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Migration of Wild Animals Towards Agricultural Fields in Response to Forest Fires in the Sunderbani Forest Range, Jammu and Kashmir

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Abstract

Forest fires can trigger short-term displacement and longer-term redistribution of wildlife into adjacent human-dominated landscapes. This study examined fire-related wildlife movement from forests toward agricultural fields in the Sunderbani Forest Range, Jammu and Kashmir, with emphasis on distance-dependent migration intensity and crop damage. A structured distance-gradient dataset covering 200–1000 m from the forest edge was used to code wildlife visitation frequency, document affected crops, and record visiting species and farmer-reported reasons for movement (Migration of wildlife towards farm fields in Sunderbani Forest Range). Wildlife visitation was very high up to 300 m, high at 400–500 m, moderate at 600–700 m, least at 800 m, very least at 900 m, and almost nil at 1000 m Linear regression showed a strong negative relationship between distance and visitation frequency, $\hat{y} = 5.6812 - 0.00536x$, with $R^2 = 0.8267$ and $F(1,7) = 33.39, p < .001$ Principal component analysis (PCA) on the standardised distance and frequency variables indicated that the first principal component (PC1) explained 95.46% of the variance, confirming a single dominant distance–frequency gradient Wheat, vegetables, and sugarcane emerged as the most affected crops The results identify a narrow but intense conflict zone within approximately 500–700 m of the forest edge and support spatially targeted fire and crop-protection measures .

Keywords: forest fires, wildlife migration, crop depredation, distance gradient, principal component analysis, Sunderbani Forest Range

Introduction

Wildfire is a natural and anthropogenic disturbance that reshapes habitat structure, resource distribution, and species interactions across forested landscapes (Kumar & Ram, 2019). In many parts of the Himalayas and Shivalik foothills, changes in land use and climate have coincided with increased fire frequency and altered fire regimes, with consequences that extend beyond forest boundaries into human-dominated systems (Sharma et al., 2014). When forest stands burn, animals face an immediate suite of stressors, including heat, smoke, loss of cover, and reduced food availability, and often respond by moving into adjacent unburnt refugia such as riparian strips, plantations, or agricultural land (Kumar & Ram, 2019; Nyhus, 2016). These displacement processes can be short-lived and local or can lead to longer-term redistribution of wildlife in ways that increase overlap with people and crops.

In South Asia, forest–agriculture mosaics are common, and even relatively small fires can therefore reconfigure the interface between wildlife habitat and cropland (Singh & Kour, 2018). At the same time, agricultural landscapes themselves have become attractive to many generalist species because high-yield crops, irrigation infrastructure, and human waste streams provide stable, predictable food and water resources (Madhusudan, 2003; Nyhus, 2016). When recurrent fires degrade in-forest food and shelter, this contrast between burnt forest and resource-rich fields can function as a powerful driver of wildlife movement toward villages, particularly for omnivores and meso-herbivores such as wild boar, monkeys, porcupines, and galliform birds. As a result, fire can act as both an ecological filter within forests and a catalyst for new or intensified patterns of human–wildlife conflict at their edges.

The Sunderbani Forest Range in Jammu and Kashmir is emblematic of such fire-prone edge landscapes. The range lies within the subtropical Shivalik foothills and is composed of chir pine (*Pinus roxburghii*) stands, mixed broadleaf forest, scrub, degraded patches, and extensive rainfed agriculture (Sharma et al., 2014). Local livelihoods depend heavily on seasonal crops such as wheat, vegetables, maize, bajra, pulses, and sugarcane, which are cultivated in close proximity to forest boundaries. The primary fire season spans the pre-monsoon months of April to June, overlapping with critical phenological stages of rabi harvest and early kharif sowing, as well as with the breeding season of many ground-nesting birds and small to medium-sized mammals (Sharma et al., 2014; Singh & Kour, 2018). Field notes from Sunderbani describe peahens incubating eggs in April–June and cases of nests and young being lost when fire fronts pass through breeding sites, with similar risks reported for wild goat kids and other ground-dwelling species. Such overlaps between fire timing and reproductive activity heighten both demographic impacts on wildlife populations and the likelihood of adults shifting into safer, food-rich environments such as croplands (Kumar & Ram, 2019).

