Journal of Environmental Biology
p-ISSN: 0254-8704 • e-ISSN: 2394-0379 • CODEN: JEBIDP

JEB®

Original Research Paper
Volume 47 Issue 3 May 2026 pp. 653-660
DOI: http://doi.org/10.22438/jeb/47/3/MRN-5819

J. Environ. Biol., 2026
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Journal website : www.jeb.co.in ★ E-mail : editor@jeb.co.in

Integrated approaches for the management of wild boar (*Sus scrofa*) infestation: Insights from a decadal study in Telangana, India

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Received: 26 June 2025 **Revised:** 07 October 2025 **Accepted:** 12 November 2025

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Abstract

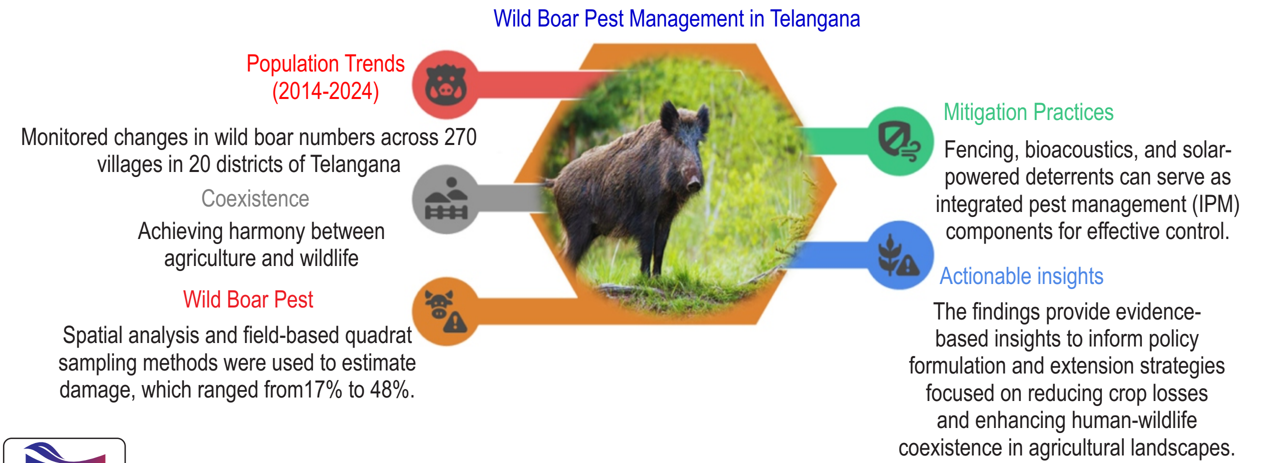
Aim: To investigate the distribution, population trends, seasonal activity, and crop damage caused by wild boars (*Sus scrofa*) across agricultural landscapes in Telangana, with the goal to identify effective mitigation practices and conveying the documented policy strategies to reduce crop losses and promote sustainable human-wildlife coexistence.

Methodology: The present study aimed at a long-term surveillance program conducted for a period of ten years from 2014-2024 across 270 villages in 20 districts of Telangana, emphasizing the distribution of wild boars, their population trends, seasonal activity, crop damage, and mitigation practices to reduce the crop loss.

Results: Spatial analysis, field-based random quadrant sampling revealed that damage due to wild boar infestation ranged from 17% to 48% depending on crop type and season. Likewise evaluation of various control technologies revealed physical fencing, bioacoustics, and solar-based deterrents, the best management practices for management of wild boar in different farming systems

Interpretation: The findings offer actionable insights for policy formulationand extension strategies aimed for mitigating crop loss and improving coexistence between agriculture and wildlife.

Key words: Damage assessment, Management, Wild boar, Wild life conflict



Triveni Enterprises (Educational Services Set-up)

How to cite: Sunitha, V., I. Aruna Sri, S. Somireddy, R. Panuganti, R. Mandla and V. Chaudhary: Integrated approaches for the management of wild boar (*Sus scrofa*) infestation: Insights from a decadal study in Telangana, India. *J. Environ. Biol.,* **47,** 653-660 (2026).

