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REVIEW ARTICLE

# Impacts of human-wild boar interactions on agricultural and natural vegetation: Challenges, management strategies and future perspectives

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## Abstract

Human-wild boar (*Sus scrofa*) interactions have intensified globally due to habitat loss, increasing boar populations and human encroachment into wildlife areas. Wild boars, highly adaptable and prolific, pose significant challenges to agriculture, public safety and ecosystem balance. They cause extensive crop damage, transmit zoonotic diseases and disrupt ecological processes. Their high reproductive rate and lack of natural predators have further exacerbated interactions. Various management strategies, including culling, fencing, repellents and contraceptive methods, have been employed to mitigate human-wild boar interactions, yet challenges remain in balancing ecological conservation and economic interests. Sustainable coexistence requires a multi-faceted approach integrating modern technologies such as GPS tracking, drones and AI-driven analytics with traditional control measures. Public awareness, policy support and community engagement are crucial in developing effective mitigation strategies. This review examines the causes, impacts and management strategies of human-wild boar interactions while highlighting the need for innovative and integrated approaches to reduce conflict and ensure sustainable coexistence between humans and wildlife.

**Keywords:** conservation; crop damage; ecological impact; human-wild boar conflict; management strategies; sustainable coexistence; wildlife conflict mitigation

## Introduction

The wild boars (*Sus scrofa* L.) have adeptly increased their range globally (1, 2) and their presence in all continents except Antarctica (3-5; Fig. 1). Most adoptable terrestrial mammals thrive in diverse environments (6), from dense forests and agricultural lands to urban areas (7). Human-wild boar interactions have become increasingly significant as expanding human activities encroach on natural habitats. Recently, its population has reached significant local densities (5) due to several factors, such as substantial reproductive ability (8) and environmental flexibility (1). Wild boars may benefit and harm various ecosystems (9, 10). In addition, wild boars can transmit diseases to human beings (11-13), livestock and wildlife health (2, 14, 15).

Wild boars are known for their adaptability (8, 16), intelligence, omnivorous diet (17) and generalist nature and their ability to spread their population quickly in human-dominated landscapes (18, 19). The conflict between humans and wild boars has grown globally due to shared resources and space (20). As per IUCN (International Union for Conservation of Nature), wild boar is listed as the least concern, whereas in IWPA (Indian Wildlife Protection Act), it is under Schedule III (21). However, their increasing influence has created significant challenges, such as crop damage, public safety concerns and ecosystem disruption. Wild boars have become a common threat to farmers in major crops, resulting in significant losses to agricultural income (22). Meanwhile, urban residents face risks from property destruction and sometimes hostile encounters.

Addressing these challenges requires a holistic approach that balances the ecological, economic and social components of problems. This review provides an in-depth analysis of the multifaceted challenges posed by human-wild boar interactions, examines mitigation strategies and considers future perspectives to ensure sustainable coexistence.

