

Case study

Household perceptions and patterns of crop loss by wild pigs in north India

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Abstract: Loss to cultivated crops by wild pigs (*Sus scrofa*) is widespread and can jeopardize low-income farmers. In India, although there is lot of political interest in the problem, efforts to understand the patterns, correlates, and underlying reasons for wild pig conflict continue to be minimal. We quantified loss of wheat (*Triticum aestivum*) to wild pigs and assessed the spatial patterns of damage in a forest settlement of Van Gujjar (Haridwar, India), which is a dairy-based pastoralist community. We chose a 4-km² cultivated area comprising 400 farmlands (each measuring 0.8 ha and belonging to a family) and assessed crop damage by wild pigs through field surveys during the harvest season. We interviewed 159 respondents who manage 219 of the total 400 farmlands in the study area to compare actual crop loss with perceived losses. Wild pigs damaged 2.29 tonnes (2,290 kg) of wheat, which was about 2.6% of the potential yield in the study area. A total of 39 farmlands (9.5%), managed by 28 respondents, suffered losses during the survey period at an average loss of about 58.8 kg (SD ± 89.5, range = 0.7–388 kg). During interviews, 81 respondents managing 155 farmlands (70.7%) reported having suffered wild pig-related crop loss during the survey period. They also perceived losing about 23.4% of the potential yield of wheat due to wild pigs. The perceived losses were much higher than actual losses. Actual losses measured through field surveys underscore the dichotomy between actual and perceived crop loss due to wild pigs. About 81% of recorded wild pig-related damage to wheat occurred within 200 m from the forest edge. The crop protection measures aimed at stopping wild pigs from entering the fields were mostly reactive. Although overall crop losses due to wild pigs seem low at the settlement level, for affected individual families, the losses were financially significant. Such recurrent crop losses can cause families to go into debt, trigger animosity toward conservation, and lead to retaliation measures, which may be indiscriminate and have the potential to affect other endangered mammals in conservation priority landscapes. Because crop losses by wild pigs are severe along the narrow band of fields along the edge of the forest, channeling monetary benefits through insurance-based compensation schemes can help assuage losses to farmers. Further, because crop damage by wild pigs is seasonal, experimenting with mobile fences that can be dismantled and packed away after use would be beneficial.

Key words: crop loss, Haridwar, human–wild pig conflict, perceived crop loss, Van Gujjar

CROP LOSS by wild herbivores is the most widespread form of human–wildlife conflict across the globe (Woodroffe et al. 2005, Barua et al. 2013). Such conflicts can be a serious impediment to achieve the twin objectives of livelihood security of local communities and biodiversity conservation (Naughton-Treves 1998, Woodroffe et al. 2005, Barua et al. 2013).

Although a wide spectrum of wildlife ranging from invertebrates to elephants (*Elephas maximus*) cause crop losses, the effects are often perceived as severe in the case of large mammals (Naughton-Treves 1998, Woodroffe et al. 2005). In a tropical country like India, diversity of wild mammalian vertebrates causes crop losses. Among them, crop damage by wild pigs

¹Deceased.

(*Sus scrofa*) is ubiquitous due to their vast distributional range and physical, physiological, and behavioral plasticity, which enable them to occur in diverse habitats (Barrios-Garcia and Ballari 2012, Jhala et al. 2020).

Wild pigs are native to Eurasia. In India, they naturally occur in diverse habitats ranging from arid scrub to wet evergreen forests (Johnsingh and Manjrekar 2016). Across its distributional range in India, wild pigs are an important ungulate prey for many large carnivores like tigers (*Panthera tigris*), leopards (*P. pardus*), Indian wild dogs (*Cuon alpinus*), Asiatic lions (*P. leo*), and others (Karanth and Sunquist 1995, Bagchi et al. 2003, Andheria et al. 2007, Meena et al. 2011, Selvan et al. 2013, Jhala et al. 2020). As part of a country-wide tiger monitoring program conducted by the Government of India, distribution and relative abundance of wild pigs have been estimated for 20 out of 29 states (Jhala et al. 2020). Additionally, many independent studies focusing on carnivore biology have generated population estimates of wild pigs in individual wildlife reserves (Karanth and Sunquist 1995, Bagchi et al. 2003, Andheria et al. 2007, Datta et al. 2008, Meena et al. 2011, Selvan et al. 2013, Jhala et al. 2020). Other than the PAN (Presence Across Nation) India wild pig distribution estimates and population estimates in select wildlife reserves, information on wild pig ecology, demography, and aspects of conflict continues to be sparse. Wild pigs are listed in Schedule-III of the Indian Wildlife (Protection) Act of 1972—federal act for protection for flora and fauna in India. Hunting of wild pigs is prohibited by law and for exceptional cases, the chief wildlife warden (the main authority of the forest department on wildlife matters) of the states may provide hunting permits.