Introduction

The wild boar (*Sus scrofa*) is one of the ubiquitously distributed large vertebrate pests known for its exceptional adaptability, hardiness, and opportunistic feeding behavior. Though ecologically significant in regulating plant species, aerating soil (Galhano, 1995), and controlling insect populations, wild boars have increasingly become a serious pest in agro-ecosystems, including those of Telangana, India. Being omnivorous in nature, wild boars consume a wide variety of food sources, ranging from seeds, fruits, tubers, roots, bark, and fungi to carrion, eggs, reptiles, and insect larvae. However, rapid habitat loss, degradation of forest cover, and overexploitation of natural resources have displaced wild boars from their native habitats, compelling them to depend on cultivated crops for sustenance (Vasudeva Rao *et al.,* 2015.). The expansion of wild boar (*Sus scrofa*) populations into agricultural landscapes has been increasingly reported across Europe and Asia, largely driven by habitat fragmentation and the high adaptability of the species (Massei *et al.,* 2015; Barrios-Garcia and Ballari, 2012). Wild boars exhibit pronounced ecological plasticity, omnivorous feeding habits, and rapid population growth, which enable them to exploit crop-dominated landscapes effectively and persist under diverse environmental conditions (Melletti and Meijaard, 2017).

The expansion of agriculture into forest fringes and the cultivation of high-utility crops such as rice, maize, sorghum, pulses, oilseeds, vegetables, and fruit crops near the verge of forest areas has further intensified wild boar raids (Vasudevarao *et al.,* 2015a). Their acute sense of olfaction enables them to detect crops from considerable distances, and their peak activity during dawn and dusk per se during minimal human activity, makes their detection and control difficult. These animals typically move in small bands and are highly adaptive in utilizing both food and shelter in agricultural landscapes, especially those adjacent to forests. Wild boars predominantly display crepuscular and nocturnal activity patterns, allowing them to raid crops during periods of minimal human disturbance (Gaynor *et al.,* 2018). The ecological role of wild boars notwithstanding, their increasing interactions with human-dominated landscapes have led to widespread antagonism, especially among farmers who suffer significant economic losses due to crop depredation (Chauhan *et al.,* 2009). While listed as "Least Concern" by the IUCN, wild boars are protected under Schedule III of the Indian Wildlife Protection Act (IWPA).

Fragmentation and isolation of populations due to poaching and habitat destruction have resulted in localized abundance, further exacerbating human-wildlife conflict. Forest degradation and the expansion of cultivation near forest fringes have further intensified crop-raiding behavior of wild boars, resulting in frequent human–wildlife conflict (Chauhan *et al.,* 2009; Vasudeva Rao *et al.,* 2015). Understanding the distribution, behavior, and damage patterns of wild boars is vital for developing effective and sustainable management strategies. Hence the present study aimed to assess the incidence of wild boars and evaluate the effectiveness of various mitigation methods in managing crop damage across the agricultural landscapes of Telangana.

Materials and Methods

Surveys were conducted from 2014 to 2024 across 20 districts spanning the three agro-climatic zones of Telangana: North Telangana Zone (NTZ), Central Telangana Zone (CTZ), and South Telangana Zone (STZ). Data were collected from 270 villages of 102 mandals through direct observations and gathered secondary information in a comprehensive way through farmer interviews and also from agricultural officers. A structured questionnaire was developed by the AINP–Vertebrate Pest Management Unit, Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad, to systematically collect information on the incidence and impact of wild boar (Sus scrofa) across different districts of Telangana.

The questionnaire recorded the location, date of survey, and geo-coordinates (GPS-based) of each site, along with the name and contact details of the respondent farmer and Agriculture Officer. Farmers were asked to indicate their total area under cultivation (in hectares) and provide details of each crop grown, including its area, growth stage, and the status of wild boar presence or absence. When present, respondents estimated the approximate population density and the extent of crop damage, specifying damage frequency (rare, occasional, frequent, or very frequent) and percentage of loss (<10%, 10–20%, 20–30%, 30–40%, 40–50%, or >50%). Additional observations included the type of adjoining habitat (forest, scrub jungle, rocky outcrop, wetland, or wasteland) and the approximate distance of the field from such habitats. Direct and indirect evidences such as footprints and faecal pellets were recorded and enumerated. The questionnaire also documented the existing management practices adopted by farmers (fencing, noise deterrents, community guarding) and their perceived effectiveness. Farmers' attitudes and adaptive responses were captured through questions on whether they had changed cropping patterns, attempted to chase or trap animals, or resorted to lethal control measures. The presence of wild boars in different villages was classified as low: <10%; medium: 10-30%; high: 50% and very high: >50%based on the percent occurrence. Wild boar populations were assessed based on the foot print analysis by using line transect method and fecal matter as a sign of species presence.

