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Construction and Validation of a Livelihood Vulnerability Index for Agriculture-Human-Wildlife Conflict

Gyanendra Singh[1], A. P. Verma[2]*, B. K. Gupta[2], Gaurav Shukla[3] and Rohit Chaudhary[4]

[1]Research Scholar, [2]Assistant Professor, Department of Agricultural Extension, [3]Assistant Professor, Department of Statistics and Computer Science, CoA, [4]Assistant Professor, Department of Wildlife Sciences, CoF, BUAT, Banda-210001, Uttar Pradesh, India
*Corresponding author email id: arjunverma45753@gmail.com

HIGHLIGHTS

- A scientifically validated Livelihood Vulnerability Index was developed for agriculture-human-wildlife conflict-affected farming households.
- The index comprised 57 sub-indicators under exposure, sensitivity, and adaptive capacity dimensions with reliability ($\alpha = 0.929$).
- The index provides a practical framework for identifying vulnerable households and prioritizing mitigation and livelihood support interventions.

ARTICLE INFO

Keywords: Agriculture-human-wildlife conflict, Exposure, Sensitivity, Adaptive capacity, Livelihood, Vulnerability.

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Reviewed by: Dr. Krishna D Karjigi (krishnadkarjigi@gmail.com); Dr. Manjunatha B. L. (manju4645@gmail.com); Dr. Monirul Haque(monirulhaque441@gmail.com); Dr. Sujay Basappa Kademani (meetbksujay@gmail.com)

ABSTRACT

Agriculture-human-wildlife conflict (AHWC) can affect farming households through crop damage, livestock loss, protection costs and constraints on livelihood security. The study was undertaken in 2026 to develop and validate a Livelihood Vulnerability Index (LVI) for farming households exposed to AHWC. An initial pool of 79 sub-indicators was generated from literature review and expert consultation and organized a priori under exposure, sensitivity and adaptive capacity following the IPCC vulnerability framework. A relevancy schedule was circulated among 75 experts, of whom 45 returned complete responses. Sub-indicators were screened using Relevancy Weightage (RW), Mean Relevancy Score (MRS), Overall Mean Relevancy Score (OMRS) and Content Validity Ratio (CVR), with retention criteria of RW $\geq$ 0.80, MRS $\geq$ OMRS (2.40) and CVR $\geq$ 0.29. Fifty-seven sub-indicators were retained, 17 under exposure, 12 under sensitivity and 28 under adaptive capacity. The final instrument was arranged on a five-point continuum and pilot-tested with 50 farming households from a non-sample area. Cronbach's alpha was 0.929 for the overall index and 0.814, 0.812 and 0.864 for exposure, sensitivity and adaptive capacity, respectively. The findings supported the use of the index as a structured tool for field assessment of livelihood vulnerability associated with AHWC.

INTRODUCTION

Agriculture-human-wildlife conflict (AHWC) has become a major challenge for farming households living near forests and wildlife habitats. In many areas, wild animals frequently enter agricultural fields and cause damage to crops, livestock, and other farm resources. These incidents often result in economic losses, reduced farm productivity, and additional burden on farming families. Farmers also spend considerable time and resources on protecting crops and livestock from wildlife attacks. As a result, repeated wildlife conflicts affect not only agricultural production but also the livelihood security of rural households. Pereira et al. (2024) reported that human-wildlife interactions can increase livelihood vulnerability by affecting household resources, livelihood opportunities, and coping capacity. Vulnerability refers to the extent to which a household is likely to be affected by different

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stresses and its ability to cope with and recover from them. The Intergovernmental Panel on Climate Change (IPCC, 2007) explained vulnerability through three major dimensions, namely exposure, sensitivity, and adaptive capacity. Exposure refers to the degree of risk faced by household, sensitivity indicates the extent of its impact, and adaptive capacity represents the ability to cope with and recover from adverse situations. This framework has been widely used for vulnerability assessment. Minh et al. (2019) used the LVI to study household vulnerability under changing livelihood conditions. Similarly, Kumar and Mohanasundari (2025) assessed livelihood vulnerability among tribal communities using the LVI-IPCC framework. Zainab and Shah (2024) observed that the LVI and LVI-IPCC frameworks are widely used for assessment across different regions and sectors. Kumar et al. (2018) emphasized that livelihood vulnerability in wildlife-affected areas is influenced by ecological, social, and institutional factors. Indicator-based approaches have been widely used to assess livelihood risks and support evidence-based planning (Pandey & Jha, 2012). Mallappa and Gadde (2025) developed a tool to assess vulnerability among climate-sensitive farming communities based on the dimensions of exposure, sensitivity, and adaptive capacity. Sahu et al. (2026) emphasized the need for scientifically validated indices in agricultural research. However, most of the available vulnerability assessment tools have been developed primarily for climate change and other environmental stresses. The vulnerability tools reviewed for the study largely addressed climatic and environmental stresses, with limited attention to indicators specific to agriculture-human-wildlife conflict.