Studies have established that among large mammals, crop losses due to wild pigs are overwhelming in India and other Asian countries (Chauhan et al. 2009, Karanth and Nepal 2012, Karanth et al. 2012). There is widespread publicity and political interest in the problem. However, addressing the problem of crop losses by wild pigs confronts many fundamental challenges. Attempts to develop fool-proof physical barriers for wild pigs have often met limited success (Cai et al. 2008, Thapa 2010). Further, knowledge gaps regarding long-term population trends and population vital rates of select

high-conflict wild pig populations preclude population regulation through fertility control and invasive approaches. Conventional active crop guarding techniques, which are known to be effective for wild pigs, are in decline due to shortage of human resources and threats associated with guarding. Even reliable assessment of crop losses in the field, which is a prerequisite for the state forest departments to pay compensation to affected farmers, is difficult for wild pigs and other relatively smaller herbivores. While use of drones was shown to be effective to assess crop damage by wild pigs in the agricultural landscapes of Belgium (Rutten et al. 2018), in landscapes where multiple wild ungulate species raid cultivated crops, attributing the losses solely to wild pigs may not be appropriate without ground assessment.

Contending with these challenges, studies that have assessed crop losses by wild pigs were largely based on village interviews or crop compensation records (e.g., Chauhan et al. 2009). Although useful in elucidating broad-scale spatial patterns of conflict, interview surveys reflect people's perception that can be at odds with the actual patterns (Naughton-Treves 1998, Suryawanshi et al. 2013, Rabinowitz 2014). Further, the interview surveys may never be able to capture the inherent variations in the patterns of conflict. Similarly, compensation records may under-represent the problem as only a small fraction of affected farmers may seek compensation. From the local farmers' perspective, the inability to get help despite suffering continual crop losses could indebt farmers and create despair (Barua et al. 2013). Consequently, sometimes out of frustration, farmers could resort to clandestine lethal control measures in the fields to deter wild pigs by laying snares and connecting solar-powered electric fences in their fields (Johnson et al. 2018). Over the years, stealthily setting snares and connecting mains to solar power fences have emerged as major conservation challenges in areas prioritized for large mammal conservation. Endangered species like the tiger, leopard, and others occasionally get ensnared and elephants get electrocuted in illegally set fences, which are often targeted for wild pigs (Gray et al. 2018, Jhala et al. 2020). Therefore, human–wild pig conflict cannot be ignored.

As a step in the right direction toward advancing evidence-based science in conflict manage-

