Research article

EFFECTIVENESS OF CROP AND LIVESTOCK PROTECTION METHODS AGAINST WILDLIFE DAMAGE: A CASE FROM CHITWAN NATIONAL PARK, NEPAL

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ABSTRACT

Human-wildlife conflict is a major issue for policymakers and conservationists due to economic loss to the communities living in the close territory of the park, affecting their livelihoods and wellbeing. This study aims at identifying and quantifying wildlife-induced damages on crops and livestock and methods used by communities for crop and livestock protection. A total of 434 households living in the vicinity of the park from the ten forest user groups around the Chitwan national parks and buffer zone were randomly sampled and interviewed with the use of semi-structured questionnaires in the year 2021. Findings revealed a total of 87.86% of rice-growing households reported the damage of rice whereas 90.32% and 87.68% of households reported the damage to wheat and maize, respectively. The annual loss of 78 kg of rice per household (NRs. 1776 at prevailing market rates) was reported along with the loss of wheat (86 Kg-worth of NRs. 2,523) and maize (96 Kg-worth of NRs. 2,019) per household. About 59% of households had lost at least a livestock species and poultry in last year, and that varied well across the sectors. Twelve different methods and techniques were identified by communities that were used regularly to prevent crop damage and livestock loss with the majority of people using certain methods and techniques against crop damage and livestock loss. A total of 425 (97.93%) were reported that they used at least one method and technique to prevent crop damage and livestock loss. Among all these methods, crop guarding, shouting, use of natural fences, guarding by dogs, and throwing stones were the most effective and safest practices/techniques, but the use of a single means and approach was found ineffective. This suggests the need for developing site-specific management techniques to minimize crop damage and livestock loss in the National Park vicinity and adjoining protected areas. Apart from the different mitigating means, construction, and maintaining permanent fences on the border of the national parks, there should be the provision of conservation education to communities bordering protected areas to practice sustainable agriculture and income-generating programs that are conservation-friendly. that may include, for example, provision of conservation educations along with income-generating programs that are conservation-friendly.

Keywords: Human-wildlife conflict, wildlife damage management, Chitwan national park

INTRODUCTION

The protected area is the geographical space that is recognized, dedicated, and managed through the legal and other effective means for the conservation of nature. It includes national parks, wilderness areas, community conserved areas, nature reserves, and so on. They are a backbone of biodiversity conservation and also contribute to local people's livelihoods by providing food, clean water supply, medicines, and mitigating natural disasters (Lopoukhine et al., 2012). Wildlife and people have co-existed for many years, usually have a certain level of conflict (Dickman, Macdonald, & Macdonald, 2011). In recent years, however, the conflict has increased, particularly in developing countries, mainly due to increasing human and livestock populations and changing socio-economic and land use patterns (Gemeda & Meles, 2018). Communities bordering protected areas may suffer the loss of economic opportunities, including prohibiting from potential resources as well as damage and depredation to crops and livestock by wild animals (Holmern, Nyahongo, & Roskaft, 2007). Conflict around protected areas also has been considered as the main obstacle for the successful management and conservation of biodiversity (Ghimire & Pimbert, 1997).

Chitwan National Park (CNP) is home to many globally significant, rare, and endangered wild animals. It is one of the most threatened national parks in Nepal (The Himalayan Times, 2021). The buffer zone area has increasing population density and similar projection in the future also; resulting in the human-wildlife conflict. Dense human populations in close vicinity to nature reserves seem to pose the greatest

challenges in many countries (Western, 1989) which is equally true in the case of CNP and its buffer zone. The people-park conflict had also been an ongoing issue due to the wildlife impacts in adjacent communities. On the other hand, local community members have been continuously ignoring regulations and are engaged in grazing their cattle inside the park (Nepal & Weber, 1995). Competition between rural communities and wild animals over natural resources is more intense in developing countries, where local human populations tend to suffer higher costs. Considering the current human population growth rate, increasing demand for resources, and the growing demand for access to land, it is clear that human-wildlife conflicts (HWC) will still be a challenge.