Human-wildlife conflict has been identified as a significant threat to rural livelihoods due to its adverse effects on crop production, livestock assets, household income, and food security (Rao et al., 2002). Similar observations have been reported by Meena et al. (2022) among households residing in the vicinity of Ranthambore Tiger Reserve. Despite the increasing impact of agriculture-human-wildlife conflict on farming households, a standardized and scientifically validated tool for assessing livelihood vulnerability in this context is not available. The study hypothesized that livelihood vulnerability arising from agriculture-human-wildlife conflict could be assessed through a multidimensional framework comprising exposure, sensitivity and adaptive capacity. The study was undertaken to develop and standardize a Livelihood Vulnerability Index for farming households affected by agriculture-human-wildlife conflict.

METHODOLOGY

The study was conducted in 2026 to construct and validate a Livelihood Vulnerability Index (LVI) for farming households affected by agriculture-human-wildlife conflict (AHWC). Relevant literature and consultation with subject matter specialists generated an initial pool of 79 sub-indicators. The dimensional structure was specified a priori from the IPCC vulnerability framework, and the sub-indicators were organized under exposure, sensitivity and adaptive capacity. A structured relevancy schedule containing the 79 sub-indicators was circulated among 75 experts. The panel comprised agricultural extension scientists and academicians, including Professors and Subject Matter Specialists, together with professionals having expertise in forestry and wildlife. From a total of 75 experts approached, 45 returned complete schedules, giving a usable response rate of 60.00 per cent. Incomplete schedules were excluded. Each sub-indicator was rated on a three-point continuum of Most Relevant, Relevant and Least Relevant, with scores of 3, 2 and 1, respectively. Relevancy Weightage (RW), Mean Relevancy Score (MRS) and Overall Mean Relevancy Score (OMRS) were computed (Sahu et al., 2026). Content Validity Ratio (CVR) was computed following Lawshe (1975), for this calculation, the Most Relevant response was treated as the essential-equivalent endorsement. For 45 experts, the minimum acceptable CVR was 0.29 at the 0.05 level (Ayre & Scally, 2014). Sub-indicators with RW $\geq$ 0.80, MRS $\geq$ OMRS and CVR $\geq$ 0.29 were retained. The OMRS was 2.40, resulting in 57 retained sub-indicators. The retained sub-indicators were arranged on a five-point continuum scored from 5 to 1. Higher scores for exposure and sensitivity represented greater livelihood vulnerability. Adaptive capacity operated in the opposite direction; hence, the scores of the 28 adaptive-capacity sub-indicators were reverse coded as $X_R = 6\text{-}X$, whereby scores of 5, 4, 3, 2 and 1 were converted to 1, 2, 3, 4 and 5, respectively. No additional normalization was applied because all sub-indicators used the same five-point scale. Mean scores were calculated separately for exposure, sensitivity and reverse-coded adaptive capacity, giving equal weight to the three dimensions. The Livelihood Vulnerability Index for the i^{th} household was calculated as:

$$E_i = \frac{\sum_{j=1}^{17} X_{ij}}{17}$$

$$S_i = \frac{\sum_{j=1}^{12} X_{ij}}{12}$$

$$AC_i^R = \frac{\sum_{j=1}^{28} (6 - X_{ij})}{28}$$

$$LVI_i = \frac{E_i + S_i + AC_i^R}{3}$$

Where, E, S, and AC_R represent the mean exposure, sensitivity and reverse-coded adaptive-capacity scores, respectively. The index ranges from 1 to 5, with higher scores indicating greater livelihood vulnerability.

