Journal of Agriculture and Natural Resources (2023) 6(1): 85-95
ISSN: 2661-6270 (Print), ISSN: 2661-6289 (Online)
DOI: https://doi.org/10.3126/janr.v6i1.71925

Review Article

Impact of wild pigs in agriculture and their management

Sajana Rai

Livestock Service Office, Bharatpur, Chitwan, Nepal

Correspondence: raisajana2079@gmail.com

Received: June 10, 2023; Revised: October 30, 2023;
Accepted: November 15, 2023; Published: November 25, 2023

ABSTRACT

Wild pigs cause substantial damage to the agriculture crops and leads to the economic loss of rural farmers. They harm the environment by shifting plant composition and decreasing its productivity. Wild pigs destroy habitat, predation and competes for resources with rare, threatened and endangered species in ecosystem. Their damage in fields can be accessed by regular monitoring which can be achieve by the use of drones. The management approaches to control wild pig encroachment in farm lands are baiting, hunting, fencing and catching with the use of dogs. Among them shooting or hunting is more common in practice. In addition, they transmit the various diseases like classical swine fever and *Brucella* spp. to livestock. This review summarizes the importance of wild pigs as genetic resources, factors affecting human-wild pig conflict, crop raiding and economic loss and various management approaches. This study suggests the controlling of wild pigs in farm lands which leads to the increase in agricultural production.

Keywords: Damage, economic loss, productivity, wild pig

Correct citation: Rai, S. (2023). Impact of wild pigs in agriculture and their management. *Journal of Agriculture and Natural Resources,* 6(1), 85-95.
DOI: https://doi.org/10.3126/janr.v6i1.71925

INTRODUCTION

Wild pig (also called feral swine, Eurasian boar, or feral hogs) severely threatens agriculture production and rural livelihoods worldwide as a harmful and destructive invasive species. Due to their feeding, rooting, trampling, and wallowing habits, wild pigs destroy fields, damage crops and reduces agricultural production. They basically prefers rice, peanuts, oats, wheat, corn, sugar cane, and sorghum and also likes fruit and vegetable crops (pumpkins, melons, spinach, and lettuce). Forest regeneration may also be impacted by wild pigs as they prevents new trees from sprouting and can delay the growth of existing trees by eating seeds, nuts, and seedlings and causing land damage.

Wild pigs may survive in a diversified environments, including semi-deserts, wetlands, forests, and even high-altitude mountains (d'Huart, 1991). Their ability to reproduce quickly, generalist nature, omnivorous diet, and resilience allowed them to spread and establish their population all over the world (Baubet *et al.,* 2004; Chauhan *et al.,* 2009; Ballari & Barrios-

ISSN: 2661-6270 (Print), ISSN: 2661-6289 (Online)
DOI: https://doi.org/10.3126/janr.v6i1.71925

Garcia, 2012; Punjabi & Rao, 2017). Due to widespread population in certain areas their feeding habits can disrupt plant regeneration and cause ecological imbalances. The local population is severely distressed by wild pigs as they destroy their crops (Calenge *et al.,* 2004; Herrero *et al.,* 2006; Linkie *et al.,* 2007; Schley *et al.,* 2008; Saito *et al.,* 2011; Pandey *et al.,*2019; Pandav *et al.,* 2021), which negatively affects livelihood and economy of villagers (Chauhan *et al.,* 2009). Wild pigs harm the environment by reducing plant population,biodiversity productivity, increasing the risk of soil erosion, and changing the properties of soil, all of which have an adverse influence on water resources (Liu *et al.*, 2019). The rooting behavior of wild boars disturbs soil, removing vegetation cover, which increases the likelihood of erosion. This can degrade soil quality over time, reduce future crop yields, and harm surrounding ecosystems. Wild pigs transmit various disease to livestock. They serve as carriers of a number of diseases and infections (Ruiz-Fons *et al.*, 2008; Nair & Jayson, 2016), and can spread to domestic pigs (Boklund *et al.*, 2008), cattle (Boadella *et al.*, 2012), and other wild animals (Vicente *et al.*, 2007). Wild pigs may contribute to the transmission of animal diseases such as Nipah virus, Foot-and-Mouth Disease, Rinderpest, Rift Valley fever, African swine fever, and classical swine fever (Dudley & Woodford, 2002). Wild pig destroys the crops and crop fields resulting great economic loss. The damage of wild pigs can be monitored through ground survey and use of drones. The management approaches to control the encroachment of wild pigs are fencing, baiting, hunting and use of dogs. Among the management practices, hunting or shooting is popular to control the invasion of wild pigs. Wild pigs are utilized as genetic resources in animal breeding program. The useful traits such as disease resistance, wider adaptability, and quality meat can be transferred to domestic pigs from wild pigs. The objective of this review is to explore the information regarding the crop raiding by wild pigs, economic loss along with their management strategies.