HWC has both direct and indirect costs for human beings. Destruction and loss of food crops, livestock depredation, and human harassment are direct costs of human-wildlife conflict. Researchers have identified elephant (*Elephas maximus*), rhino (*Rhinoceros unicornis*), wild boar (*Sus scrofa*), deer (*Axis axis*), monkey (*Macaca mulatta*), snow leopard (*Uncia uncia*), parakeets (*Psittacula eupatria nipalensis*) as the main destroyers in most of the protected areas of Nepal (Adhikari, 2000; Baral & Heinen, 2007; Oli et al., 1994; Strudsrod & Wegge, 1995). These animals feed on a variety of crops including, rice (*Oryza sativa*), wheat (*Triticum aestivum*), maize (*Zea mays*), lentils (*Lens culinaris*), underground tubers such as potato (*Solanum tuberosum*), yam (*Dioscorea alata*), and Colocasia (*Colocasia esculenta*). The level of damage varies according to the distance between the park and the farmland (Thapa, 2010). Livestock depredations by leopards or tigers are common around the major protected area of Nepal (Sijapati, Sharma, Sharma, Subedi, & Belant, 2021). Villagers use different means to guard against these wild animals, such as fences, trenches, and traditional means. However, due to the difference in these wild animals' sizes, feeding habits, types of crops, and distance to farmland, no single measure can be sufficient for all of them (Thapa, 2010). Human activities such as expansions of settlements, increasing population, cultivation, overgrazing, bushfire, and deforestation reduce wildlife habitats thus forcing wild animals to enter the croplands causing trampling and destruction of crops (Galanti, Preatoni, Martinoti, Wauters, & Tosi, 2006; Roskaft, Larsen, Mojaphoko, Sarker, & Jackson, 2013). To control human-wildlife conflict the first approach should be to understand the negative impacts of wild animals on livelihood (Mekonen, 2020). The paper aims to identify the nature and extent of the wildlife damage, and the efficacy of damage management methods by the local people around the Chitwan National Park, Nepal to help the park management to formulate sound management strategies to support the communities' livelihoods and also to improve park-people relationships.

MATERIALS AND METHODS

Study area

The study was done in the buffer zones of Chitwan National Park in southern central Nepal (27°16.56'–27°42.14'N and 83°50.23'– 84°46.25'E). The Chitwan National Park (CNP) is one of the largest parks in the lowland Terai region that covers an area of 952.63km^2 including those from Chitwan, Nawalparasi, Parsa, and Makawanpur districts in south-central Nepal (Figure 1). The area was gazetted as the country's first national park in 1973, recognizing its unique ecosystems of international significance. UNESCO declared CNP a World Heritage Site in 1984. In 1996 an area of 750 km^2 surrounding the park was declared a buffer zone, which consists of forests and private lands including cultivated lands.