The finalized instrument was pilot-tested with 50 farming households from a non-sample area for reliability assessment. Internal consistency was assessed using Cronbach's alpha (Cronbach, 1951) for the overall index and separately for the three dimensions. The formulas used for relevancy and content-validity assessment were as follows:

$$RW = \frac{MR \times 3 + R \times 2 + LR \times 1}{MPS}$$

$$MRS = \frac{MR \times 3 + R \times 2 + LR \times 1}{N}$$

$$OMRS = \frac{\text{Sum of obtained Relevancy Score}}{N \times S}$$

$$CVR = \frac{Ne - N/2}{N/2}$$

Where, RW = Relevancy Weightage; MRS = Mean Relevancy Score; OMRS = Overall Mean Relevancy Score; CVR = Content Validity Ratio; MR, R and LR = Most Relevant, Relevant and Least Relevant responses; MPS = Maximum Possible Score; N = experts; and S = sub-indicators.

RESULTS

Relevancy analysis of sub-indicators

The relevancy assessment resulted in the retention of 57 of the 79 initially proposed sub-indicators, representing 72.15 per cent of the original pool. The overall mean relevancy score (OMRS) was 2.40. The screening retained 17 of 23 exposure sub-indicators, 12 of 16 sensitivity sub-indicators and 28 of 40 adaptive-capacity sub-indicators. Among the retained sub-indicators, Relevancy Weightage (RW) ranged from 0.82 to 0.93, Mean Relevancy Score (MRS) from 2.47 to 2.78 and Content Validity Ratio (CVR) from 0.29 to 0.60. The complete relevancy statistics and retention decisions for all 79 proposed sub-indicators are provided in Supplementary Table 1.

Table 1. Relevancy statistics and retention decisions for initial sub-indicators

S.N.	Code	RW	MRS	CVR	Decision
1.	EXP1	0.86	2.58	0.38	Retained
2.	EXP2	0.86	2.58	0.42	Retained
3.	EXP3	0.67	2.02	-0.24	Excluded
4.	EXP4	0.84	2.51	0.33	Retained
5.	EXP5	0.88	2.64	0.42	Retained
6.	EXP6	0.84	2.53	0.29	Retained
7.	EXP7	0.64	1.91	-0.47	Excluded
8.	EXP8	0.84	2.53	0.33	Retained
9.	EXP9	0.84	2.53	0.38	Retained
10.	EXP10	0.60	1.80	-0.56	Excluded
11.	EXP11	0.82	2.47	0.29	Retained
12.	EXP12	0.86	2.58	0.38	Retained
13.	EXP13	0.84	2.51	0.33	Retained
14.	EXP14	0.85	2.56	0.38	Retained
15.	EXP15	0.67	2.02	-0.24	Excluded
16.	EXP16	0.86	2.58	0.42	Retained
17.	EXP17	0.83	2.49	0.29	Retained
18.	EXP18	0.84	2.53	0.33	Retained
19.	EXP19	0.84	2.53	0.33	Retained
20.	EXP20	0.90	2.71	0.56	Retained
21.	EXP21	0.59	1.78	-0.51	Excluded
22.	EXP22	0.84	2.51	0.38	Retained
23.	EXP23	0.74	2.22	-0.07	Excluded
24.	S1	0.93	2.78	0.60	Retained
25.	S2	0.84	2.51	0.29	Retained
26.	S3	0.86	2.58	0.38	Retained
27.	S4	0.84	2.51	0.29	Retained
28.	S5	0.84	2.51	0.33	Retained
29.	S6	0.86	2.58	0.33	Retained
30.	S7	0.64	1.93	-0.33	Excluded
31.	S8	0.64	1.93	-0.38	Excluded
32.	S9	0.87	2.60	0.42	Retained
33.	S10	0.87	2.60	0.42	Retained
34.	S11	0.86	2.58	0.42	Retained
35.	S12	0.71	2.13	-0.24	Excluded
36.	S13	0.85	2.56	0.33	Retained
37.	S14	0.84	2.51	0.29	Retained
38.	S15	0.64	1.93	-0.42	Excluded
39.	S16	0.84	2.53	0.29	Retained
40.	AC1	0.82	2.47	0.24	Excluded
41.	AC2	0.84	2.53	0.33	Retained
42.	AC3	0.81	2.42	0.20	Excluded
43.	AC4	0.84	2.53	0.33	Retained
44.	AC5	0.86	2.58	0.47	Retained
45.	AC6	0.86	2.58	0.47	Retained
46.	AC7	0.88	2.64	0.42	Retained
47.	AC8	0.63	1.89	-0.42	Excluded
48.	AC9	0.84	2.51	0.33	Retained
49.	AC10	0.85	2.56	0.38	Retained
50.	AC11	0.64	1.91	-0.51	Excluded
51.	AC12	0.83	2.49	0.33	Retained
52.	AC13	0.85	2.56	0.38	Retained
53.	AC14	0.86	2.58	0.42	Retained
54.	AC15	0.66	1.98	-0.42	Excluded
55.	AC16	0.63	1.89	-0.47	Excluded
56.	AC17	0.84	2.53	0.33	Retained
57.	AC18	0.82	2.47	0.33	Retained
58.	AC19	0.85	2.56	0.33	Retained
59.	AC20	0.61	1.84	-0.56	Excluded
60.	AC21	0.83	2.49	0.33	Retained
61.	AC22	0.84	2.51	0.33	Retained
62.	AC23	0.85	2.56	0.38	Retained
63.	AC24	0.64	1.93	-0.33	Excluded
64.	AC25	0.85	2.56	0.33	Retained
65.	AC26	0.85	2.56	0.38	Retained
66.	AC27	0.84	2.53	0.33	Retained
67.	AC28	0.70	2.09	-0.24	Excluded
68.	AC29	0.87	2.60	0.38	Retained
69.	AC30	0.84	2.53	0.33	Retained
70.	AC31	0.83	2.49	0.33	Retained
71.	AC32	0.83	2.49	0.29	Retained
72.	AC33	0.87	2.60	0.42	Retained
73.	AC34	0.87	2.60	0.47	Retained
74.	AC35	0.86	2.58	0.33	Retained
75.	AC36	0.64	1.91	-0.38	Excluded
76.	AC37	0.87	2.62	0.47	Retained
77.	AC38	0.72	2.16	-0.33	Excluded
78.	AC39	0.84	2.51	0.33	Retained
79.	AC40	0.60	1.80	-0.51	Excluded