Foot print analysis: A systematic footprint survey was conducted across selected agricultural and forest fringe areas to estimate the presence and relative population density of wild boars. The method involved tracking and identifying fresh footprints in soft soil, crop fields, and along forest margins during early morning and late evening hour times known for peak wild boar activity. Each footprint or track group was carefully documented using GPS tagging and photographed for verification. Based on standardized field protocols and literature references, it was estimated that each distinct footprint group corresponded to approximately 1–2 individual wild boars. This estimation was validated by repeated observations and local farmer interviews.

Scat Analysis: To supplement the footprint data, a scat analysis was carried out, where wild boar activity was reported to be high. Scat samples were collected across multiple survey transects covering different crop types, terrain, and forest interfaces. Each scat sample was considered indicative of 2–3 individual wild boars. The density of scat per square kilometer was then extrapolated to estimate relative population levels. Additionally, scat composition was analyzed qualitatively to determine dietary patterns, revealing the presence of crop residues, tubers, and occasionally insect parts, confirming their omnivorous and crop-raiding behaviour (Acevedo *et al.,* 2007).Direct sightings of wild boars are often difficult in dense vegetation and during nocturnal activity periods. Therefore, indirect signs (footprints and scat) were employed as reliable indices of relative abundance, a standard approach in wildlife population studies where direct counts are impractical.

Wild boar damage estimation: Wild boar damage was assessed by the Quadrat method. Thirty quadrats per hectare area were taken during vulnerable stages of the crop. In this method the quadrats of 10m x10m length was laid in the crop fields randomly by systematic random sampling method and the damage percentage was calculated by counting the damaged plants and healthy plants in the quadrats.. The Average percent damage was calculated by using the following Formula.

$$\text{Damage \%} = \frac{\text{Total number of damaged plants in all quadrats}}{\text{Total number of quadrats studied}} \text{ X } 100$$

Habitat and Spatial Mapping: GIS/GPS tools were employed to record site coordinates and proximity to forested areas. The landscape matrix and habitat features influencing boar activity were also analyzed. Both GPS and GIS tools were employed for field mapping and spatial analysis. A handheld GPS unit (Garmin eTrex 32x) was used to record site coordinates, elevation, and proximity to forest boundaries during field surveys. The recorded data were later imported into QGIS (version 3.30, open-source GIS software) for spatial visualization and analysis. The landscape matrix—including distance from forest edges, water sources, crop types, and fragmentation patterns—was analyzed using QGIS to identify habitat features influencing wild boar activity.

Seasonal Monitoring: Seasonal crop calendars and wild boar movement patterns were mapped to identify high-risk crop stages and vulnerable periods.

Statistical Design: The present investigation is based on a decadal (2014–2024) multi-location dataset involving surveillance and adaptive management trials across 270 villages in 20 districts of Telangana. As the study comprised observational and participatory field data rather than controlled experimental plots, the data set did not conform to the assumptions of a randomized block design. Hence, trend-based and comparative analyses were employed. Wild boar incidence and crop damage data were subjected to descriptive statistics (mean ± SE) and Kruskal–Wallis non-parametric tests for annual comparisons. Spatial data were analyzed using Moran's I and Getis-Ord Gi* statistics in QGIS 3.30 to assess distributional clustering. The efficacy of management interventions was expressed as percent damage reduction, and confidence intervals were derived through bootstrap resampling (n = 1,000). Temporal trends were validated using linear regression models (R^2 values). This analytical framework provides statistically robust inference suitable for long-term, non-replicated ecological datasets where classical ANOVA or CD/CV estimations are not applicable.