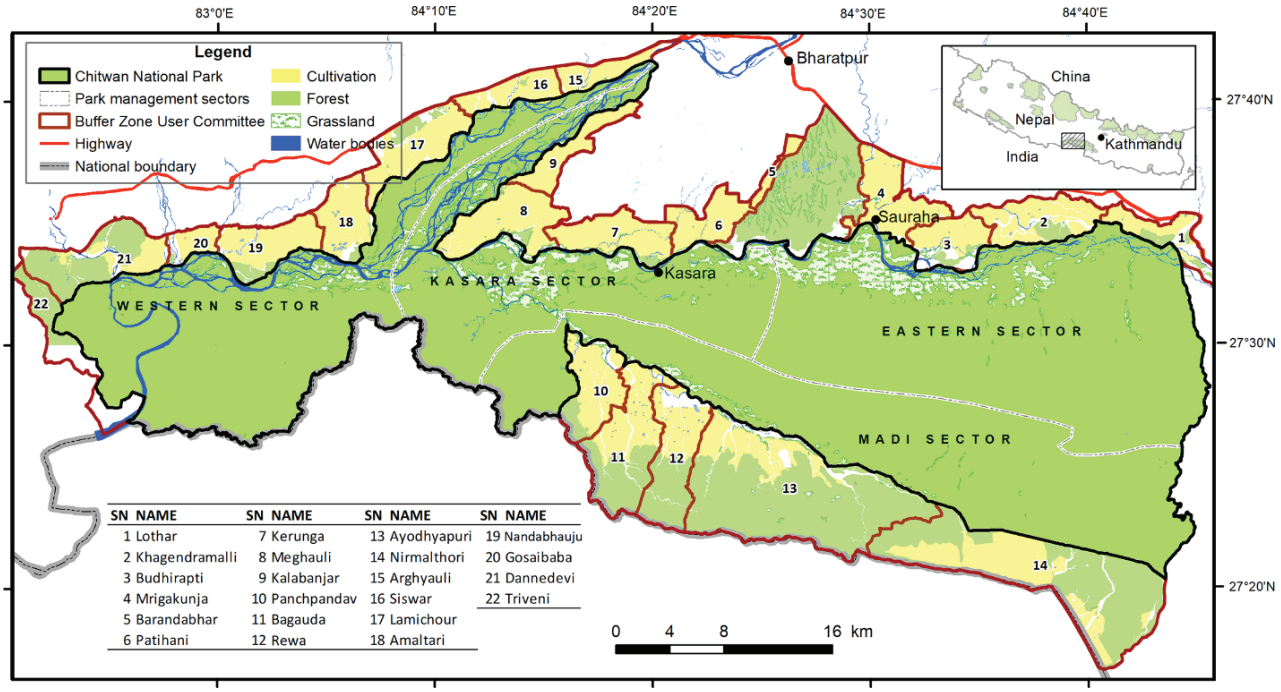

Figure 1. Locations of the buffer zones (study area) of Chitwan National Park, Nepal.

Note: The labels (1–22) represents the Buffer Zone User Committees (BZUC)

Sampling technique and methods of data collection

To achieve the objectives of the study, the target population comprised the households living adjacent to the park. The sample size was determined by using the formula of Kothari (2004) at a 95% confidence level. The study population is a total of 50,943 households adjacent to the Park (buffer zone area) and 434 households were sampled in the study. From the secondary source, the total number of conflicts were recorded from the different forest users' groups in the last four years and the top ten forest user groups were selected (wildlife damage and relief distribution records book and annual reports of CNP, https://www.chitwannationalpark.gov.np/). Based on the total number of conflicts that occurred in the last four years, the number of samples in each forest user group was estimated (Table 1). In each forest user group, the households near the national parks are considered as the population and simple random sampling was employed in that area.

Table 1. Top ten committees based on the number of human-wildlife conflicts (HWC) encountered in the last four years and number of samples from respective forest user groups

Forest user groups	No of conflict	Address	Number of samples	Sector
Ayodhyapuri	330	Ayodhyapuri-1*, 6, 7, 8, Madi 7, 8, 9, 10*, 11, 12	155	Madi
Rewa	101	Madi-6, 7*, 8, 9; Kalyanpur 3, 4, 5, 7, 8, 9*	50	Madi
Panchpandab	78	Gardi 1*, 2, 4, 7 Madi 1*	40	Madi
Mriga Kunja	70	Ratnanagar-5*, 6, 7*, 8, 9, 17, 18, Bachhyauli-2	34	Sauraha
Barandabhar	64	Gitanagar 4, 6, Bharatpur 6, 8*,13, 20, 21*	32	Kasara
Nirmal Thori	59	Nirmal Basti 1, 2*, 3, 7, Thori 8	30	Madi
Meghauli	46	Narayani 1, 2, 3, Bharatpur 27, 28	25	Kasara
Baghauda	34	Bagauda 2, 4 Madi 3, 5	18	Madi
Kerunga	32	Bharatpur 23, 24, Jagatpur 1, 9, Narayani 10, 11	15	Kasara
Lamichaur	27	Pithauli 4, Kawasoti 11, 13	35	Amaltari
Total			**434**	

Note: * Highly conflict ward

Face-to-face interviews were conducted with the head of the household (wherever possible) with the help of a semi-structured questionnaire from August to October of 2021. The questionnaires were first pretested on 20 households of Bharatpur Metropolitan – 8, Gaurijung, Chitwan and necessary modifications were done. The household questionnaire consisted of two parts: i) crop damage and problem animals ii) measures used for crop and livestock production protection and their effectiveness.