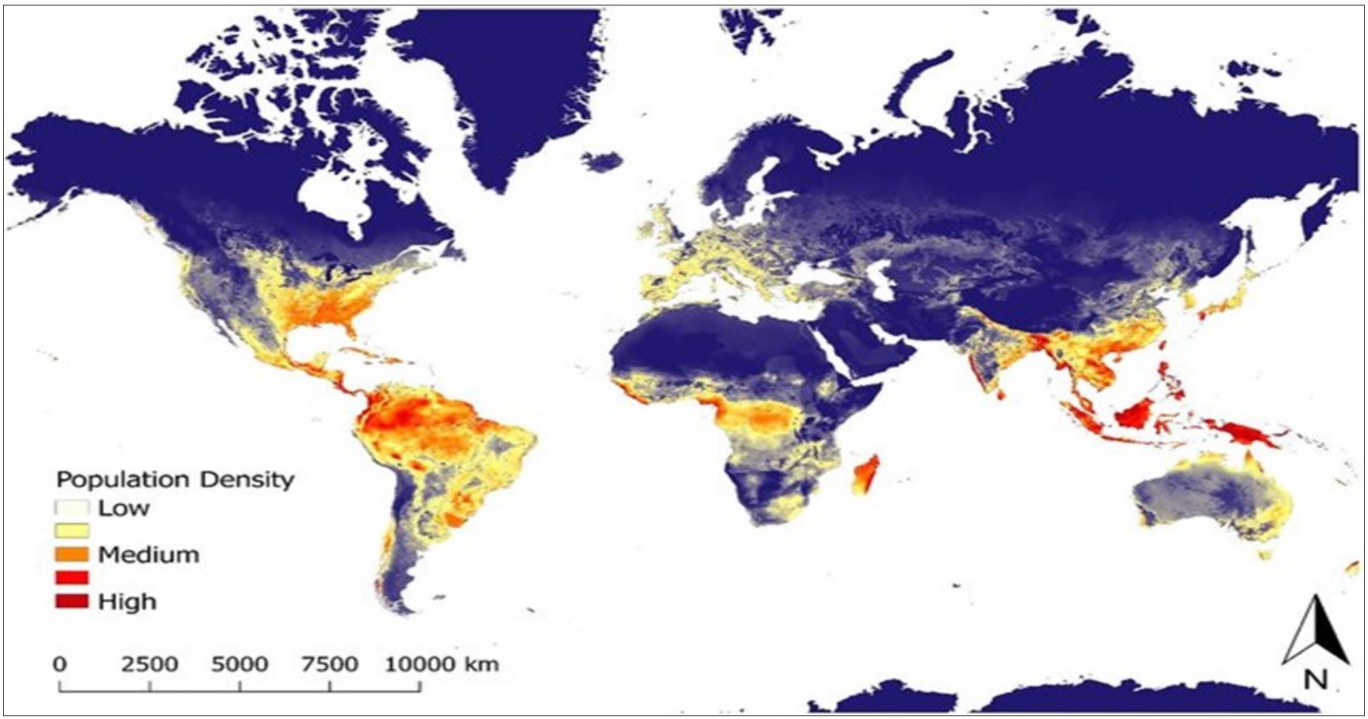


**Fig. 1.** Map of predicted population density of wild boars. Source: Jesse Lewis et al. (4).

## Causes of human-wild boar interactions

The relationship between humans and wildlife has always been complex. Wild boar is a highly adaptable animal (7, 23) with high reproductive ability (24), becoming a symbol of human-wild boar conflict in many parts of the world. The root causes of these interactions are multifaceted, driven by habitat destruction (25) and the absence of natural predators (19, 26) (Fig. 2).

### Habitat degradation

Wild pigs are termed "ecosystem engineers" (25, 27). Wild boar can be found in grasslands (28) and ecotones. While wild boars are known for their adaptability, habitat degradation affects their natural behaviors, ecological roles and interactions with humans. Wild boars have invaded forest-fringed villages and farms because their native habitats are shrinking (29) (Fig. 3).

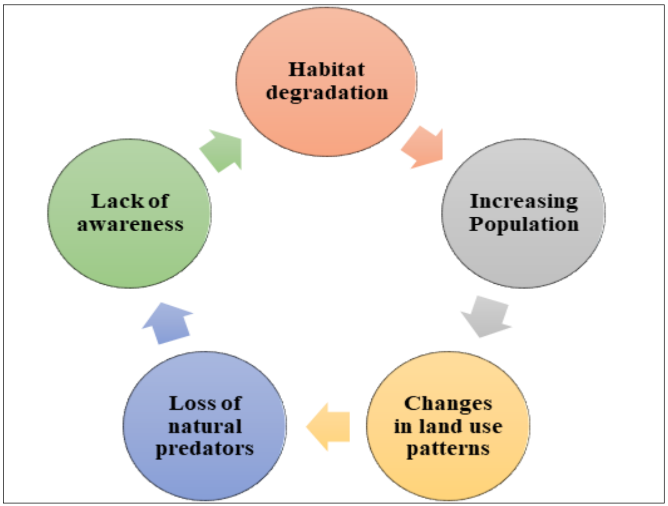


**Fig. 2.** Causes of human-wild boar interactions.

### Loss of natural predators

Wild boars are prey for many wild animals (30). The dramatic decrease in natural predator-prey interaction is a critical issue affecting ecosystems globally (31). Predators manage prey numbers, which help to maintain ecological equilibrium (30). Non-human predation of wild boar is restricted due to low predator abundance (19).

### Increasing population

The development and spread of wild boar populations, driven by their opportunistic and omnivorous nature, have increased interactions with humans due to higher activity in farmlands (17). Forest expansion has also significantly contributed to their population growth and range expansion (26).

## Impacts of human-wild boar conflict

Due to their flexibility and lack of natural predators, their interactions with humans have thrived. As a result, their interaction with humans has increased, particularly in agricultural and forested areas. These interactions often lead to substantial economic losses, ecological imbalances and social challenges. Wild boars are known to cause extensive damage to crop, leading to farmers in difficult financial situations and food insecurity in affected communities. In addition to agriculture (32), their activities disrupt ecosystems through soil disturbance and competition with native species. Furthermore, wild boars are carriers of zoonotic diseases, posing health risks to both humans and livestock.