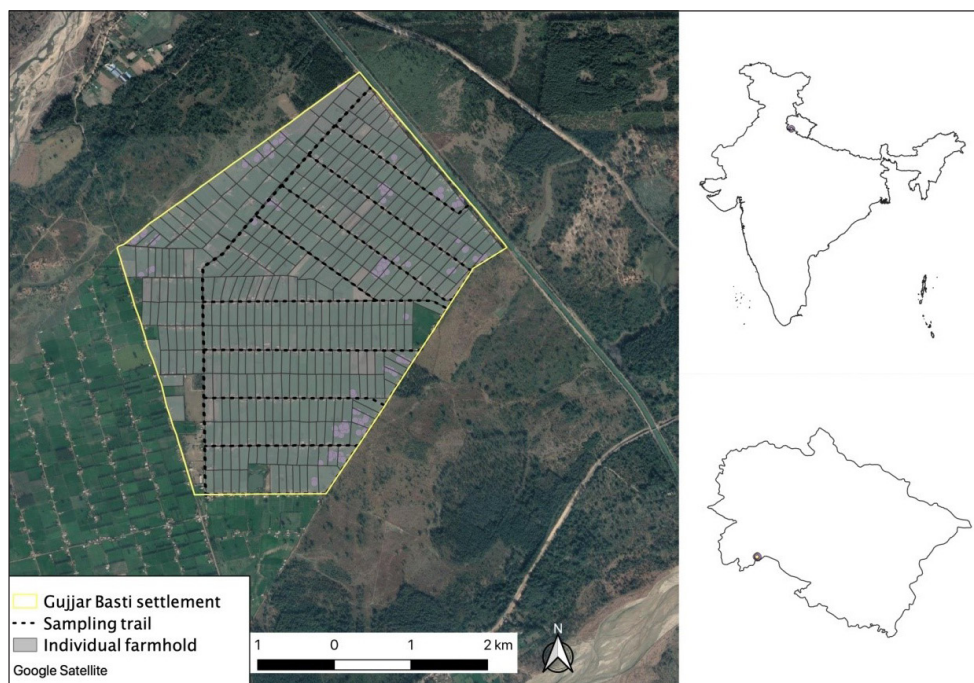


Figure 1. Study area of Gujjar Basti settlement in Gaindikhata village in Haridwar. Inset, top: India outline; inset bottom: Uttarakhand state in north India where the study was conducted.

ment, it is essential to objectively assess crop losses by wild pigs. Fine-scale field assessment of crop loss by wild pigs could provide insights on the extent of damage within the community and per-capita losses for individual farmers that are useful in policy formation. Such assessments, along with documentation of best practices in restraining wild pigs from entering crop fields, can provide objective base data for implementing conflict resolution strategies. The aim of the paper is to quantify the extent of damage to wheat (*Triticum aestivum*) by wild pigs in a forest enclave in the Terai region of India. In the forest, cultivation hard edges, most of the crop damages reportedly occur close to the boundary (Naughton-Treves 1998, Cai et al. 2008). We tested if distance from the forest edge explains the potential variation in crop damage by wild pigs in an enclave surrounded by forests. We also conducted interview surveys with households to test how their perceptions regarding wild pig-related crop losses compare with actual losses measured in the field. Since management options to deal with wildlife-related crop losses are often costly, field measurement and an understanding of underlying reasons for spatial variability would be useful.

Methods

Study area

We carried out our study in the Gujjar Basti settlement of Gaindikhata village, an enclave surrounded by multiple-use reserved forests of Haridwar Forest Division (FD) in Uttarakhand, India. The total area of Gaindikhata village is around 14 km². Of this, around 4 km² in the north-east portion is Gujjar Basti settlement (Figure 1). Haridwar FD is part of the Terai Arc Landscape that supports the largest populations of the endangered tiger and a regional population of elephants. Haridwar FD is connected to Rajaji Tiger Reserve and Corbett Tiger Reserve through a narrow corridor in the Lansdowne FD. The state forest department established Gujjar Basti settlement in Gaindikhata and resettled Van Gujjars from protected areas. During resettlement, each Van Gujjar family was allotted 0.80 ha of agricultural land (Harihar et al. 2015). Because the land was allotted for them in the fertile Gangetic plains with a high water table, Van Gujjars, although originally pastoralists, have taken to cultivation crops like paddy (*Oryza sativa*), wheat, and pulses. The multiple-use forests around Gujjar Basti settlement in Gaindikhata village support large herbivores including the Asian elephant,

Table 1. Demographic and livelihood details of the households surveyed in Gujjar Basti settlement of Gairdikhata village, Haridwar, India.