Table 1 contd...

(EXP = Exposure, S = Sensitivity, AC = Adaptive Capacity, RW = Relevancy Weightage, MRS = Mean Relevancy Score, CVR = Content Validity Ratio)

Exposure dimension

The exposure dimension retained 17 of the 23 proposed sub-indicators (73.91%), as presented in Table 2. The retained sub-indicators represented six indicators which were wildlife presence, crop raiding, livestock predation, conflict occurrence, cropping risk and grazing risk. Cronbach's alpha for the exposure dimension was 0.814, indicating satisfactory internal consistency.

Table 2. Validated sub-indicators under the exposure dimension

Code	Sub-indicator	Statement
Wildlife Presence		
EXP1	Field intrusion	Level of wildlife intrusion into cultivated fields
EXP2	Movement corridors	Presence of wildlife movement corridors near agricultural land
EXP4	Fear of wildlife presence	Level of fear experienced due to the presence of wildlife near agricultural fields
Crop Raiding		
EXP5	Crop damage	Severity of crop damage caused by wildlife
EXP6	Crop feeding	Extent of crop consumption by wildlife
EXP8	Repeated attacks	Frequency of recurring wildlife attacks on crops
Livestock Predation		
EXP9	Grazing attacks	Severity of wildlife attacks on grazing livestock
EXP11	Predation risk	Level of risk of livestock predation by wildlife
Conflict Occurrence		
EXP12	Seasonal incidents	Occurrence of wildlife conflicts during specific seasons
EXP13	Conflict hotspots	Degree of exposure to wildlife conflict-prone locations
EXP14	Wildlife congregation	Intensity of wildlife congregation near agricultural areas
Cropping Risk		
EXP16	Attractive crops	Extent of cultivation of crops preferred by wildlife
EXP17	Forest proximity	Degree of proximity of agricultural land to forest areas
EXP18	Cropping adjustment	Extent of changes made in cropping practices due to wildlife threats
EXP19	Crop substitution	Extent of adoption of alternative crops to reduce wildlife damage
Grazing Risk		
EXP20	Forest grazing	Level of livestock exposure through grazing near forest boundaries
EXP22	Predator sightings	Occurrence of predator sightings in grazing locations

Cronbach's α for the exposure dimension = 0.814.

Sensitivity dimension

The sensitivity dimension retained 12 of the 16 proposed sub-indicators (75.00%), as presented in Table 3. The retained sub-indicators represented four indicators which were production impact, protection burden, economic loss and livelihood dependence. Cronbach's alpha for the sensitivity dimension was 0.812, indicating satisfactory internal consistency.