Methods of data analysis

Chitwan National Park Office (2015) was divided into four sectors and the area of responsibilities were assigned i.e. Amaltari (Western sector), Kasara (Mid sector), Sauraha (Eastern sector), and Madi-Bagai (southern sector). After the collection of primary data, it was coded and entered in Microsoft Excel, and analysis was done by using Statistical Packages for Social Sciences (SPSS). Mean, frequency and percentage were calculated using the SPSS. Major wildlife that caused the crop damage was ranked with the use of the index. The intensity of wild animals being faced by the respondents was identified by using the five-point scaling technique (1.00, 0.80, 0.60, 0.40, and 0.20). The formula given below was used to find the index for the intensity of problems faced by respondents.

$$I_{prob}=\sum \frac{S_i \quad F_i}{N}$$

Where,

I_{prob} = Index value for intensity of problem
Σ = Summation
S_i = Scale value of i^{th} intensity
F_i = Frequency of i^{th} response
N = Total number of respondents

RESULTS AND DISCUSSION

Data on loss by wildlife to humans and properties were collected from the record of the CNP authorities and the buffer zone user committee (BZUC) mainly for the period of 1998 to 2018. People began reporting loss from wildlife (primarily attacks to human and livestock depredation) to the BZUCs just after the relief scheme for wildlife victims was launched in 1999 along with the implementation of the Buffer Zone Program (GoN, 1996; CNP, 2015). The wildlife victims in the BZ self-reported the incidents through applications to the local authorities (CNP or BZUC) primarily to claim compensation (only partial cost). The conflict incidents were verified by the BZUC and subsequently, relief was released as per the guidelines. These data of relief application and distribution were kept in registers by BZUCs between 1998 and 2009. The government-endorsed the relief guideline of wildlife losses in 2009 and designated respective protected areas or district forest offices for relief distribution. Thus, CNP started to process and verify the relief applications from 2009 onwards. We compiled all the relief applications of wildlife victims reported to both BZUCs and CNP during 20 years (1998 to 2018). The data were managed according to the Nepalese fiscal year which runs from mid-July to mid-July based on the Nepalese Calendar (Bikram Sambat). For the consistency of the data for time series analysis, we used these fiscal years. The trend of the total number of damages was slightly in increasing trend (Figure 2a). The pattern of human-wildlife conflict (HWC) in the BZUCs of the CNP revealed that livestock predation is the most common type of harm caused by wild animals in the study area followed by crop damage and human injuries (Figure 2b).

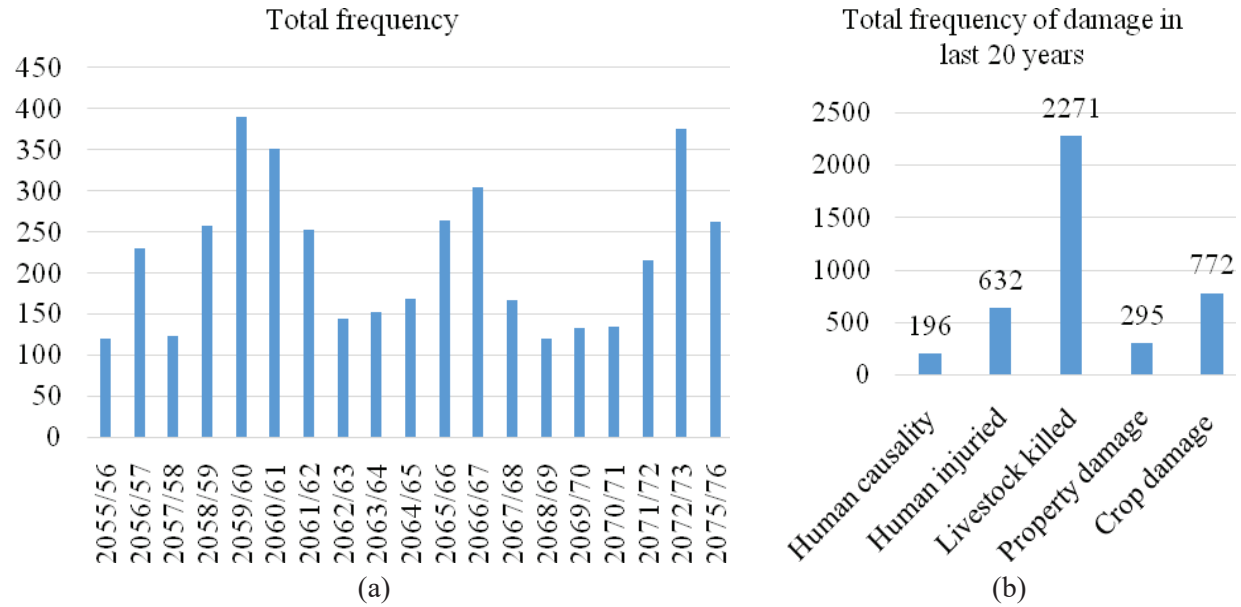

Figure 2. Frequency of (a) total damages due to wild-life encroachment around CNP, (b) different types of wild-life related damages to crops, livestock, properties, and human life in the last 20 years around Chitwan National Park