Attribute	Details
Number of respondents	155 (representing 219 farmlands)
Household members	Mean (\pm SD) = 8.6 (4.0)
Age of respondents	Mean (\pm SD) = 50 (\pm 14.2) Range = 22–85
Dependent family members	Mean (\pm SD) = 6.1 (\pm 3.1)
Occupation (not mutually exclusive)	Agriculture = 99% Dairy = 39% Labor and others = 77.6%
Agriculture details	Wheat (<i>Triticum aestivum</i>) = 98.6% Paddy (<i>Oryza sativa</i>) = 21% Black gram (<i>Vigna mungo</i>) = 76.7%
Wild herbivores reportedly damaging crops	Wild pig (<i>Sus scrofa</i> ; 85%) Chital (<i>Axis axis</i> ; 71.2%) Sambar (<i>Rusa unicolor</i> ; 42.4%) Elephant (<i>Elephas maximus</i> ; 22.3%)

sambar (*Rusa unicolor*), chital (*Axis axis*), nilgai (*Boselaphus tragocamelus*), barasingha (*Rucervus duvaucelii*), muntjac (*Muntiacus muntjac*), wild pig, common langur (*Semnopithecus entellus*), and rhesus macaque (*Macaca mulatta*; Johnsingh et al. 2004). Consequently, the settlement reportedly witnesses a substantial degree of conflict with many species of wild herbivores. We demarcated 4 km² of the northern portion of the settlement as our study area (sampling frame). The choice of demarcation was influenced by access to crop fields and day-to-day logistics therein.

Field surveys

We monitored wild pig-related crop losses for 32 days from March 10 to April 10, 2017. We digitized all individual 0.8-ha farmlands within the sampling frame in QGIS (QGIS Core Development Team 2017). We reasoned that each farmland would be sufficiently large to accommodate an independent crop damage event by wild pigs. Further, protection measures could differ between households, and therefore, we decided to measure crop loss at the level of individual farmlands. In the sampling frame, there were 400 farmlands. These 400 farmlands were currently managed by 219 households, as some of the original farmland grantees had entrusted their lands to others due to inability to manage themselves.

To locate and quantify damage to wheat caused by wild pigs, we identified a 14-km network of dirt tracks that criss-cross the farmlands

(Figure 1). The dirt tracks offered good visibility to crop fields on both sides. A team comprised of 2 researchers and a field assistant from the local community traveled on a motorcycle at a standard speed of 10–15 km per hour along the tracks, carefully looking for damage. Based on visual cues of disturbed fields, the team would examine the field for signs of wild pigs, including scat deposits, eschewed wheat grains, rooting signs and tracks. In addition to direct field searches, we had inquired with local farmers about crop damage locations. The crop loss locations for each day would be geo-referenced using a hand-held Global Positioning System unit. In the crop loss locations, we overlaid 1-m² quadrats to enumerate the total area of crop field damaged by wild pigs. To avoid duplication, we recorded only fresh crop losses.

Perception surveys

We prepared a 2-page questionnaire containing 27 questions (see supplemental material). The questions were all close-ended. The elaborate details provided by the respondents were recorded as field notes. Wherever possible, interview surveys were often supplemented with field observation. A total of 159 respondents representing 219 farmlands with households covering 55% of the total 400 farmlands with households in the demarcated settlement were surveyed. During interviews we recorded background information of respondents, their agricultural and animal husbandry practices, per-

ceived crop losses, and aspects of crop guarding (Table 1). We carried out our interview surveys when the crops were ready for harvest. During interviews, we specifically asked the respondents to report crop damage by wild pigs for the current harvest period and not based on their past experiences. We printed the questionnaires in English but administered them in Hindi, the regional language. We obtained prior consent verbally from all respondents before involving them in our surveys. We did not obtain written consent from the respondents due to poor literacy levels and a general reluctance amongst villages in signing papers. We maintained confidentiality and anonymity of the interviewees.

Data analysis

At the time of harvest, we clipped standing crop within a 1-m² quadrat from 3 random locations to estimate average yield per quadrat. We measured actual crop loss in kilograms by multiplying the estimated average yield per quadrat by the number of quadrats of wheat damaged by wild pigs. We estimated the potential yield per 1-m² quadrat as 0.70 kg, calculated based on the guideline value of the Indian Council of Agricultural Research (www.ICAR.gov.in) for the district of Haridwar. We used a Student's paired *t*-test in program R (R Development Core Team 2019) to compare actual and perceived crop damage (Dytham 2011).