**Fig. 3.** Causes of wild boar habitat degradation.

**Economic loss**

The financial impacts of introduced boars can be considerable in agricultural ecosystems, estimated at $1.5 billion per year in the United States alone (33). Reported crop losses caused by feral swine across 12 U.S. states amount to $ 272 million (34). In Europe, compensation for wild boar-related crop damage exceeds millions each year, with France's compensation rising from 2.5 million Euros in 1973 to 32.5 million Euros by 2008.

**Agricultural damage**

Wild boars often raid agricultural fields, causing substantial losses (35, 36). Wild boars are known to favor agricultural fields as a habitat (37). Their rooting behavior destroys crops, damages irrigation systems (38) and affects soil quality (39). Wild boars exhibit a high degree of ecological plasticity. Being omnivores, wild boars consume carrion, roots, crops and tubers. In general, wild boars travel in groups and are most active during early morning and evening (40). They have the unique ability to use their sense of smell to find cropped regions (41). Over the past few decades, the species has organically expanded into new places. Due to their affinity for crops and the potential harm that their feeding habits might do to crops, wild boars are regarded as agricultural pests in many countries (42).

Although crop damage caused by wild boars is recorded less frequently in the introduced region than in the native range, it nevertheless occurs. Wild boars damage various crops worldwide, including maize (*Zea mays*) in Iberia (43) and rice (*Oryza sativa*) paddies in Japan (44). Wild boars eat a lot of crops, including oilseeds, wheat, sorghum (17), barley (43, 45), pasture (46), sugar cane, grapes, potatoes (47), oats and maize (43), as well as tree seedlings causing serious damage (48).

**Transmission of infectious diseases**

Wild boars are carriers of several bacterial and viral diseases (18, 49). They can cause several threats of infection to livestock (49), wildlife (50) and humans. Certain infections introduced by wild pigs to people, such as brucellosis (51), tuberculosis (50) and tick-borne diseases (49), may occur due to the preparation of harvested pigs. Wild boars also endanger the health of domestic pigs by spreading diseases like swine fever, resulting in significant economic losses (52). Wild boars can carry zoonotic infections, posing major risks to human health (12, 13). These health and environmental threats underscore the importance of understanding their ecology to properly evaluate risks effectively and implement appropriate management solutions.

**Environmental impacts**

Wild boars play an important role in their native ecosystems by dispersing seeds and scavenging. Their presence in overpopulated areas often negatively impacts vegetation, biodiversity, water resources and soil erosion (53-57). Their behaviors, particularly rooting, foraging and wallowing, can disrupt ecosystems and harm vegetation (10). These impacts not only endanger biodiversity but can also affect agricultural productivity and exacerbate human-wildlife interactions.

Wild boars have a huge global impact on soil qualities, plants and animals (2). Their behavior has the potential to harm reptile nests (58) and ground-nesting birds (46, 59, 60), disrupt plant height growth (61) and increase seed predation (62). In wetlands, they facilitate plant invasions (63) and disrupt pollinator-plant interactions, such as butterfly behavior and feeding (64). Wild boars significantly alter the properties of soil, lowering pH, bulk density and moisture content while increasing porosity, inorganic nitrogen concentration and mineralization (65). Their rooting behavior is more pronounced on softer soils with reduced rock cover and slope steepness (66) and raises soil respiration and microbial biomass while reducing soil moisture (67). Although they have a limited impact on soil bacterial communities and microbial biomass carbon (68), their rooting decreases species diversity (61) and negatively impacts local animal communities through predation, habitat loss and competition (3).

These impacts include seedling survival, plant biomass and soil arthropod diversity (61, 69), as well as water quality (70). While decreasing soil moisture, rooting behavior can boost soil respiration and microbial activity (67, 69). Overall, they have a detrimental impact on biodiversity, reducing species richness and abundance (18, 61). They occasionally contribute positively by dispersing native and exotic seeds and invertebrates (9, 71, 72) and enhancing soil biodiversity (73). Their rooting behavior significantly impacts belowground biomass (60) and rainfall, which softens the soil (74).

## Management strategies

Effective management of human-wild boar interactions requires an intricate approach that incorporates conventional methods with modern technologies. However, these methods have had limited success in regions where wild boar populations are large and rapidly expanding (Table 1). A comprehensive review of methods for managing wild boars can be found (75, 76). This makes it critical to establish tools and strategies for population reduction (77, 78).