Wild pig as genetic resources

Introducing wild pig genetics into domestic pig breeding worldwide, are of increasing interest to enhance genetic diversity which contribute to food security, income generation and adaptation to different environments. The extant genetic richness of wild pig in East Asia has contributed to the genetic diversity of local domestic pig population (Choi *et al.*, 2014). Because of their natural resistance to specific diseases and their ability to adapt to a variety of environments, wild pigs can increase resilience against endemic diseases and frequent infections while also promoting overall hardiness. Compared with conventional domestic pig meat, wild pig meat is frequently said to have a distinct flavor profile.The quality of pork could be improved by introducing wild pig genetics, making it more appealing to consumers seeking speciality products. Domestic and wild pigs have different fat compositions, which can affect the meat's flavor and healthfulness. Breeding initiatives can try to balance both species' beneficial qualities. Wild boar infections can cause livestock to be less productive, less feed efficient (less food intake affects animal growth and overall health), less successful in reproduction and more herd mortality, and more expensive veterinary care, which can result in financial loss.

Factors affecting human-wild pig conflict

Human-wild pig conflict is a common issue worldwide, especially in regions where human populations encroach on natural habitats. It is prominent issues in Nepal also particularly in areas adjacent to protected areas where wild boar cause substantial damage to the agricultural

Journal of Agriculture and Natural Resources (2023) 6(1): 85-95
ISSN: 2661-6270 (Print), ISSN: 2661-6289 (Online)
DOI: https://doi.org/10.3126/janr.v6i1.71925

crops and affect the lives of rural farmers leading economic loss (Gharti Magar *et al.*, 2024). Several factors influence the frequency and intensity of conflicts between humans and wild pigs which includes expansion of agricultural and urban areas into wild pig habitats which increases the likelihood of encounters. Besides, deforestation, urbanization, and land conversion reduce the natural habitats of wild pigs, pushing them towards human settlements for food and shelter. The crops like corn, rice, and other high-calorie plants attract wild pigs due to their nutritional value. The major crops damaged by wild boar were paddy in the lowlands and potatoes in the highlands due to these crops rich in carbohydrates which could result in greater use (Kanter and Elkin, 2019; Ramanathan and Krishnamoorthy, 1973). Seasonal harvesting and monoculture plantations make farms more accessible and attractive food sources. In years when natural food sources (e.g., acorns, fruits) are scarce, wild pigs may move closer to human habitats in search of alternative food. Waste disposal sites and improperly stored food also attract wild pigs, increasing the chances of conflict. Intentional feeding of wild pigs or unintentional food waste provides wild pigs with easy meals, encouraging them to stay close to human areas.

Unpredictable weather patterns, like droughts or floods, can reduce food availability in natural habitats, driving wild pigs to human areas. Warmer climates and extended growing seasons contribute to higher reproduction rates in wild pig populations, increasing their numbers. Wild pigs have a high reproductive rate, and population growth can lead to higher competition for resources. Larger populations tend to roam farther in search of food, increasing encounters with humans. In many areas, large predators like tiger, lions, wolves or bears are absent, allowing wild pig populations to grow unchecked. The lack of natural predation forces humans to manage wild pig populations through hunting, which can sometimes exacerbate conflicts. In some cultures, wild pigs are considered valuable for hunting and meat, leading to conflicts over hunting rights or management practices. Lack of effective management policies, or a ban on hunting, can result in uncontrolled population growth.

Wild pigs can carry diseases like African swine fever, brucellosis, and leptospirosis, which pose risks to livestock, wildlife, and even humans. Concerns about disease transmission lead to stricter measures to control wild pig populations, which can trigger conflicts, especially where hunting is restricted. Economic losses due to crop damage, fencing costs, and veterinary costs for disease control add pressure on local economies, prompting conflict. Regional policies, such as hunting regulations or restrictions on land use, influence human-wild pig interactions. Some areas have ineffective management programs, which can increase frustrations among local communities affected by wild pig damage. Addressing human-wild pig conflict requires a multi-faceted approach, including habitat management, population control, public awareness, and policy adjustments.