Local forest and agriculture departments in Sunderbani have documented frequent complaints of crop depredation by wild boar, porcupine, monkeys, jungle cat, foxes, and several pheasant and francolin species, particularly in villages adjacent to the forest boundary. Farmers often attribute these incursions to repeated forest fires that "force the wild animals to move to safe places with their families," framing the fields as refuges that combine food, cover, and relative safety from fire. Similar narratives have been reported from other Indian landscapes where large mammals and generalist species exploit croplands as secondary habitats following disturbance inside protected areas (Madhusudan, 2003; Nyhus, 2016). Yet, most documentation from Sunderbani remains anecdotal, with few attempts to quantify how migration intensity changes with distance from the forest edge or to disentangle fire-related movements from other drivers such as seasonal food scarcity or habitat degradation.

Conceptually, distance from the forest edge can be viewed as a simple but informative spatial gradient that integrates multiple processes affecting wildlife movement and crop vulnerability. Near-edge fields often experience more frequent incursions because they are closest to escape cover, require minimal travel by animals, and may be visited at night or at dawn when human activity is low (Nyhus, 2016). Farther into the agricultural matrix, movement costs, exposure to humans, and lack of cover may dampen visitation intensity, even if crops remain attractive. Quantifying how visitation scores decay with distance can therefore help delineate “high-conflict belts” and guide spatial prioritisation of mitigation measures such as fencing, choice of crop types, early-warning systems.

Against this background, the present study uses a distance-gradient dataset from the Sunderbani Forest Range to characterise how wildlife visitation intensity to crops varies between 200 and 1,000 m from the forest edge, and to examine the statistical strength and structure of this relationship via linear regression and principal component analysis. By combining simple ordinal scoring with basic multivariate techniques, the study aims to provide a transparent, reproducible account of fire-associated migration patterns in Sunderbani, and to translate these patterns into concrete spatial recommendations for conflict mitigation.

Objectives

The study aimed to:

1. Characterise wildlife visitation frequency across distance bands from the forest edge using an ordinal scoring system.
2. Quantify the relationship between distance and visitation frequency with linear regression.
3. Summarise the dominant spatial gradient using PCA.
4. Identify the crops most affected by wildlife visitation and discuss implications for management.

Study Area

The study was conducted in the Sunderbani Forest Range, Jammu and Kashmir, India, within the Himalayan foothill landscape (Sharma et al., 2014). The area has a subtropical climate with hot summers, a dry fire-prone season from April to June, and a monsoon season that provides most annual rainfall (Sharma et al., 2014; Singh & Kour, 2018). The surrounding land use is a mosaic of forest, scrub, degraded land, and cultivated fields growing wheat, vegetables, pulses, maize, bajra, tuber crops, and sugarcane

The fire season overlaps with the breeding period of several species in the landscape. Field observations included notes that peahens are often incubating eggs during April–June and that nests may be destroyed by fire, while young wild goats and other ground-dwelling species may also be trapped in fast-moving flames. These seasonal overlaps likely intensify the ecological consequences of fire and may increase movement toward safer habitats, including farms (Kumar & Ram, 2019).