Female wild pigs exhibit polyandrous behavior, mating with multiple males. The average number of piglets per litter varies. These animals have a remarkable reproductive capacity, producing two litters annually or up to three within 14-16 months. Contraceptive treatment emerges as a non-lethal and environmentally friendly method for managing wild boar populations. These treatments aim to regulate reproduction, reducing overpopulation's ecological, agricultural and social impacts.

## Challenges of management

The challenges of managing this conflict are multifaceted. On the one hand, controlling wild boar populations through methods such as culling, fencing, or relocation can be resource -intensive and may face resistance from wildlife conservation advocates. Understanding these challenges is crucial for developing effective, sustainable and socially acceptable solutions to mitigate human-wild boar conflict (Table 2).

## Future directions

To manage wild boar populations effectively, a multi-faceted approach is essential. Sustainable practices include environmental modifications, exclusion methods, controlled hunting and advanced technologies like GPS tracking, drones and AI-driven predictive analytics. Economic and social solutions include compensation schemes for affected communities and alternative livelihoods. Understanding wild

**Table 1.** Different methods of wild boar management

| | Method of management | Reference |
|---|---|---|
| Phytochemical | Castor oil (Ecodon), Ginger extract, Garlic extract | (79) |
| | *Calotropis gigantean* L., *Vitex negundo* L., *Dendrocnide sinuate* (Bl.) Chew, *Ricinus communis* L., *Ruta graveolens* L., *Datura metal* L., *Nerium oleander* L., *Capsicum chinense* Mill. | (80) |
| Plant barriers | *Zanthoxylum bungeanum* Maxim. *Pyracantha fortuneana* Maxim., *Albizia julibrissin* (Durazz.), *Citrus reticulate* Blanco., *Citrus limon* L., *Morus alba* L., *Ricinus communis* L. | (81) |
| Physical | Local dogs, Electric fences, Fires, sounds, torches, Use of colored sarees | (80, 82, 83) |
| | Crackers, Manual guarding, Boundary clearing, Metal cow bells, Shining tapes, Scarecrows | (84) |
| | Trapping (cage traps), Euthanasia | (85) |
| | Bait, Trigger Designs, Shooting and Hunting | (77, 86) |
| | Aerial gunning | (76, 77) |
| Deterrents | Radios, Passive Infra-Red (PIR)-activated horns, Gas cannons, solar-powered LED blinkers | (87) |
| | Human scalp hair with non-ionic detergent, acetone and fermented corn bait | (88) |
| Chemical | Pig out, Hoggone | (89) |
| | Boar Buffer | (90) |
| | Immunocontraceptive vaccine | (91) |

**Table 2.** Challenges and solutions in wild boar management techniques

| Management method | Challenges | Solutions |
|---|---|---|
| **Trapping** | Broader spatial scales due to high implementation costs (77, 86) | Use corral traps with a camera and remote activation system (92) |
| **Hunting** | Often insufficient for effectively managing populations (76, 93) and in some areas, illegal to hunt | Employ the Judas technique for increased success in targeted areas (76, 77) |
| **Aerial Gunning** | Limited research on its effectiveness in controlling populations (94) | Conduct further research to determine its long-term impact and effectiveness |
| **Chemical toxicants** | In some countries, chemical toxicants are not yet approved (95) | Recent research focusing on the toxicant type (89), species-specific attractants (96) |
| **Contraceptive treatments** | Targeting males may be less effective than targeting females (97) | Combine with other management techniques for the greatest efficacy |
| **Electrical fences** | Time-consuming, costly maintenance and a lack of government support | Deterrents can be an alternative solution |

boar ecology and behavior is crucial for designing effective solutions. Community involvement through education and collaboration fosters awareness and stakeholder engagement. This integrated approach ensures sustainable management of wild boar populations, minimizes human-wild boar interactions and promotes coexistence while preserving ecosystems.

## Conclusion

An all-encompassing, progressive strategy is needed for managing human-wild boar interactions. Incorporating technology like drones, GPS tracking and artificial intelligence predictive analytics. Community engagement and public awareness campaigns are crucial. Policy frameworks should emphasize coexistence and support sustainable farming practices. These strategies strike a balance between conservation and human needs, fostering biodiversity preservation while minimizing conflict and promoting harmonious coexistence.

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## Authors' contributions

KB helped choose the review topic and its outline. TC contributed ideas related to the topic and drafted the manuscript. PP and PR corrected my review article. RR participated in the sequence alignment. PH, MV, RM and W helped with the overall correction of the manuscript. All authors read and approved the final manuscript.

## Compliance with ethical standards

**Conflict of interest:** Authors do not have any conflict of interest to declare.

**Ethical issues:** None

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