Crop raiding, yield loss and economic loss

Crop raiding by wild pig is a significant issue in Nepal, particularly in rural and agricultural areas adjacent to forests and protected zones. The Terai region and mid-hill areas of Nepal adjacent to forest reserves like Chitwan National Park, Bardia National Park, and Shuklaphanta Wildlife Reserve experience the highest levels of crop raiding. In these regions, farmland is often located directly along forest edges, making them easily accessible to wild pigs. The wide range of distribution and ability to adapt to different ecosystems, wild pigs are

Journal of Agriculture and Natural Resources (2023) 6(1): 85-95
ISSN: 2661-6270 (Print), ISSN: 2661-6289 (Online)
DOI: https://doi.org/10.3126/janr.v6i1.71925

well known for causing crop damage (Barrios-Garcia & Ballari, 2012; Jhala *et al.,* 2020). Crop fields attract wild boars because of their potent scent nature (Sridhara, 2006; Singh & Kumar, 2018). According to Thapa (2010), they invade the crops more frequently throughout the flowering and fruiting seasons and continuing it till every crop is destroyed. Crop raiding can result in significant yield losses, affecting local food security and farmers' incomes. The damage caused by wild pigs to crops is substantial (Schley *et al.*, 2008; Barrios-Garcia & Ballari, 2012). The several studies around the world have proven the negative impact of wild pigs on agricultural crops (Seward *et al.*, 2004; Herrero *et al.*, 2006; Gentle *et al.*, 2011; McKee *et al.,* 2020). Damage from wild pigs to agriculture costs millions of dollars annually, according to Hill (1997), Gong *et al.* (2009), and Pedrosa *et al.*(2015).

In India, Madua crop damage from wild pigs was the largest in Uttar Pradesh (38%), followed by cholai and katu (30%), maize (29%), sugarcane (25%), and jowar, bajra, and pulses (23%). Wild pigs had the least impact on the harvests of wheat and barley. Wheat/barley (6%) and rice (5%), followed by wild pigs, caused the most damage to the maize crop in Himachal Pradesh (14%).The state of Rajasthan experienced the largest percentage of damage to its maize crop (32%), followed by guar (25%), oil seeds (17%), wheat/barley (15%), pulses (13%), and jowar/bajra (12%). Groundnuts (9%) and oilseeds (6%), wheat/barley (20%), maize (18%), jowar/bajra (13%), and rice (26%), were the crops most damaged by wild pigs in Madhya Pradesh (Chauhan *et al.,* 2009).

A wide range of agricultural crops, such as sugarcane, bananas, watermelons, potatoes, barley maize, oats, and fruits, can be seriously damaged by wild pigs through consumption and trampling (Brown *et al.,* 2018; Bolds *et al.,* 2022). In Shivapuri Nagarjun National Park (SNNP), the annual damage to 0.28 km^2 of crop area is about USD 24,000, with potatoes, maize, and paddy being the most common crop losses (Pandey *et al.*, 2016). With an average yearly crop loss of NRs. 11243 per household, wild pigs were the most crop-damaged animal in the Banke National Park's Buffer Zone, where the primary crops destroyed were maize, paddy, wheat, potatoes, and mustard (Subedi *et al.*, 2020). In Shuklaphata National Park (ShNP), the primary predators of paddy, wheat, and maize are wild boar and Asian elephants (Bhatta & Joshi, 2021). In the buffer zone area of CNP, Greater One-horned Rhinos and Wild pigs were the primary crop raiders, causing economic losses of NRs. 9211.4 annually per household (Ghimire, 2019). The most damaging crops in the buffer zone of CNP were maize, rice, wheat, and mustards. Paddy (63.83%), maize (19.15%), potatoes (17.02%) and wheat were the crops most severely damaged due to wild water buffalo, wild pigs, and wild Asian elephants in in the nearby Koshi Tappu Wildlife Reserve (KTWR) (Dahal *et al.*, 2022; Karki *et al.*, 2022). In response to wild pig incursions, farmers spend additional time and resources on protective measures. This often includes constructing makeshift barriers, maintaining watch over fields, or employing deterrents. These measures require labor and financial investment, which is burdensome for smallholder farmers

Disease carrier

Wild pigs serve as reservoirs of disease and parasites that may affect livestock, and people and wildlife. According to Gibbs (1997) and Ruiz-Fons *et al.* (2008), wild boars are hosts to several viruses that cause serious diseases in humans as well as livestock. Livestock may get infections from wild pigs that roam freely. Economic losses result from this, including lower productivity, reduced feed efficiency (reducing food intake impacts animal growth and

Journal of Agriculture and Natural Resources (2023) 6(1): 85-95
ISSN: 2661-6270 (Print), ISSN: 2661-6289 (Online)
DOI: https://doi.org/10.3126/janr.v6i1.71925

overall health), decreased reproductive success and increased herd mortality, and increased veterinary care expenses. Bacterial diseases like Brucellosis, Leptospirosis, *E. Coli*, Salmonellosis, Tuberculosis, and Tularemia; viral diseases like African Swine Fever (ASF), Classical Swine Fever (CSF or Hog Cholera), Foot and Mouth Disease (FMD), Hepatitis E Virus (HEV), Influenza A Viruses (H1N1 and H3N2), Porcine Circovirus type 2 (PCV2), Porcine Epidemic Diarrhea (PED), Porcine Reproductive and Respiratory Syndrome (PRRS), Pseudorabies Virus (PRV), and Vesicular Stomatitis Virus (VSV) are all known to be carried by wild pigs (JAGER PRO, 2024) .