Crop damage

Wild animals in general damaged all types of crops cultivated at the farmland, but with a varying degree of damage. We found seven different crops that were cultivated at the farm in the vicinity of the park including rice, wheat, maize, mustard, lentils, potato, and seasonal vegetables. A total of 369 (87.65%) households reported that the rice crop was damaged by the wildlife (not including the birds) in a significant amount followed by wheat as responded by 90.3% of respondents. Likewise, about four-fifth of respondents reported similar damages for maize whereas three-fourth of them responded to the damage also for oilseed crops (Table 2). Hundred percent of respondents from Amaltari reported the rice crop damage by the wildlife whereas 83.16% from the Madi sector reported the rice damage. More than 95% of respondents reported their rice crop damage from the Kasara and Sauraha sectors. Hundred percent of respondents from Sauraha reported the wheat crop damage by the wildlife whereas 80% from the Kasara sector reported the wheat damage. More than 90% of surveyed households reported their wheat crop damage. More than 90% of respondents from Sauraha, Kasara, and Amaltari reported the maize crop damage by the wildlife (Table 2).

Table 2. Proportion of household report damage of common crops

Crops	Households (HH)	Study site				Total
		Amaltari	Kasara	Madi	Sauraha	
Rice	Cultivated	35	68	285	33	421
	Report damage	35 (100)	65 (95.59)	237 (83.16)	32 (96.97)	369 (87.65)
Wheat	Cultivated	0	5	86	2	93
	Report damage	-	4 (80.00)	78 (90.70)	2 (100)	84 (90.32)
Maize	Cultivated	28	57	169	30	284
	Report damage	26 (92.86)	53 (92.98)	141 (83.43)	29 (96.67)	249 (87.68)
Oilseed	Cultivated	20	38	178	28	264
	Report damage	15(75.00)	29(76.32)	127(71.35)	28(100.00)	199(75.38)
Legumes	Cultivated	4	22	36	1	63
	Report damage	3(75.00)	17(77.27)	28(77.78)	1(100.00)	49(77.78)
Potato	Cultivated	14	18	62	7	101
	Report damage	11(78.57)	14(77.78)	26(41.94)	4(57.14)	55(54.46)
Vegetables	Cultivated	6	16	15	2	39
	Report damage	6(100.00)	8(50.00)	6(40.00)	2(100.00)	22(56.41)

Source: Field Survey, 2021

Note: Figures in the parentheses indicate the percent of households' report damage

The scenario of the magnitude of wildlife damage to the major crops in the study sites has been presented in Table (3). Out of 13.12 kattha rice cultivation, 3.21 kattha was damaged by the wildlife with average proportion damage of 25.74% (Table 3). Out of 8.31 kattha wheat cultivation, 3.14 kattha was damaged by the wildlife with average proportion damage of 41.27%. On average 86 kg wheat/HH in terms of grains was damaged by the wildlife with a worth of NRs. 2583 per household at the prevailing market price. The scenario of rice damage is more visible in all sectors with the highest in Sauraha whereas wheat crop damage is also highly visible in Sauraha followed by Madi. Likewise, maize crop damage is higher in Madi followed by Sauraha. Wheat is not sown in Amaltari (Table 3). The Rhino is often regarded as the most destructive raider (Uprety, 1995) and prefers crops such as maize, rice, vegetables, and mustard resulting in substantial losses to the local farmers (Studsrod & Wegge, 1995).