Results and Discussion

Wild boars (*Sus scrofa*) are widely distributed across Telangana, causing significant agricultural damage and leading to increased human-wildlife conflicts. Their presence spans the state's three agro-climatic zones: North Telangana Zone, Central Telangana Zone, and South Telangana Zone. From 2014 to 2024, a systematic surveillance was conducted across 20 districts in Telangana, covering 102 mandals and 270 villages. This extensive survey focused on higher vertebrate pests, specifically wild boars, whose crop-raiding activity was used as an indicator of their population status. The survey aimed to assess the impact of wild boars on agriculture and to inform pest management strategies. The survey revealed a steady increase in wild boar populations and crop-raiding activity, indicating their range expansion into agricultural landscapes. The findings highlight significant crop losses in maize, paddy, and groundnut fields, with damage severity varying by season and proximity to forest fringes. The study revealed the widespread presence of wild boars (*Sus scrofa*) as a significant vertebrate pest across surveyed locations. Out of the 270 villages surveyed, the distribution indicates a persistent and wide-ranging pressure of wild boars on agricultural crops, with an estimated crop loss ranging between 17 and 33% across all surveyed locations.

The survey's conducted acrossall the three zones, mandals, and villages with the use of geo spatial tools. Habitat preference and crop-raiding behavior were likely analyzed in relation to landscape features, crop availability, and proximity to forests using these methodologies (Fig. 1). Wild boars target specific stages of crop growth when food availability and palatability are high (Table 1). The intensity of wild boar crop raids fluctuated seasonally, correlating with the stages of crop growth (Table.2). The consistent monitoring over a 10-year period suggests that wild boars target fields, especially during fruiting or harvesting stages when crops are most vulnerable, driving medium to intensive occurrences in several villages during specific periods of the agricultural calendar.

The survey covered three agro-climatic zones of Telangana (Table 3 and Fig. 2). North Telangana Zone which