We assigned "1" on detecting crop damage by wild pigs in the farmlands and "0" for farmlands where no damage was recorded. Distance from forest was measured in GIS by calculating the Euclidean distance from the center of the farmland to the forest boundary. The second variable used in the logistic regression models was the cumulative crop protection. Crop protection measures used by the respondents included active crop guarding with drums and lights (83.5%), stone wall (16.8%), bush fence (15.5%), and wire fences (17.8%). Respondents were observed using a combination of the aforementioned crop protection measures. In the models, the sum of crop protection measures, ratio data were used as a covariate in the models. We used generalized linear models to quantify the influence of potential explanatory variables on the probability of crop loss by wild pigs. The response variable in our models is the detection/non-detection of crop losses by wild

pigs, which was assumed to follow a logistic regression (Bolker 2008). We assessed variance inflation factor to assess collinearity between explanatory variables (Crawley 2007). We followed an information theoretic approach for model selection by comparing plausible models with an intercept-only model (Burnham and Anderson 2002, Johnson and Omland 2004). We assessed the fit of the model based on slope estimates and McFadden's *R*² (Hu et al. 2006, Smith and McKenna 2013). We performed our analysis in program R (R Development Core Team 2019). We used Moran's *I* coefficient scores implemented in program ArcGIS to check spatial autocorrelation of crop loss locations.

Results

Within the sampling frame comprised of 400 farmlands, the total wheat loss due to wild pigs during the survey period was estimated to be 2.29 tonnes (2,290 kg). A total of 39 farmlands (9.75%) suffered wild pig-related crop loss, where the average loss was estimated at 58.8 kg ($\sigma = \pm 89.5$ kg, range = 0.7–388 kg). Of the 32 days of monitoring, wild pigs entered crop fields and damaged them for 17 days (Figure 2).

During interviews, 81 respondents of 155 farmlands (70.7%) perceived losing crops to wild pigs. They purported losing an average of 520 kg ($\sigma = \pm 279.3$ kg) per farmland. The perceived crop losses were significantly higher than actual losses caused by wild pigs ($t = 19.89$, $df = 171$, $P < 0.001$).

We tested 5 logistic regression models to examine the influence of explanatory variables on the response variable (Tables 2 and 3; Figure 3). In the candidate set, the top 2 models received similar support with $\Delta AIC < 1.63$. However, both the models were nested. Therefore, model averaging was used to obtain parameter estimates of the predictor variables. Proximity to the forest explains the observed variations in the probability of crop damage by wild pigs ($\beta = -1.65$ [SE = 0.34], $P < 0.001$). As hypothesized, wild pig damage to wheat was relatively high in the farmlands located close to the forest boundary (Figure 2). The second variable in our models, the crop protection, adds to the effect of proximity to forest in explaining the observed spatial patterns of crop damage by wild pigs ($\beta = -0.04$ [SE = 0.13], $P = 0.74$). However, the independent explanatory power of the variable was low (McFadden's *R*² = 0.04). Spatial autocorrelation between crop loss