Detection of wild pig damage

In crop field, the rooting, tracks, trails, nests or beds, wallows, rubs and trees damage are important signs of wild pig damage. The sign of wild pig damage can be identified through walking through the fields on foot and use of a remotely controlled aerial drones. Drones equipped with multispectral or hyperspectral sensors can capture changes in vegetation health and soil conditions, offering data on the environmental impacts of wild pig damage. Using drones to monitor wild pig damage has become an effective tool for researchers, landowners, and wildlife managers. Wild pigs are an invasive species that cause extensive environmental and agricultural damage, especially to crops, native vegetation, and ecosystems. Drones offer a non-invasive, cost-effective, and rapid way to assess and monitor the impact of wild pigs over large areas, especially in hard-to-reach places. Drones equipped with high-resolution cameras can fly over fields, forests, and wetlands to capture images and videos, documenting the extent of wild pig damage. This data helps create detailed maps that highlight areas affected by pig activity, which aids in assessing the scale of the problem. Drones with thermal cameras can detect heat signatures from wild pigs, even at night. This capability is invaluable for monitoring pig movements, especially since they are often most active at dawn, dusk, or nighttime. Thermal imaging also helps distinguish between wild pigs and other animals in densely vegetated areas. By conducting regular drone flights over the same area, managers can track the progression of wild pig damage over time. This approach provides insights into patterns of pig activity, helping to estimate population numbers, understand movement patterns, and plan management strategies accordingly. According to Herrero *et al.*(2006), Poudyal *et al.*(2017), and Boyce *et al.*(2020), assessing wild pig damage using ground surveys takes a lot of time and gets more challenging as plant growth obscures the field's vision and decreases the area that surveyors can sample (Engeman *et al.*, 2018).

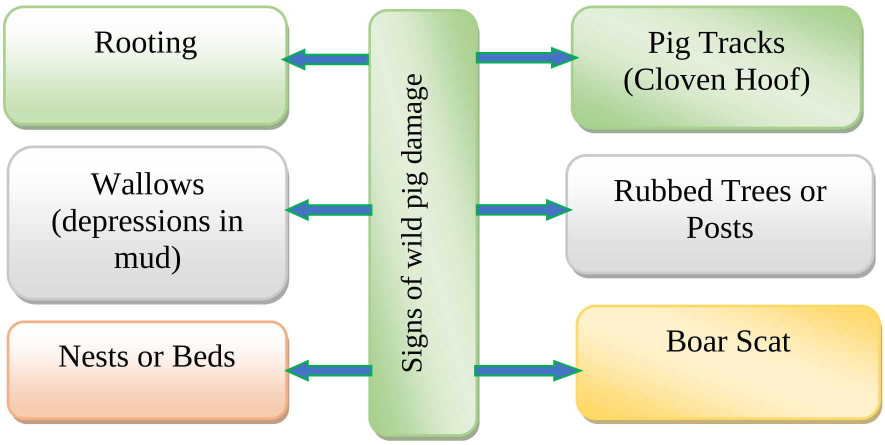

Figure 1. Different signs of wild pig damage in agricultural lands

ISSN: 2661-6270 (Print), ISSN: 2661-6289 (Online)
DOI: https://doi.org/10.3126/janr.v6i1.71925

In order to monitor and evaluate wild pig damage, remote sensing techniques that are already employed in precision agriculture methods at the farm and field size may offer a more effecti ve way (Bohon, 2014; Rembold *et al.*, 2015; Houborg & McCabe, 2016; Garza *et al.*, 2020; Weiss *et al.*, 2020). High-definition video, multispectral, thermal, hyperspectral, and natural color high-resolution data can all be obtained from drones (Hodgson *et al.*, 2016; Green *et al.*, 2019; DiMaggio *et al.*, 2020). Rapid advancements in drone technology are making them more widely used in the agriculture and wildlife sectors. For landowners and producers, drones can be an excellent instrument for precisely estimating crop yield loss and damage by wild pigs, as well as for obtaining compensation for income lost (Friesenhahn *et al.*, 2023).

Management of wild pigs:

Fencing

Fencing can be an effective technique when integrated with other control techniques or for high value agricultural areas or where other control techniques are not possible. Fencing was recommended as a successful method for reducing the issue of crop damage (Hone & Ackison, 1983). A barrier that prevents wild pigs interference can be created with appropriate fencing that is at least four feet high. The best option for wild pigs is woven wire field fencing, which offers a strong barrier that prevents any space from getting under the fence, even though electric or barbed wire may deter some animals. Woven wire field fence, high-tensile electric wire and barbed wire are used to deter the wild pigs. Woven wire field fence is a wire mesh made of tight grid construction offers a strong, long-lasting fence line that depends on tensioning for strength. High-tensile electric wire are strands of smooth wire reinforced with electricity and tension for strength. Barbed wire are smooth wire strands with barbs or knots with sharp edges spaced every few inches.