Data Source

Migration of wildlife towards farm fields in Sunderbani Forest Range								
S.No	**Distance from forest(mtr)**	**Species frequincy**	**Crop effected**	**Season o migration**	**Main reason o migration**	**Remarks**	**Main Visitors**	**Most effected crop**
1	200	very high	Wheat, Vegetables, Tuber crops maize, pulses, Bajra sugarcane	April tc June	Easy availability o food, shleter safety, safe place fo breeding anc roosting the young ones	Repeated fire forces the wilc animals tc move tc safe places with thei families	Peacock, rec jungle fowl khalijj peasent, Francolin, chir peasent wild boar leapord, wild goat hair, percupine, jungle cat	Wheat, vegetables, sugarcane
	300	Very high	Wheat, Vegetables, Tuber crops maize, pulses, Bajra	April tc June	Easy availability o food, shleter safety, safe place fo breeding anc roosting the young ones	Repeated fire forces the wilc animals tc move tc safe places with thei families	Peacock, rec jungle fowl khalijj peasent, Francolin, chir peasent wild boar leapord, wild goat hair, percupine, jungle cat	Wheat, vegetables, sugarcane
	400	High	Wheat, Vegetables, Tuber crops maize, pulses, Bajra	April tc June	Easy availability o food, shleter safety, safe place fo breeding anc roosting the young ones	Repeated fire forces the wilc animals tc move tc safe places with thei families	Peacock, rec jungle fowl khalijj peasent, Francolin, chir peasent wild boar leapord, wild goat hair, percupine, jungle cat	Wheat, vegetables, sugarcane
	500	High	Wheat, Vegetables, Tuber crops maize, pulses, Bajra	April tc June	Easy availability o food, shleter safety, safe place fo breeding anc	Repeated fire forces the wilc animals tc move tc safe places	Peacock, rec jungle fowl khalijj peasent, Francolin, chir peasent	Wheat, vegetables, sugarcane

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					roosting th young ones	with thei families	wild boar leapord, wild goat hair, percupine, jungle cat fox, monkey	
	600	Moderate	Wheat, Vegetables, Tuber crops maize, pulses, Bajra	April to June	Easy availability o food, shleter safety, safe place fo breeding and roosting the young ones	Repeated fire forces the wild animals to move to safe places with thei families	Wild boar Percupine, Wild cat Fox, monkey	Wheat, vegetables, sugarcane
	700	Moderate	Wheat, Vegetables, Tuber crops maize, pulses, Bajra	April to June	Easy availability o food, shleter safety, safe place fo breeding and roosting the young ones	Repeated fire forces the wild animals to move to safe places with thei families	Wild boar Percupine, Wild cat Fox, monkey	Wheat, vegetables, sugarcane
	800	Least	Wheat, Vegetables, Tuber crops maize, pulses, Bajra	April to June	Easy availability o food, shleter safety, safe place fo breeding and roosting the young ones	Repeated fire forces the wild animals to move to safe places with thei families	Wild boar Percupine, Wild cat Fox, monkey	Wheat, vegetables, sugarcane
	900	Very Least	Wheat, Vegetables, Tuber crops maize, pulses, Bajra	April to June	Easy availability o food, shleter safety, safe place fo breeding and roosting the young ones	Repeated fire forces the wild animals to move to safe places with thei families	Wild boar monkey	Wheat, vegetables, sugarcane
	1000	almost nil	Wheat, Vegetables, Tuber crops maize, pulses, Bajra	April to June	Easy availability o food, shleter safety, safe place fo breeding and roosting the young ones	Repeated fire forces the wild animals to move to safe places with thei families	Wild boar monkey	Wheat, vegetables, sugarcane

The analysis used the dataset titled *Migration of wildlife towards farm fields in Sunderbani Forest Range* Observations were recorded at nine distance bands from the forest edge: 200, 300, 400, 500, 600, 700, 800, 900, and 1,000 m For each distance class, the dataset documented species visitation frequency, affected crops, season of migration (April to June), stated reasons for migration (for example, "easy availability of food, shelter, safety"), remarks about fire-induced movement, main visiting species, and the most affected crops.

Variable Coding

Species visitation frequency was converted from ordered qualitative categories to ordinal numeric scores for statistical analysis. The categories were coded as almost nil = 0, very least = 1, least = 2, moderate = 3, high = 4, and very high = 5 .Distance from the forest edge was treated as a continuous predictor in meters.

Crop impact indicators were derived from the crop categories listed in the "crop effected" and "most effected crop" fields. Wheat, vegetables, and sugarcane were repeatedly identified as the most affected crops and thus treated as the core crop-impact variables for interpretation.