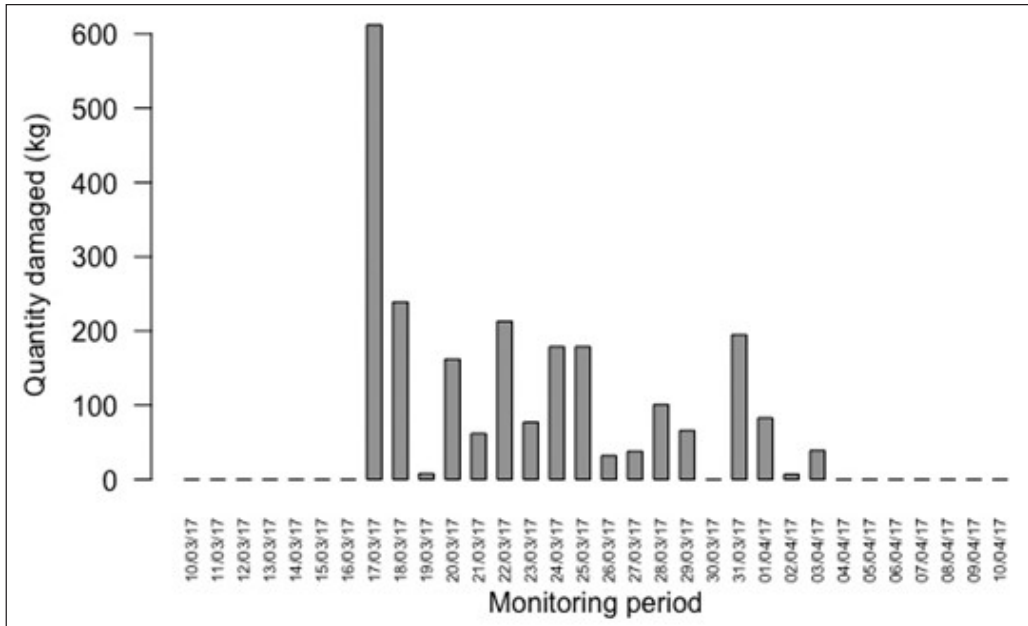


Figure 2. Day-wise loss of wheat (*Triticum aestivum*) crop by wild pigs (*Sus scrofa*) recorded during harvest season in Gujjar Basti settlement in Gaidikhata village in Haridwar Forest Division, India.

Table 2. Summary of model selection results to assess the effect of 2 covariates on probability of crop damage by wild pigs (*Sus scrofa*) in Gujjar Basti settlement in Gaidikhata village. DistFor = proximity to forest boundary; CropProt = cumulative crop protection measures used by the respondents.

Logistic regression model	K	Residual deviance	Null deviance	AIC	ΔAIC	McFadden’s R ²
CropLoss~DistFor	2	163.74	205.19	167.64	0	0.20
CropLoss~DistFor + CropProt	3	163.27	205.19	169.27	1.63	0.20
CropLoss~DistFor*CropProt	3	163.25	205.19	171.25	3.61	0.20
CropLoss~CropProt	2	196.77	205.19	200.77	32.83	0.04
CropLoss~1 (intercept only)	1	205.19	205.19	207.19	39.55	

Table 3. Parameter estimates based on model averaging of the top models (ΔAIC<1.63). DistFor = proximity to forest boundary; CropProt = cumulative crop protection measures used by the respondents.

Variable	Estimate	SE	95% CI (lower)	95% CI (upper)	Z	P
Intercept	-2.12	0.42	-2.96	-1.27	4.93	<0.001
DistFor	-1.65	0.34	-2.34	-0.97	4.73	<0.001
CropProt	-0.04	0.13	-0.54	0.26	0.33	0.74

locations was not high (Moran’s I = 0.199, Z = 6.24, P < 0.001).

Discussion

Large herbivores like wild pigs damage cultivated crops particularly during flowering and grain setting stages (Gubbi 2012, Pandey et al. 2016). This motivated us to monitor wild pig-related crop losses after standing wheat started

flowering. Of the 32 days of monitoring crop loss by wild pigs, most of the losses occurred for a short period of around 17 days when the grain appears succulent. As grains mature, dry up, and get ready for harvest, the intensity of damage by wild pigs reduced. Therefore, it seems plausible that intensive guarding of cereal crops for a short duration of about 20–25 days when grains mature could bring down losses substantially. Further,