Trapping

The most effective way to manage wild pig populations is by using trapping, which is a continuous activity that takes a lot less time and effort than other techniques like shooting and dog hunting. From a logistical perspective, prefabricated box traps and cage traps are more practical and do not require on-site construction; nevertheless, larger corral-style traps enable removal of whole sounders (family groups) per trapping operation. Pig trapping success depends on a number of essential elements: Finding busy areas of wild pig movements for possible trap locations; pre-baiting to help pigs become used to entering and exiting the trap securely; constructing trap enclosures of a suitable size; employing game cameras to track wild pig visits to the trap; and having patience to perform the activities.

B**aiting**

Before pre-baiting or baiting any wild pig, farmers should make sure they have read the state-specific baiting regulations. In many places, wild pig have the provision to choose one form of bait over another so commercial scents or attractants, sweet potatoes, shelled maize (dry or fermented), or other grains, overripe fruits, molasses, and other baits can be used alone or in combination (Kornacher, 2006; Abbas *et al.*, 2004). These baits give off strong scents that wild pig can detect from a distance. Mixing bait with diesel (a commonly used hog attractant) or adding anise oil or berry gelatin powder intensifies the scent, helping attract boars from farther away. Wild pigs are crepuscular in nature, so baiting around dawn and dusk is best. As boar prefer to stay nearby trails or water resources so for efficacy of bait it should be placed in these areas. Monitoring with Trail Cameras helps to track activity patterns of wild

Journal of Agriculture and Natural Resources (2023) 6(1): 85-95
ISSN: 2661-6270 (Print), ISSN: 2661-6289 (Online)
DOI: https://doi.org/10.3126/janr.v6i1.71925

pig, so one can refine bait placement and timing for even better results. The different types of baits used for hunting wild pigs is given in Table 1.

Table 1. Types of baits for hunting wild pigs

SN	Baits
1	Jello or Kool-Aid Drink Mix
2	Anise Oil
3	Sour Corn
4	Sweetened Corn
5	Diesel Alternative

(Source: https://eatingthewild.com/bait-hogs-quickly/)

Hunting

Hunting and shooting with gunfire is less effective methods for controlling wild pigs, as they require a large amount of effort and time, and rarely have a noticeable impact on the number of pigs. Among the many forms of night hunting, a rifle and spotlight may light up pigs up to 100 meters away. They perform best in open areas and provide greater eyesight under strong moonlight, but quite challenging and have a poor success rate. Because of the tusked animal's ambush tactics, thick hide, and dense bones, which made them tough to kill with pre-modern weapons. Hunting wild pig typically requires a hunting permit that has been issued by the government. Nepal government has been decided to enlist wild pigs as a ‘pest animal’ and allow its capture and killing.

Use of Dog

Using dogs for hunting wild boar is a traditional and effective method employed by many hunters around the world. Dogs can assist in locating, tracking, and even holding or catching wild boar. In recent years, wild pig hunting with dogs has grown in popularity as a sport hunting method. It is an effective technique in areas where boars have evolved increased night time activity patterns due to excessive gunshots and stress from capture (Thurfjell *et al.*, 2013; Sodeikat & Pohlmeyer, 2003; Geisser & Reyer, 2004). Wild pigs are hunted with a variety of dog breeds. Most typically, bay or strike dogs are either hounds or curs. Due to an excellent sense of smell, these dogs can run long distances in challenging conditions. Numerous worker breeds are mixed together to create hog dogs. Hunters will breed their own hog dogs considering ecological region and their needs to operate.

CONCLUSION

Wild pigs are major concern for landowners, managers, and agencies. They damage the field crops and cause economic loss of rural farmers. The use of drones which takes digital photographs of field is more effective than field visit on foot to locate and measure patches of wild boar damage. Trapping, baiting, hunting or shooting, use of dog, fencing are management practices for controlling wild pigs. Among management practices, hunting is more performed and solution to reduce human-wildlife conflicts and provide economic benefits to local communities where such practices are permitted. Reducing the population of wild pigs to desired level is difficult to achieve and quite expensive. The utilization of manpower for patrolling wild boar is costly. Therefore, adoption of cost-effective eco-friendly techniques like recreational hunting, is necessary for controlling wild pig encroachment in farm lands.

ACKNOWLEDGMENT

The author would like to acknowledge the libraries of AFU and NPI, Chitwan Nepal.

AUTHOR'S CONTRIBUTION

Sajana Rai wrote the manuscript.

CONFLICT OF INTEREST

The author declares no conflict of interest.