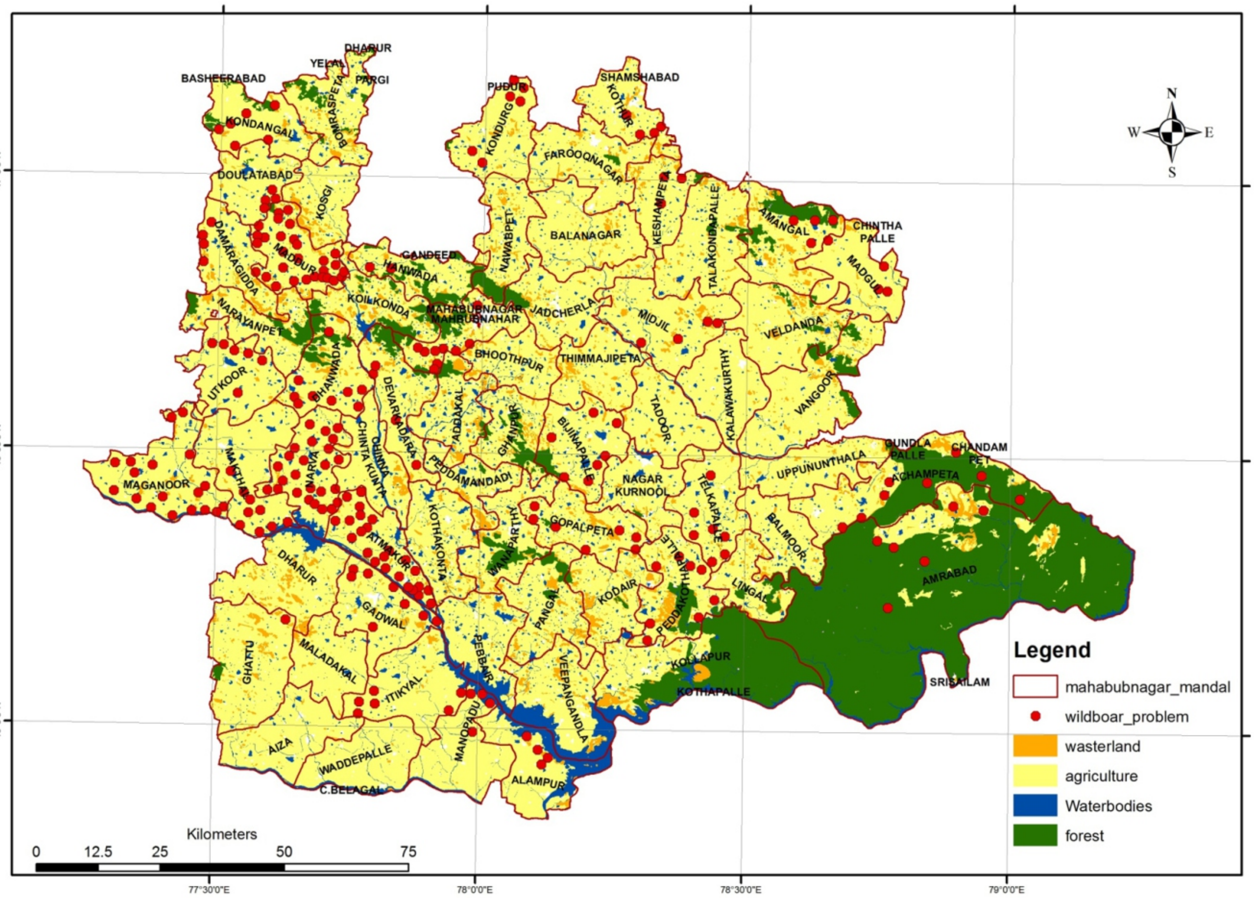


Fig.1: Habitat Mapping of wild boarby using GIS/GPS.

Table 1: Crop stage associations of wild boar

Crop	Vulnerable stage	Seasonal timing	Wild boar activity
Maize	Milky cob stage	July – September	High
Paddy	Tillering to ripening	August – November	Very High
Groundnut	Pod development	June – August	Medium–High
Sugarcane	Stalk maturity	September – February	High
Vegetables	Fruiting/harvest stages	Year-round	Variable

Includes districts like Adilabad, Karimnagar, Nizamabad, etc., with forested areas such as Eturnagaram Wildlife Sanctuary. Central Telangana Zone that Covers Warangal, Khammam, and Medak; major crops include rice, cotton, soybean, sorghum, and pulses. South Telangana Zone which includes Ranga Reddy, Mahabubnagar, and Nalgonda; key crops are rice, sorghum, bajra, maize, and oilseeds like castor and safflower.

Wild boars have been reported to cause significant damage to various crops in Telangana. Damage estimates includes, 22–35%, Paddy; 30–38% Maize; 28–30% Groundnut; 38% Sugarcane and ~21% Vegetables (Table 4). Wild boars primarily target crops during the early growth stages. They uproot seedlings, trample young plants, and forage for roots and tubers. As crops approach maturity, wild boars continue to cause damage. Wild boar damage caused 5–50% yield loss, translating into substantial economic losses across crops. Sugarcane (Rs. 43,200–1,20,000 ha^{-1}) and groundnut (Rs. 18,000–43,200 ha^{-1}) suffered the highest losses, followed by maize (Rs. 7,500–23,500 ha^{-1}) and rice (Rs. 5,400–18,900 ha^{-1}). Pulses, despite moderate damage, showed notable losses due to high market value (Table 5). In 2014–15, a pioneering intervention involved the installation of a 2-ft high circular blade wire fence around maize fields at PJTAU, Rajendra Nagar, Hyderabad, Telangana. This physical

Fig. 2: Distribution pattern of wild boar in three agro climatic zones of Telanagana.

barrier provided 100% protection from wild boars and resulted in a 55% increase in yield, marking a break through in vertebrate pest management. Building on this success, 2015–16 trials at Rajendranagar revealed that the circular blade wire fence enabled the highest. Other techniques like nylon netting, castor oil–soaked ropes, and egg solution sprays also offered effective protection, significantly outperforming the control yield of 3409 kg ha^{-1}. In 2016–17, the biological fencing techniques were evaluated. Surrounding groundnut fields with dense safflower and maize fields with castor plants successfully prevented wild boar intrusion, showcasing the efficacy of crop-based deterrents.In rainfed regions, the trenches (2×3 ft) combined with Galvanised iron (GI) wire fencing placed 1 ft above crop height proved to be highly effective in physically excluding the wild boars, offering full protection even in vulnerable locations. A major advancement came with the use of bioacoustics technology broadcasting predator and alarm calls. Across 32 sites in Telangana, this method completely eliminated crop damage, which had previously ranged between and 58%. The effectiveness of bioacoustic deterrents observed in the present study aligns with earlier findings that sound-based repellents can significantly reduce wild boar intrusion when habituation is minimized (Honda *et al.,* 2009).