Statistical Analysis

A simple linear regression model was used to test whether distance from the forest edge predicted wildlife visitation frequency. The model was expressed as

$$y_i = \beta_0 + \beta_1 x_i + \varepsilon_i$$

where y_i is the visitation frequency score, x_i is distance in meters, β_0 is the intercept, β_1 is the slope, and ε_i is the error term . The coefficient of determination was calculated as

$$R^2 = \frac{\mathrm{SS}_{\mathrm{reg}}}{\mathrm{SS}_{\mathrm{tot}}}$$

and the F-statistic as

$$F = \frac{\mathrm{MS}_{\mathrm{reg}}}{\mathrm{MS}_{\mathrm{res}}}$$

where $\mathrm{MS}_{\mathrm{reg}}$ is the regression mean square and $\mathrm{MS}_{\mathrm{res}}$ is the residual mean square.

PCA was applied to standardised distance and frequency variables to summarise the dominant gradient in the data. Standardisation used z-scores. The correlation matrix of the standardised data was

$$S = \frac{1}{n-1} X^{\top} X$$

and principal components were obtained from

$$S\mathrm{v}_k = \lambda_k \mathrm{v}_k$$

where λ_k is the eigenvalue and v_k is the eigenvector of component k . The percentage of variance explained by each component was computed as

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$$\text{Variance explained}_k = \frac{\lambda_k}{\sum_{j=1}^{p} \lambda_j} \times 100$$

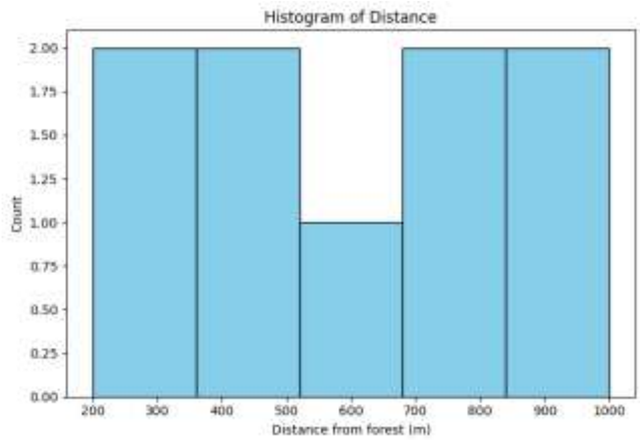
where p is the number of variables.

Results

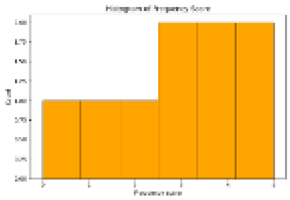
Descriptive Distance Pattern

Wildlife visitation intensity declined consistently with increasing distance from the forest edge . The 200 m and 300 m distance bands were classified as very high, 400 m and 500 m as high, 600 m and 700 m as moderate, 800 m as least, 900 m as very least, and 1,000 m as almost nil . This pattern indicates a strong edge effect, with the highest pressure concentrated within about 500–700 m of the forest boundary.

Table 1
Distance from forest and wildlife visitation frequency



Distance (m)	**Frequency score**	**Qualitative frequency**
200	5	Very high
300	5	Very high
400	4	High
500	4	High
600	3	Moderate
700	3	Moderate



Distance (m)	Frequency score	Qualitative frequency
800	2	Least
900	1	Very least
1,000	0	Almost nil

Linear Regression

A simple linear regression examined whether distance from the forest edge significantly predicted wildlife visitation frequency . The fitted equation was

$$\hat{y} = 5.6812 - 0.00536x$$

where $\hat{y}$ is the predicted frequency score and x is distance in metres. The negative slope indicates that visitation frequency decreases by approximately 0.00536 points per metre, or about 0.536 points per 100 m increase in distance .

The model explained 82.67% of the variance in visitation frequency, $R^2 = 0.8267$, indicating a strong linear relationship between distance and wildlife activity . The regression was statistically significant, $F(1,7) = 33.39, p < .001$, showing that distance is a highly significant predictor of visitation intensity.

Table 2
Regression ANOVA summary

Source	df	SS	MS	F	p-value
Regression	1	19.8406	19.8406	33.39	< .001
Residual	7	4.1594	0.5942	—	—
Total	8	24.0000	—	—	—

Principal Component Analysis

PCA on standardized distance and frequency variables showed that the first principal component captured nearly all variation in the data . PC1 explained 95.46% of the variance, whereas PC2 explained 4.54%, indicating that the dataset is effectively one-dimensional and structured by a single distance–frequency gradient.