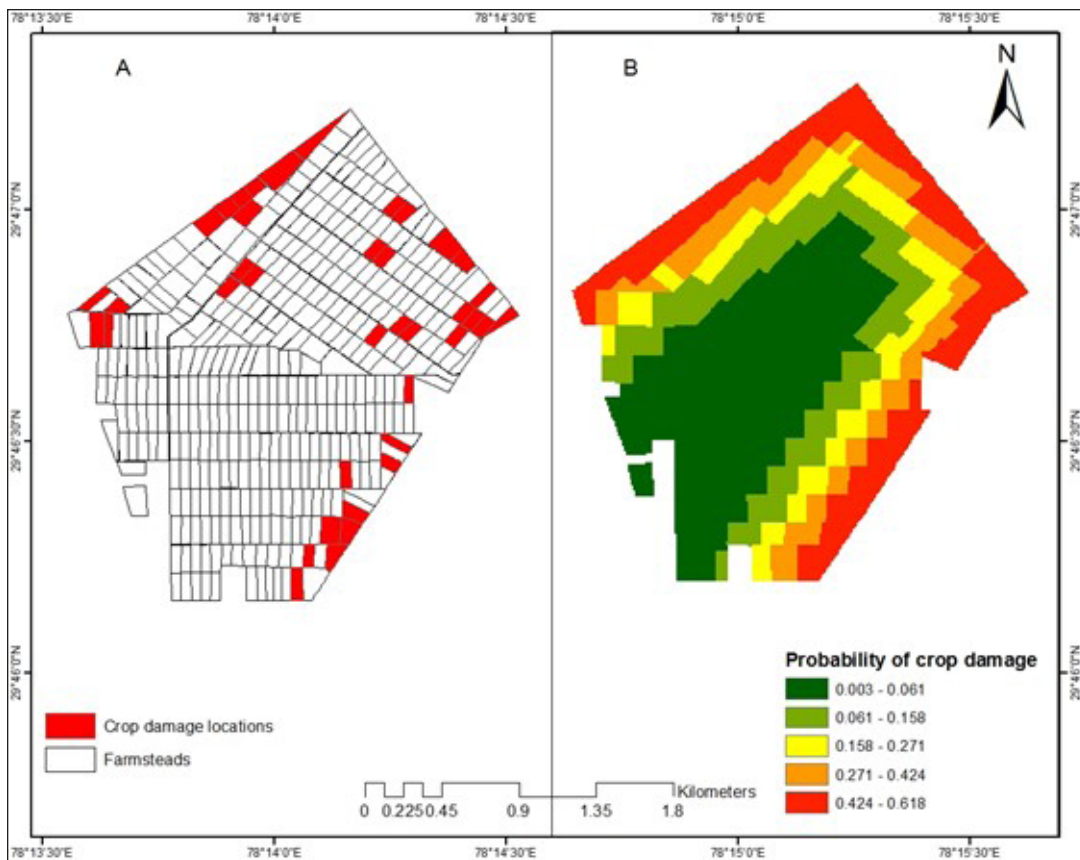


Figure 3. (A) Locations of crop damage by wild pigs (*Sus scrofa*) recorded in the field; (B) probability of crop damage predicted by the regression model with distance to forest as a covariate.

because crop damage by wild pigs is seasonal, mobile fences that can be dismantled and packed away after use would be beneficial.

At the settlement level (comprised of 400 farmsteads), quantified losses due to wild pigs may seem insignificant. However, for affected individual farmers and their families, losses can be substantial. For example, a farmer whose farm was adjoining the forest had lost about 17% of the potential yield to wild pigs. Such high financial losses could be economically devastating for highly marginalized families. Recurrent losses of this magnitude can increase their debts, which are usually obtained with high interest rates, and affect social wellbeing, livelihood, and food security, creating a deep-seated antipathy toward wildlife (Woodroffe et al. 2005, Barua et al. 2013). Our results corroborate with Naughton-Treves (1998), who suggested that average losses are meaningless for farmers who lose most of the yield to wild animals. Therefore, implementing schemes like Pradhan Mantri Fasal Bima Yojana

(Prime Minister's crop insurance scheme of the Federal Government, <https://pmfby.gov.in>) to assuage the losses of individual farmers in areas of high wildlife conflict would be beneficial for both wildlife and local communities.

Our results underscore notable differences between perceived and actual crop losses. Quantified actual crop losses were significantly lower than losses perceived by communities. The respondents' reported losses seem to reflect high levels of losses suffered by a few individual farmers during the survey period. It is noteworthy that the perception about wildlife-related losses may not necessarily be influenced only by current losses but also by factors like past experiences, perceived ownership of wildlife, anticipated future losses, and others (Gillingham and Lee 2003). Perceived conflict being at odds with reality was observed in the case of other large mammals as well. In the trans-Himalayan region, although livestock depredation by wolves (*Canis lupus*) was lower than snow leopards (*Panthera uncia*)

and feral dogs, local communities perceived conflict to be higher with wolves than snow leopards (Suryawanshi et al. 2013). Similarly, Rabinowitz (2014) elucidates that perceived conflict due to jaguars (*Panthera onca*) in South America was much higher than the actual levels of conflict. These studies emphasize the need to supplement stakeholder interviews with objective assessment of losses wherever possible to gain a finer level of understanding of the problem.