Farmer feedback on this innovative technology was overwhelmingly positive: 15% rated it excellent, 38% very good, 23% good, while 15% found it average and only 8% poor. Positive farmer feedback and favorable cost–benefit ratios emphasize the importance of participatory, field-validated management strategies for long-term sustainability (Massei *et al.,* 2015). To further strengthen defences, bioacoustics were integrated with HDPE nylon nets, effectively reducing rice crop damage to 1% and eliminating damage in maize fields.In 2022–23, Agri-solar

Table 2: Seasonal occurrence of wild boar

Season	Wild boar movement	Crop association
Summer (Mar–June)	High (water scarcity drives movement)	Early sowing of maize/groundnut
Monsoon (July–Sept)	Peak activity	Maize cob stage, paddy tillering
Post-Monsoon (Oct–Nov)	High	Paddy ripening, sugarcane maturing
Winter (Dec–Feb)	Moderate	Sugarcane harvest, vegetables

Table 3: Distribution pattern of wild boar in three agro climatic zones of Telanagana

Zone	Districts	Mandals	Villages	Low (<3)	Medium (3–5)	High (5–7)	Very High (>7–10)
South Telangana Zone	6	24	51	9	22	12	8
Central Telangana Zone	3	9	27	4	8	9	6
North Telangana Zone	2	4	14	3	3	4	4

Table 4: Crop growth stage verses damage by wild boar

Crop stage	Affected crops	Nature of damage	Estimated damage (%)
Seedling/Vegetative	Maize, Groundnut, Cotton, Pulses	Uprooting of seedlings, trampling young plants, feeding on seeds and roots	Maize/Groundnut: 28–38%
Reproductive/ Ripening	Paddy, Sugarcane, Vegetables	Trampling mature plants, foraging and eating mature crops	Paddy: 22–35%Sugarcane: ~38%Vegetables: ~21%
Harvest/Post-harvest	Maize, Onion, Green chilli	Consuming ripe produce, rooting and disturbing crops even if not consumed directly	Maize (pre-harvest): up to 61%

Table 5: Economicevaluation of losses by wild boar

Crop	% Damage	Avg. Yield loss (kg ha^{-1})	Market Price (₹ kg^{-1})	Estimated Loss Range (₹ ha^{-1})
Rice	10–35%	3000	₹18	₹5,400 – ₹18,900
Maize	15–47%	2500	₹20	₹7,500 – ₹23,500
Sorghum	10–20%	1800	₹22	₹3,960 – ₹7,920
Red gram	10–15%	1000	₹70	₹7,000 – ₹10,500
Chickpea	10–35%	1200	₹60	₹7,200 – ₹25,200
Groundnut	20–48%	1800	₹50	₹18,000 – ₹43,200
Sugarcane	18–50%	80,000 (kg/ha)	₹3	₹43,200 – ₹1,20,000
Cotton	5–10%	1500	₹60	₹4,500 – ₹9,000
Vegetables	5–12%	20000	₹10	

fencing technology was deployed at 10 field locations. This solar-powered solution resulted in zero wild boar damage, compared to 20–45% losses in untreated control plots. The intervention also proved economically viable, with cost-benefit ratios ranging from 1:0.98 to 1:6.97, the highest being observed in groundnut cultivation. The latest innovation in 2023–24 was the demonstration of E-Cannons in maize and sorghum fields. These devices produced loud, randomized blasts post-treatment and successfully repelled wild boars, with no reported crop damage thereafter. The decadal investigation conducted across Telangana revealed that wild boar (*Sus scrofa*) populations have progressively expanded from forest fringes into cultivated landscapes, causing substantial crop losses particularly in maize, paddy, groundnut, and sugarcane systems. The recorded damage levels ranging 17–48% closely correspond with earlier reports that wild boar depredation can lead to 15–60% yield loss depending on crop type, growth stage, and proximity to natural habitats (Schley and Roper, 2008; Vasudeva Rao *et al.*, 2015).