Table 3

PCA eigenvalues and variance explained

Component	Eigenvalue	Variance %	Cumulative %
PC1	1.9092	95.46	95.46
PC2	0.0908	4.54	100.00

The loadings were

$$\mathrm{PC1} \approx 0.7071 z_{\text{distance}} - 0.7071 z_{\text{freq}}$$

$$\mathrm{PC2} \approx 0.7071 z_{\text{distance}} + 0.7071 z_{\text{freq}}$$

Table 4

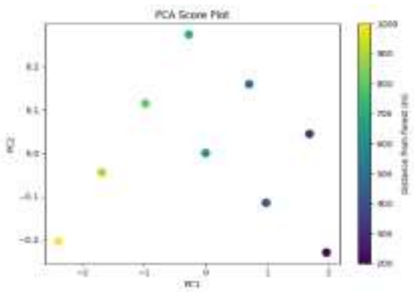
PCA loadings

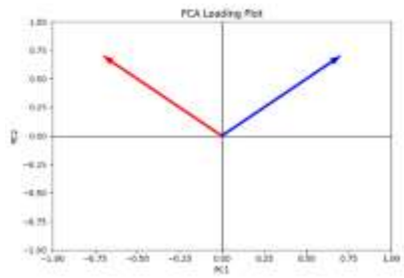
Variable	PC1	PC2
distance_m	0.7071	0.7071
freq_score	-0.7071	0.7071

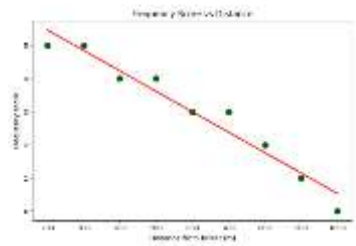
PC1 represents the dominant ecological gradient, with negative scores corresponding to shorter distances and higher visitation frequency and positive scores corresponding to greater distances and lower visitation frequency. PC2 captured only minor deviation from this pattern.

Table 5

PCA scores by distance

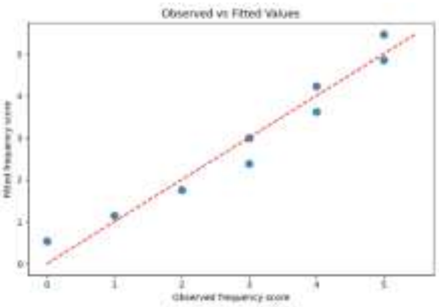






Distance (m)	**Freq score**	**PC1**	**PC2**
200	5	-1.539	0.094
300	5	-1.298	0.335
400	4	-0.649	0.168
500	4	-0.408	0.408
600	3	0.241	0.241
700	3	0.481	0.481
800	2	1.130	0.314
900	1	1.779	0.146
1,000	0	2.428	-0.021

Crop Impact Pattern



The dataset indicates that wheat, vegetables, and sugarcane were the most affected crops across the distance classes. This suggests that wildlife movement is concentrated on a small number of highly palatable and economically important crops rather than being evenly distributed across all crop types. The pattern supports the interpretation that fire-induced movement creates crop-specific conflict hotspots near the forest edge (Madhusudan, 2003).

Discussion

The findings show that forest fires are a major driver of wildlife movement into agricultural areas in the Sunderbani landscape (Kumar & Ram, 2019). The strong negative relationship between distance and visitation frequency indicates that the forest edge acts as a narrow conflict interface where displaced animals concentrate before entering farm fields (Nyhus, 2016). This concentration is strongest within about 500–700 m of the boundary, which matches the descriptive pattern of very high to high visitation close to the forest and low visitation farther away.

The overlap between the fire season and the breeding period of several species likely amplifies these effects (Kumar & Ram, 2019). When nests, eggs, and young animals are exposed to fire, adults may abandon damaged forest patches and shift into agricultural fields where food, cover, and water are more accessible. In this sense, the farms function both as refuges and foraging areas, particularly when forest habitat becomes degraded after repeated burns.