Proximity to the forest explains the observed spatial variation in patterns of crop loss by wild pigs, whereby the probability of crop loss decreased with increase in the distance to the forest boundary. About 81% of farmlands that suffered crop damage by wild pigs were within 200 m of the forest boundary. Further, about 58% of the recorded damages were within 100 m of the forest boundary. This result was intuitive as our study site was an enclave surrounded by forest, where crops like wheat and paddy are cultivated. Short-statured crops like paddy and wheat may not provide daytime shelter to wild pig sounders, unlike tall-statured crops like sugarcane (*Saccharum officinarum*). Therefore, wild pigs might return to forests during daytime and raid crops during the night. Given this, developing appropriate barriers and intensive guarding along the perimeter of agricultural areas could be effective in reducing crop losses due to wild pigs. Therefore, if farmers at the edges are adequately incentivized and assisted in guarding by other members of the community, crop damage over a large area can potentially be reduced. Further, since the problem of crop damage is acute only for a few weeks, developing seasonal fences can be beneficial instead of investing in permanent barriers.

The second variable in our models, the crop protection measures by households, adds to the effect of proximity to forest boundary in explaining the observed spatial variation in wild pig-related crop loss. However, its independent effect was weak. We observed that crop protection measures in the settlement were mostly reactive, based on daily management decisions as observed by Naughton-Treves (1998) in Kibale National Park, Uganda. During the study, it was observed that farmers intensified crop guarding only after wild pigs raided their farms. This was likely the reason why crop protection index did not emerge significant in our regression models.

Regardless of the effect of crop protection as a variable, farmers in the study area do invest in a variety of crop protection measures to guard their fields from wild herbivores (L. Natarajan, personal observation).

Notwithstanding the severity of conflict with wild pigs, efforts to understand their population dynamics and management aspects continue to be negligible. With significant gaps in their basic ecology and behavior, even designing a field study to assess conflict is far from easy. Therefore, in high conflict areas, monitoring wild pig populations and objectively evaluating management strategies aimed at mitigating losses assume priority. Here, we demonstrate the utility of field surveys to provide important insights on patterns of crop losses as well as general perceptions of villagers about conflict. We hope that our study, which certainly is limited in scope because we could not replicate it in other areas as well as other seasons, nevertheless fuels future research and consequent policy perspectives.

Limitations of the study

Given the scope of the study, our assessment was carried out in just 1 settlement, where the community stakeholders are similar. To generalize the findings of the study, experimenting in a few more forest enclaves would be important. Being a short-duration study with a very specific set of *a priori* objectives, relative abundance of wild pigs, can be an important variable in influencing local crop losses. Nevertheless, the findings discussed in the paper demonstrate the significance of evidence-based approaches (Sutherland et al. 2004) to the management of human–wildlife conflict.

Acknowledgments

We thank Uttarakhand Forest Department for funding support. In particular, we acknowledge the support provided by the chief wildlife warden and principal chief conservator of forests (wildlife), Government of Uttarakhand. We also extend our thanks to additional principal chief conservators of forests, wildlife and CAMPA divisions, for their unstinting support for the project. We thank the director, dean, and research coordinator of the Wildlife Institute of India for providing us institutional support. We acknowledge the superb assistance in the field by our assistants I. Hussein, I. Ali, and B. Ali.

Comments provided by J. Tomeček, HWI associate editor, and 3 anonymous reviewers greatly improved an earlier version of our paper.

Supplemental materials

The questionnaire can be downloaded as a supplemental file at <https://digitalcommons.usu.edu/hwi/vol15/iss1/12>.

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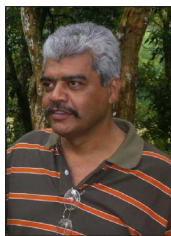
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