REFERENCES

Abbas, M., Khan, S. H., Khan, R. A., & Shahbaz, M. (2004). Efficacy of different methods to control wild boars: a perception of farmers of the Faisalabad Division. Pakistan *Journal of Agricultural Science, 41*(3/4), 144-145.

Barrios-Garcia, M. N., & Ballari, S. A. (2012). Impact of wild boar (*Sus scrofa*) in its introduced and native range: a review. *Biological invasions, 14,* 2283-2300.

Baubet, E., Bonenfant, C., & Brandt, S. (2004). Diet of the wild boar in the French Alps. *Galemys*, *16*(1), 101-113.

Bhatta, M., & Joshi, R. (2021). Analysis of human-wildlife conflict in Buffer Zone Area: A case study of Shuklaphanta National Park, Nepal. *Grassroots Journal of Natural Resources, 3*(3): 28-45.

Boadella, M., Vicente, J., Ruiz-Fons, F., De la Fuente, J., & Gortázar, C. (2012). Effects of culling Eurasian wild boar on the prevalence of *Mycobacterium bovis* and Aujeszky's disease virus. *Preventive veterinary medicine, 107*(3-4), 214-221.

Bohon Jr, R. K. (2014). Comparing Landsat7 ETM+ and NAIP imagery for precision agriculture application in small scale farming: A case study in the south eastern part of Pittsylvania County, VA (Master's thesis, University of Southern California).

Boklund, A., Goldbach, S. G., Uttenthal, A., & Alban, L. (2008). Simulating the spread of classical swine fever virus between a hypothetical wild-boar population and domestic pig herds in Denmark. *Preventive Veterinary Medicine*, *85*(3-4), 187-206.

Bolds, S. A., Lockaby, B. G., Kalin, L., Ditchkoff, S. S., Smith, M. D., & VerCauteren, K. C. (2022). Wild pig removal reduces pathogenic bacteria in low-order streams. *Biological Invasions, 24*(5), 1453-1463.

Boyce, C. M., Vercauteren, K. C., & Beasley, J. C. (2020). Timing and extent of crop damage by wild pigs (*Sus scrofa* Linnaeus) to corn and peanut fields. *Crop Protection, 133,* 105131.

Brown, V. R., Bowen, R. A., & Bosco-Lauth, A. M. (2018). Zoonotic pathogens from feral swine that pose a significant threat to public health. *Transboundary and emerging diseases*, *65*(3), 649-659.

Calenge, C., Maillard, D., Fournier, P., & Fouque, C. (2004). Efficiency of spreading maize in the garrigues to reduce wild boar (*Sus scrofa*) damage to Mediterranean vineyards. *European Journal of Wildlife Research*, *50,* 112-120.

Chauhan, N. P. S., Barwal, K. S., & Kumar, D. (2009). Human-wild pig conflict in selected states in India and mitigation strategies. *Acta Silvatica et Lignaria Hungarica: An International Journal in forest, wood and Environmental sciences, 5,* 189-197.

Choi, S.K., Lee, JE., & Kim, YJ. (2014). Genetic structure of wild boar (*Sus scrofa*) populations from East Asia based on microsatellite loci analyses. *BMC Genet* **15**, 85.

Dahal, N. K., Harada, K., Adhikari, S., Sapkota, R. P., & Kandel, S. (2022). Impact of wildlife on food crops and approaches to reducing human wildlife conflict in the protected landscapes of Eastern Nepal. *Human Dimensions of Wildlife*, *27*(3), 273-289.

d'Huart, J. P. (1991). Habitat utilization of old world wild pigs. *Biology of suidae*, 30-48.

DiMaggio, A. M., Perotto-Baldivieso, H. L., Ortega-S, J. A., Walther, C., Labrador-Rodriguez, K. N., Page, M. T., & Wester, D. B. (2020). A pilot study to estimate forage mass from unmanned aerial vehicles in a semi-arid rangeland. *Remote Sensing*, *12*(15), 2431.

Dudley, J. P., & Woodford, M. H. (2002). Bioweapons, bioterrorism and biodiversity: potential impacts of biological weapons attacks on agricultural and biological diversity. *Revue scientifique et technique-Office international des épizooties, 21*(1), 125-138.

Engeman, R. M., Terry, J., Stephens, L. R., & Gruver, K. S. (2018). Prevalence and amount of feral swine damage to three row crops at planting. *Crop Protection, 112*, 252-256.

Friesenhahn, B.A., Massey, L.D., DeYoung, R.W., Cherry, M.J., Fischer, J.W., Snow, N.P., VerCauteren, K.C., & Perotto-Baldivieso, H.L. (2023). Using drones to detect and quantify wild pig damage and yield loss in corn fields throughout plant growth stages. *Wildlife Society Bulletin*, *47*(2), p.e1437.