Table 3. Magnitude of wildlife damage to major crops (June 2019 to April 2020)

Crops	Variables		Study site				Overall
			Amaltari	Kasara	Madi	Sauraha	
Rice	Average area (kattha/HH)	*Overall*	9.5	10.43	14.65	9.24	13.12
		Damage	3.66	2.66	3.17	4.16	3.21
	Proportion of damage (%)		33.99	28.22	22.09	38.72	25.74
	Damage amount/HH	*Volume (kg)*	172	101	57	221	78
		Value (NRs.)	3,958	2,517	1,253	5,736	1,776
Wheat	Average area (kattha/HH)	Overall	-	12.8	8.17	3	8.31
		Damage	-	3.25	3.17	1.5	3.14
	Proportion of damage (%)			-	32.28	41.5	50
	Damage amount/HH	Volume (kg)	-	73	87	68	86
		Value (NRs.)	-	2,196	2,597	2,030	2,583
Maize	Average area (kattha/HH)	Overall	7.64	8.51	9.71	6.62	8.94
		Damage	3.33	4.73	3.97	2.87	3.94
	Proportion of damage (%)			29.6	52.72	38.12	39.05
	Damage amount/HH	Volume (kg)	91	185	79	68	96
		Value (NRs.)	2,004	4,266	1,585	1,555	2,019

Source: Field Survey, 2021

Note: Rice price depends on the area, on average 1 kg of rice is priced NRs. 23 at Amaltari, 25 at Kasara, 22 at Madi, and 26 at Sauraha; on an average 1 kg wheat-priced NRs. 30; and maize price depends on the area, on an average 1 kg maize priced NRs. 22 at Amaltari, 23 at Kasara, 20 at Madi and 23 at Sauraha.

Households identified mainly 12 different problem species: elephant (*E. maximus*), rhino (*R. unicornis*), blue bull (*B. tragocamelus*), wild boar (*S. scrofa*), chital (*Axis axis*), Himalayan ghoral (*Naemorhedus goral*), rhesus monkey (*Macaca mulatta*), wild cat (*Felis silvestris*), rabbit (*Oryctolagus cuniculus*), fox (*Vulpes vulpes*), birds, and porcupine (*Erethizon dorsatum*). Among these, rhinos, wild boars, elephants, chital, and birds especially the peacock (*Pavo cristatus*) posed severe damage to the crops. The ranking of the problem animals was varied across the sectors. In Amaltari and Kasara wild boar was the major species so as the rhino in the Madi sector and the elephant in the Sauraha sector (Table 4). The damage by the peacock was less significant and limited to specific farms and few villages.

Table 4. Ranking of problem animals in the surveyed area around the Chitwan National park

Wild animals	Study site								Overall	
	Amaltari		Kasara		Madi		Sauraha			
Rhino	0.80	II	0.64	III	0.85	I	0.70	III	0.80	I
Elephant	0.44	IV	0.47	IV	0.65	III	0.76	I	0.63	III
Wild bore	0.87	I	0.94	I	0.76	II	0.75	II	0.80	I
Chital	0.71	III	0.68	II	0.54	IV	0.63	IV	0.58	IV
Birds	0.48	V	0.41	V	0.31	V	0.33	V	0.34	V

Source: Field Survey, 2021

Rhino, wild boars, and elephants were the most damaging animals (Table 4), which is similar to the finding of Sukumar (1994). The damage by wild boar was probably the most widespread (Subedi, Joshi, Poudel, & Lamichhane, 2020). Dangol, Ghimire, & Bhattarai (2020) reported that elephants raided cropland due to lack of natural food in the forest mainly due to increasing human encroachment and settlement near the forest. According to Shrestha (2007), Pradhan et al. (2011), and Neupane et al. (2013), the rate of HWC incidents in Nepal was increasing. Crop damage by the rhinos was the major source of conflict between farmers and wildlife in communities that surround Chitwan National Park (Bailey, 2011).

It was observed that most of the wild animals grazed the farmers' fields between dusk and dawn. Animals were active from 4:00-5:00 pm to 5:00-6:00 am. Most of the households at Kasara and Madi area mentioned that chitals grazed almost daily as they grazed everything whatever was found green even in the mid-day. Similarly, wild boar was a daily visitor to their farmlands. Households reported that the visits of elephants were restricted to once or twice a month or even rare, particularly during the rice ripening season. It was observed that the frequency of visits by animals depended on the crops grown and the season. For instance, if there is a potato in the farmland wild boar continued to visit the farmland until it has destroyed all the potatoes, so the frequency would be daily within that period. Similarly, during the season of growing rice, which is during September and October, elephants make a daily visit, whereas in other times the visits are limited to once or twice a month. The visit of most of the wild animals was frequent in the season when there was a lack of forage in the national park and the buffer zone.