Crop damage levels recorded in the present study are consistent with earlier reports indicating 15–60% yield loss due to wild boar depredation, depending on crop type and growth stage (Schley and Roper, 2008; Chauhan *et al.*, 2009). The higher intensity of damage near forest–agriculture interfaces observed in this study substantiates the ecological principle that edge habitats with adequate cover, shade, and water sources promote boar incursions (Chauhan *et al.,* 2009; Galhano-Alves, 1995). Higher damage incidence near forest–agriculture interfaces supports the concept that edge habitats facilitate frequent wild boar incursions into cultivated fields (Galhano-Alves, 1995; Can *et al.,* 2014). Seasonal analysis indicated that boar activity and crop damage were most pronounced during the monsoon and post-monsoon periods, coinciding with the reproductive and ripening stages of major crops. Seasonal peaks in wild boar activity during monsoon and post-monsoon periods coincide with critical crop growth stages, reflecting increased food availability and crop palatability (Acevedo *et al.,* 2007). This trend aligns with findings that food abundance and crop palatability during these periods strongly influence wild boar movement and foraging dynamics (Acevedo *et al.,* 2007).

Among the evaluated management techniques, integrated deterrent strategies comprising fencing, bioacoustic systems, crop-based barriers, and solar-powered deterrents proved to be the most effective and sustainable. Integrated management strategies combining physical barriers and sensory deterrents have consistently proven more effective than single-method approaches in reducing wild boar damage (Geisser and Reyer, 2004; Campbell and Long, 2009). These results are consistent with behavioral ecology concepts that multi-sensory deterrents combining visual, auditory, and tactile stimuli enhance aversive conditioning and reduce habituation (Campbell and Long, 2009). The successful performance of circular blade wire fencing, biological barriers, and bioacoustic broadcasting systems also confirms the value of integrating ecological knowledge of animal behavior into vertebrate pest management frameworks (Vasudeva Rao *et al.,* 2015). Furthermore, positive farmer feedback and favorable cost–benefit ratios indicate high potential for field-scale adoption and long-term sustainability. Overall, the study reaffirms that region-specific, integrated management approaches supported by ecological understanding and farmer participation are essential for mitigating human–wildlife conflict and ensuring coexistence between agriculture and wildlife.

The increasing presence of wild boars in Telangana's agriculture underscores the need for region-specific vertebrate pest management strategies. This 10-year study demonstrated that integrated management approaches—involving fencing, crop diversification, bioacoustics, and solar deterrents—can dramatically reduce crop damage. Moving forward, scaling up these proven interventions with farmer participation and state support will be essential for protecting livelihoods and reducing human-wildlife conflict.

Acknowledgments

The authors express sincere thanks to the farmers, agricultural officers, and extension workers who participated in the survey and trials. Gratitude is extended to PJTAU for their support and infrastructure for long-term ecological monitoring.

Authors' contribution: S. Vanam: Played a key role in conceptualizing the design by leading the conceptual framework, conducting field research, and analyzing data; **I. Aruna Sri:** Contributed to field coordination, farmer interactions, and impact documentation. Supported the refinement of eco-friendly management strategies; **S.R. Somireddy:** Executed trials on bioacoustics and barriers, monitored crop protection efficacy, and collected field observations; **R. Panuganti:** Provided overall guidance and scientific leadership to the project. Supervised implementation, ensured alignment with scheme objectives, critically reviewed findings, and contributed strategic insights for sustainable vertebrate pest management policy and outreach; **R. Mandla:** Assisted in field data collection, device maintenance (bioacoustics systems), crop damage assessments, and farmer demonstrations. Played a key role in logistical support, field documentation, and coordinating on-ground implementation activities; **V. Chaudhary:** Provided overall guidance and scientific leadership to the project.

Funding: 335109-Recurring Contingencies of All India Network Project on Vertebrate Pest Management, ICAR-CAZRI, Jodhpur.

Research content: The research content of manuscript is original and has not been published elsewhere.

Ethical approval: In this study, we strictly followed ethical guidelines and standard protocols prescribed for wildlife research and observational field studies under the Wildlife (Protection) Act, 1972 (Government of India), and the ICAR guidelines for research involving animals to ensure respect and protection for the animals and the environment. Animal activity and crop damage were recorded through footprints, and feces. No animals were handled or harmed during the entire research process.

Conflict of interest: The authors declare that is there is no conflict of interest.

Data availability: Yes

Consent to publish: All authors agree to publish the paper in *Journal of Environmental Biology.*

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