Garza, B. N., Ancona, V., Enciso, J., Perotto-Baldivieso, H. L., Kunta, M., & Simpson, C. (2020). Quantifying citrus tree health using true color UAV images. *Remote Sensing*, *12*(1), 170.

Geisser, H., & Reyer, H. U. (2004). Efficacy of hunting, feeding, and fencing to reduce crop damage by wild boars. *The Journal of Wildlife Management, 68*(4), 939-946.

Gentle, M., Phinn, S., & Speed, J. (2011). Assessing pig damage in agricultural crops with remote sensing. Bureau of Rural Sciences Australian Pest Animal Management Program Final Report.

Gharti Magar,Y., Pant, B., Regmi, S., Katuwal , H.B.,Jerrold L.B., Sharma,H.P.(2024). Economic effects of wild boar damage to crops in protected areas of Nepal. *The Journal of Global Ecology and Conservation 56 (2024) e03301*.

Ghimire, P. (2019). Analysis of Human Wildlife Conflict in Buffer Zone Area: A Study from Chitwan National Park. *International Journal of Natural Resource Ecology and Management*,*4*(6), 164-172

Gibbs, E. P. (1997). The public health risks associated with wild and feral swine. *Revue scientifique et technique (International Office of Epizootics), 16*(2), 594-598.

Gong, W., Sinden, J., Braysher, M., & Jones, R. (2009). The economic impacts of vertebrate pests in Australia (pp. 60-pp).

Green, D. R., Hagon, J. J., Gómez, C., & Gregory, B. J. (2019). Using low-cost UAVs for environmental monitoring, mapping, and modelling: Examples from the coastal zone. *In* Coastal management (pp. 465-501). Academic Press.

Herrero, J., García-Serrano, A., Couto, S., Ortuño, V. M., & García-González, R. (2006). Diet of wild boar *Sus scrofa* L. and crop damage in an intensive agroecosystem. *European Journal of Wildlife Research*, *52*, 245-250.

Hill, C. M. (1997). Crop-raiding by wild vertebrates: The farmer's perspective in an agricultural community in western Uganda. *International Journal of Pest Management, 43*(1), 77-84.

Hodgson, J. C., Baylis, S. M., Mott, R., Herrod, A., & Clarke, R. H. (2016). Precision wildlife monitoring using unmanned aerial vehicles. *Scientific reports*, *6*(1), 22574.

Hone, J., & Atkinson, B. (1983). Evaluation of fencing to control feral pig movement. *Wildlife Research, 10*(3), 499-505.

Houborg, R., & McCabe, M. F. (2016). High-Resolution NDVI from planet's constellation of earth observing nano-satellites: A new data source for precision agriculture. *Remote Sensing, 8*(9), 768.

JAGER PRO. (2024). Wild hog damage and disease. https://jagerpro.com/wild-hog-damage-and-disease/

Jhala, Y. V., Gopal, R., & Qureshi, Q. (2008). Status of tigers, co-predators, and prey in India. National Tiger Conservation Authority, Government of India and Wildlife Institute of India, Dehradun, India.

Kanter, M., Elkin, C.(2019). Potato as a source of nutrition for physical performance. Am. J. Potato Res. 96, 201–205.

Karki, D., Poudel, N., Dixit, S., Bhatta, S., Gotame, B., Dhamala, M.K., & Khadka, D. (2022). Human-Wildlife Conflicts in Paschim Kusaha Village of Koshi Tappu Wildlife Reserve, Sunsari District, Nepal. *Journal of Resources and Ecology, 13*(6), 1022-1029.

Kornacher, P. (2006). Wild Boar *Sus Scrofa* damage reduction through large scale management: applying hunting and feeding as management tools (Doctoral dissertation, Institutionen för skoglig zooekologi, Sveriges lantbruksuniversitet).

Linkie, M., Dinata, Y., Nofrianto, A., & Leader-Williams, N. (2007). Patterns and perceptions of wildlife crop raiding in and around Kerinci Seblat National Park, Sumatra. *Animal conservation, 10*(1), 127-135.

Liu, Q., Yan, K., Lu, Y. F., Li, M., & Yan, Y. Y. (2019). Conflict between wild boars (*Sus scrofa*) and farmers: distribution, impacts, and suggestions for management of wild boars in the Three Gorges Reservoir Area. *Journal of Mountain Science, 16*(10), 2404-2416.

McKee, S., Anderson, A., Carlisle, K., & Shwiff, S. A. (2020). Economic estimates of invasive wild pig damage to crops in 12 US states. *Crop protection, 132*, 105105.

Nair, R.P., & Jayson, E.A. (2016). Wild pig rabies-A case study from Pathippara, Malappuram, Kerala. *Int J Res Med Sci, 6*(2), 1–5.