Livestock and poultry losses

Among 434 households, 256 (58.99%) households lost one or more types of livestock and poultry last year, and the scenario varied across the sectors. More than four-fifth of the respondents from the Amaltari (85.71%), Sauraha (82.35%), and Kasara (77.78%) reported that they lost at least a livestock species and poultry in last year (table not presented).

The status of households with the loss of at least one livestock species, poultry, and fish in the last two years has been presented in Table (5). Accordingly, overall, about three-fourth of the respondents reported the loss of poultry/duck and half of the respondents had the situation of goat loss. Less than one-tenth of the respondents reported the loss of cattle, buffalo, pigs, and fish (Table 5). If we look at the scenario from a sectoral perspective, poultry /duck loss was highest in all sectors with the highest loss in Amaltari followed by Madi and Sauraha. Kasara, Madi, and Sauraha also had the highest number of goat losses due to wildlife attacks. The status of cattle and buffalo losses are somehow similar in all sectors (Table 5). It was also learned that the tiger was the major predator of the livestock, leopard and wolf were of poultry and crocodile for fish. A significant number of the fish growers in the Madi area reported that crocodiles catch and eat the fish of the pond. Respondents ranked leopard as the most serious cause of the livestock loss followed by the fox, tiger, crocodile and the least problem is from the bear.

Table 5. Households reported the loss of at least livestock, poultry, and fish in the last two years due to wild animals

Livestock, poultry and fish loss	Study site				Overall
	Amaltari	Kasara	Madi	Sauraha	
Cattle	1(3.23)	15(23.44)	11(5.67)	2(7.14)	29(9.15)
Buffalo	2(6.45)	2(3.13)	14(7.22)	2(7.14)	20(6.31)
Pig	1(3.23)	2(3.13)	4(2.06)	0.00	7(2.21)
Poultry/Duck	29(93.55)	40(62.50)	150(77.32)	20(71.43)	239(75.39)
Goat	5(16.13)	22(34.38)	105(54.12)	10(35.71)	142(44.79)
Fish	4(12.90)	0.00	14(7.22)	0.00	18(5.68)

Source: Field Survey, 2021

Note: response from the multiple response types of questions

Methods and techniques used and their effectiveness for crop protection

It was observed that a single crop was fed on by more than one animal during the entire cultivation period. Thus the households have developed a combination of different methods to minimize the crop, livestock, and poultry loss around their farmland, and grazing sites. Findings revealed that out of 434 respondents, a total of 425 (97.93%) had reported that they used at least one method for crop and livestock protection from the wild animals' attack and encroachment. About nine-tenth (91.43%) of respondents from the Amaltari, and almost all respondents from the Madi (97.95%), Kasara and Sauraha reported that they have been adopting these methods. The methods and techniques followed to protect their crop and livestock were different and varied well according to the sector (data not included). Crop guarding, shouting, use of the flashlight, throwing stones, scaring by hitting tin, and the use of scarecrow was some of the common methods used for protection (Table 6).

Table 6. Local methods and techniques used by the respondents for protection of crops and animals against wildlife attack and encroachment in the study sites, CNP, Chitwan

Methods and techniques	Problematic animals						
	Wild bore (N = 422)	Fox (N=355)	Leopard (N=298)	Rhino (N=377)	Elephant (N=384)	Chital (N=386)	Birds (N=327)
Crop guarding	68.01	48.17	33.22	51.19	45.83	64.77	59.94
Shouting	88.86	82.54	66.78	71.09	66.15	83.16	96.94
Following with fire	19.43	8.73	49.66	80.37	81.51	11.66	3.36
Alarm	4.50	2.25	23.15	26.53	27.60	1.04	0.31
Change in farming system	11.14	31.27	5.03	14.32	9.38	8.55	7.65
Flashlight	26.07	13.24	51.68	59.42	57.55	19.17	4.89
Natural fence	47.63	47.61	16.78	33.42	19.53	47.93	28.75
Throwing stones	56.87	60.56	10.07	15.38	12.24	50.52	57.80
Scaring by hitting the tin	70.85	61.97	66.44	79.58	80.47	63.99	77.98
Try to kill the wildlife	5.69	0.85	0.67	0	0	1.04	3.36
Scarecrow	56.40	47.32	5.03	18.30	7.81	52.33	80.12
Guarding by dogs	28.91	31.27	15.10	19.36	12.76	27.20	16.82

