration with digital tools such as sensor-based monitoring and mobile advisories, and exploration of community-shared ownership models can further enhance effectiveness and affordability. Additionally, convergence with crop insurance schemes, policy support through subsidies, and participatory extension approaches will be critical for sustainable adoption. Strengthening these dimensions can transform bioacoustics from localized demonstrations into a widely accepted strategy for wildlife management in agriculture.

Conflict of Interest

The authors declare that they have no known financial or non-financial conflicts of interest that could have influenced the outcomes or interpretation of this study.

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Author Contributions

The first author conceptualized, designed, and executed the study, and drafted the manuscript.

D. Shivaraj provided support in field implementation and data collection. Dr. Sai Priyanka led the data analysis and interpretation. Dr. C. Varaprasad and Dr. Shaik N Meera critically reviewed the manuscript and approved the final version for submission.

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