Pandav, B., Natarajan, L., Kumar, A., Desai, A. A., & Lyngkhoi, B. (2021). Household perceptions and patterns of crop loss by wild pigs in north India. *Human–Wildlife Interactions, 15*(1), 12.

Pandey, L., Arunachalam, A., & Joshi, N. (2019). Challenges of hill farming due to crop-raiding by wild pigs in the Indian Himalayan region. *Current Science, 116*(6), 1015-1019.

Pandey, P., Shaner, P. J. L., & Sharma, H. P. (2016). The wild boar as a driver of human-wildlife conflict in the protected park lands of Nepal. *European journal of wildlife research, 62*, 103-108.

Pedrosa, F., Salerno, R., Padilha, F. V. B., & Galetti, M. (2015). Current distribution of invasive feral pigs in Brazil: economic impacts and ecological uncertainty. *Perspectives in ecology and conservation, 13*, 84–87

Poudyal, N. C., Caplenor, C., Joshi, O., Maldonado, C., Muller, L. I., & Yoest, C. (2017). Characterizing the economic value and impacts of wild pig damage on a rural economy. *Human Dimensions of Wildlife, 22*(6), 538-549.

Punjabi, G. A., & Rao, M. K. (2017). Large herbivore populations outside protected areas in the human-dominated Western Ghats, India. *Mammalian Biology, 87*(1), 27-35.

Ramanathan, K.M., Krishnamoorthy, K.K.(1973). Nutrient uptake by paddy during the main three stages of growth. Plant Soil 29–33.

Rembold, F., Meroni, M., Urbano, F., Royer, A., Atzberger, C., Lemoine, G., Eerens, H., & Haesen, D. (2015). Remote sensing time series analysis for crop monitoring with the SPIRITS software: new functionalities and use examples. *Frontiers in Environmental Science, 3*, 46.

Ruiz-Fons, F., Segalés, J., & Gortázar, C. (2008). A review of viral diseases of the European wild boar: effects of population dynamics and reservoir role. *The Veterinary Journal*, *176*(2), 158-169.

Ruiz-Fons, F., Vidal, D., Vicente, J., Acevedo, P., Fernández-de-Mera, I. G., Montoro, V., & Gortázar, C. (2008). Epidemiological risk factors of Aujeszky's disease in wild boars (*Sus scrofa*) and domestic pigs in Spain. *European Journal of Wildlife Research*, *54*, 549-555.

Saito, M., Momose, H., & Mihira, T. (2011). Both environmental factors and countermeasures affect wild boar damage to rice paddies in Boso Peninsula, Japan. *Crop Protection*, *30*(8), 1048-1054.

Schley, L., Dufrêne, M., Krier, A., & Frantz, A. C. (2008). Patterns of crop damage by wild boar (*Sus scrofa*) in Luxembourg over a 10-year period. *European Journal of Wildlife Research, 54*, 589-599.

Seward, N. W., VerCauteren, K. C., Witmer, G. W., & Engeman, R. M. (2004). Feral swine impacts on agriculture and the environment. *Sheep & Goat Research Journal, 19*, 34–40

Singh, R., & Kumar, M. (2018). Preliminary observations on the Indian wild boar (*Sus scrofa*) and its damage in agricultural crop fields. *J. Entomol. Zool. Stud*, *6*, 743-747.

Sodeikat, G., & Pohlmeyer, K. (2003). Escape movements of family groups of wild boar *Sus scrofa* influenced by drive hunts in Lower Saxony, Germany. *Wildlife Biology, 9,* 43-49.

Sridhara S. 2006. Vertebrate pests in Agriculture-The Indian Scenario. Scientific Publishers, Jodhpur, India

Subedi, P., Joshi, R., Poudel, B., & Lamichhane, S. (2020). Status of human-wildlife conflict and assessment of crop damage by wild animals in buffer zone area of Banke National Park, Nepal. *Asian Journal of Conservation Biology*, *9*(2), 196-206.

Thapa, S. (2010). Effectiveness of crop protection methods against wildlife damage: a case study of two villages at Bardia National Park, Nepal. *Crop protection*, *29*(11), 1297-1304.

Thurfjell, H., Spong, G., & Ericsson, G. (2013). Effects of hunting on wild boar *Sus scrofa* behaviour. *Wildlife biology*, *19*(1), 87-93.

Vicente, J., Höfle, U., Garrido, J.M., Acevedo, P., Juste, R., Barral, M., & Gortazar, C. (2007) .Risk factors associated with the preva-lence of tuberculosis-like lesions in fenced wild boar and red deer in south central Spain. *Vet Res 38*, 451–464

Weiss, M., Jacob, F., & Duveiller, G. (2020). Remote sensing for agricultural applications: A meta-review. *Remote sensing of environment*, *236*, 111402.

.