Source: Field Survey, 2021

Note: Figures in the parentheses indicate the percent of household report damage and responses from the multiple response types of questions

Effectiveness was measured in terms of the quality of methods being able to keep the target animals away from farmland. Findings revealed that crop guarding, shouting, use of a natural fence, scaring by hitting tin, and throwing stones are the most effective measures (Table 7). The effectiveness is also varied across the sector due to the variation in types and nature of wild animals. Finding also revealed the fact that changes in farming system/cropping pattern and use of alarm were less effective measures compared to others. Some farmers reported that the killing of wild animals was also practiced but was less effective. Thapa (2010) reported that crop guarding through the use of Machan combined with group shouting and throwing flaming sticks was most effective for all kinds of wild animals to drove them away from the farm and barn. Strudsrod & Wegge (1995) in their study in Bardia National Park reported that guarding by using different combinations of methods was found most effective for crop protection. Similarly, in the Chitwan National Park, Nepal & Weber (1995) mentioned that crop guarding using Machans was found highly effective. In Bardia also, it was observed that crops in the farmland close to the buffer zone community forest were damaged more than in other areas. Although guarding through the use of Machan was the most effective, financially viable, and safest means, it was a tedious and time-consuming process. Crop guarding using Machan was especially useful against elephants and rhinos as these animals could chargeback and even kill when they find humans in their way (Thapa, 2010). Other methods involving noise-making through different means were hardly successful (Nepal & Weber, 1995). These kinds of methods such as noise-making through group warning, use of claps for the early warning can only work for a short time and erode over time due to habituation (Sitati, Walpole, & Leader-Williams, 2005).

Table 7. Local methods and techniques used for protection of crops and animals against wildlife attack and encroachment in the study sites, CNP, Chitwan

Rank	Amaltari	Kasara	Madi	Sauraha	Overall
I	Crop guarding	Shouting	Shouting	Crop guarding	Shouting
II	Shouting	Natural fence	Flashlight	Shouting	Natural fence
III	Throwing stones	Crop guarding	Natural fence	Natural fence	Crop guarding
IV	Scaring by hitting the tin	Flashlight	Crop guarding	Scaring by hitting the tin	Flashlight
V	Flashlight	Scarecrow	Guarding by dogs	Throwing stones	Throwing stones

Source: Field Survey, 2021

Natural fencing also termed as the bio-fencing with *Ipomoea* species as well as *Euphorbia* species creates a wall-like structure making entry difficult for small size as well large animals. *Euphorbia* species was most effective for rhinos and elephants as the plant is covered with long and sharp thorns which makes it completely impossible for wild animals to pass without being wounded (Thapa, 2010). Respondents in our study also stressed that when fully grown, the *Euphorbia* fence had completely stopped rhinos. Despite being effective, it was also reported that two main drawbacks arise if *Euphorbia* species were used: i) it takes a long time to grow to act as a barrier by creating a wall-like structure, and ii) when the plants grow older, the roots start to decompose and the whole plant falls. On the other hand, *Ipomea* species fencing was not reported effective for larger size animals such as rhinos and elephants. In Sariska Tiger Reserve, India, Sekhar (1998) also reported that combinations of measures are employed by households for effective crop protection.

CONCLUSION

Wildlife-induced damage to crops is threatening people's life near the borders of protected areas while humans have encroached the boundaries of Chitwan National Park and buffer zone making the situation further complicated. There were negative interactions between wildlife and local communities with the increased wildlife induced-damages over the years. The major problematic animals in the study area are rhino, wild boar, elephant, spotted deer, and birds whereas the majority of the people are suffering from crop damage as well as loss of livestock including poultry. Twelve different methods and techniques were identified by communities that were used regularly to prevent crop damage and livestock loss with the majority of people using certain methods and techniques against crop damage and livestock loss. Among all these means, crop

guarding, shouting, use of a natural fence, guarding by dogs, and throwing stones were the most effective and safest modes of crop guarding for all kinds of animals and crops. Different measures were used for different types of animals as well as different varieties of crops and crops growth stages; no single means would be regarded as effective. Problem animals differed according to the sectors and crops being damaged, which suggests that the use of a single measure would be ineffective. This highlights the need for developing site-specific management techniques to minimize the crop damage problem and livestock loss in the national Park vicinity and adjoin protected areas that may include, for example, income generation programs that are conservation-friendly.

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