The regression and PCA results are mutually reinforcing. Linear regression demonstrates that distance strongly predicts wildlife visitation frequency, whereas PCA shows that nearly all variation in the dataset is captured by a single axis linking distance and frequency. Together, these analyses suggest that the wildlife movement pattern is not random but is organized around a dominant spatial gradient from forest to field. This makes the conflict landscape relatively predictable and therefore amenable to spatially targeted management.

The crop data further indicate that impact is not evenly distributed. Wheat, vegetables, and sugarcane appear repeatedly as the most affected crops, implying that wildlife is selecting crops that are both attractive and readily available near the edge. This has practical implications because these crops are also economically important to farmers. Crop-specific protection, including fencing, guarding, and diversification, focused within the first 500–700 m of the forest boundary may therefore be more effective than uniform interventions across the whole landscape (Madhusudan, 2003; Nyhus, 2016).

At the same time, several limitations should be acknowledged. The dataset is small and based on a single distance transect, and the visitation scores are qualitative rather than count-based. The data do not include multiple years, replicated sites, or direct fire-intensity measurements. Future studies should combine fire history, wildlife counts, and crop-loss estimates with GPS-based movement data to quantify these relationships more precisely (Kumar & Ram, 2019; Singh & Kour, 2018).

Overall, the results indicate that repeated forest fires likely reduce habitat quality within the forest, pushing wildlife into adjacent agriculture where palatable crops and relatively safe cover are available (Kumar & Ram, 2019; Nyhus, 2016). This creates a narrow but intense conflict zone near the forest edge and supports the need for integrated fire management, crop planning, and community-based mitigation.

Conclusion

This study provides quantitative evidence that forest-fire-associated wildlife movement in the Sunderbani Forest Range is strongly structured by distance from the forest edge, both in terms of visitation intensity and crop impact. Ordinal frequency scores derived from a simple distance-gradient dataset revealed a steep decline in visitation from very high at 200–300 m to almost nil at 1,000 m, defining a narrow but distinct conflict belt around the forest boundary The fitted linear regression model, $\hat{y} = 5.6812 - 0.00536x$, explained approximately 83% of the variance in visitation scores and showed that each additional 100 m from the forest was associated with a decline of about 0.54 points on the 0–5 frequency scale PCA further demonstrated that a single principal component accounted for 95.46% of the variance in standardised distance and frequency, confirming that the system is effectively one-dimensional and dominated by a distance–frequency trade-off.

Taken together, these results indicate that wildlife movements following repeated forest fires do not diffuse evenly into the agricultural matrix but are concentrated in a relatively predictable spatial band along the forest–farm interface. This has important implications for both ecological understanding and management. Ecologically, the patterns support the idea that burnt or degraded forest stands generate strong “push” factors that displace animals, while high-value crops and irrigation infrastructure in nearby fields generate “pull” factors, especially during the April–June fire season when in-forest resources are scarce and breeding demands are high (Kumar & Ram, 2019; Nyhus, 2016). The concentration of visits by wild boar, porcupine, monkeys, and ground birds in near-edge fields, combined with reports of nest and juvenile losses inside burnt forest patches, suggests that fire is reshaping both movement behavior and demographic risks for multiple species in Sunderbani

From a management perspective, the study underscores the value of treating the first 500–700 m from the forest edge as a priority zone for integrated interventions. Within this belt, the consistently high visitation scores and repeated identification of wheat, vegetables, and sugarcane as the most affected crops point to a core "conflict interface" where mitigation can yield disproportionate benefits (Madhusudan, 2003). Spatially targeted strategies might include promoting less palatable or more resilient crops in high-risk fields, reinforcing physical and biological barriers, enhancing night-time monitoring, and prioritizing rapid compensation for losses in this zone. Complementary efforts inside the forest—such as reducing human-induced ignitions, creating and maintaining fuel breaks, securing water sources, and protecting key breeding refuges—could reduce the frequency and severity of fires that currently push wildlife into croplands (Kumar & Ram, 2019; Sharma et al., 2014).

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