Adaptive capacity dimension

Relevancy and content-validity assessment retained 28 of the 40 adaptive-capacity sub-indicators (70.00%), as presented in Table 4. The retained sub-indicators were distributed across ten indicators covering livestock management, physical protection, crop guarding, deterrent practices, institutional access, extension support, financial coping, compensation access, community cooperation and conflict

Table 3. Validated sub-indicators under the sensitivity dimension

Code	Sub-indicator	Statement
Production Impact		
S1	Yield reduction	Magnitude of crop yield reduction due to wildlife damage
S2	Growth damage	Severity of crop damage during the growth stage
S3	Harvest damage	Severity of crop damage during harvesting
S4	Repeated field damage	Magnitude of recurring damage in the same agricultural fields
Protection Burden		
S5	Guarding time	Burden of time devoted to protecting crops from wildlife
S6	Night vigilance	Burden of night-time crop protection activities
Economic Loss		
S9	Crop loss	Magnitude of crop production losses due to wildlife damage
S10	Livestock loss	Magnitude of livestock losses due to wildlife attacks
S11	Protection expenses	Magnitude of expenditure incurred on wildlife protection measures
Livelihood Dependence		
S13	Crop reliance	Degree of dependence on crop farming for livelihood
S14	Livestock reliance	Degree of dependence on livestock rearing for livelihood
S16	Income instability	Magnitude of instability in household income resulting from wildlife conflict

Cronbach's α for the sensitivity dimension = 0.812.

Table 4. Validated sub-indicators under the adaptive capacity dimension

Code	Sub-indicator	Statement
Livestock Management		
AC2	Shed safety	Adequacy of livestock shelters in preventing wildlife attacks
AC4	Herd supervision	Level of supervision of livestock during grazing to reduce wildlife predation risk
Physical Protection		
AC5	Farm fencing	Effectiveness of farm fencing in preventing wildlife intrusion
AC6	Physical barriers	Effectiveness of trenches and barriers in restricting wildlife movement
AC7	Barrier maintenance	Adequacy of maintenance of protective structures
Crop Guarding		
AC9	Manual guarding	Level of effort devoted to guarding crops against wildlife
AC10	Watch posts	Adequacy of watch posts for monitoring wildlife activity
AC12	Community guarding	Level of participation in collective guarding activities
Deterrent Practices		
AC13	Noise deterrents	Effectiveness of sound-based wildlife deterrents
AC14	Light deterrents	Effectiveness of light-based wildlife deterrents
Institutional Access		
AC17	Scheme awareness	Level of awareness regarding wildlife compensation and support schemes
AC18	Incident reporting	Level of reporting wildlife conflict incidents to authorities
AC19	Institutional response	Adequacy of response received from responsible agencies
Extension Support		
AC21	Awareness programmes	Extent of participation in wildlife awareness programmes
AC22	Training exposure	Extent of exposure to wildlife conflict mitigation training
AC23	Advisory services	Availability of advisory services on wildlife conflict management
Financial Coping		
AC25	Savings availability	Availability of household savings for coping with wildlife-related losses
AC26	Credit access	Accessibility of institutional credit during wildlife-related emergencies
AC27	Recovery ability	Capacity of the household to recover from wildlife-related losses
Compensation Access		
AC29	Claim awareness	Level of awareness regarding compensation claim procedures
AC30	Claim submission	Ease of submitting compensation claims
AC31	Payment timeliness	Timeliness of compensation payments received
AC32	Payment adequacy	Adequacy of compensation received for losses suffered
Community Cooperation		
AC33	Mutual support	Availability of support from community members during wildlife conflict situations
AC34	Information sharing	Level of information sharing regarding wildlife movement and threats
AC35	Collective protection	Level of participation in collective crop and livestock protection efforts
Conflict Awareness		
AC37	Wildlife awareness	Level of awareness regarding risks associated with wildlife conflict
AC39	Safety practices	Extent of adoption of recommended practices for reducing wildlife conflict

Cronbach's α for the adaptive capacity dimension = 0.864.

awareness. The adaptive capacity dimension incorporated not only household-level preventive and coping practices but also access to institutional, financial, informational and collective resources that may assist farming households in managing and recovering from wildlife-related losses. The dimension recorded a Cronbach's alpha coefficient of 0.864, indicating satisfactory internal consistency.

DISCUSSION

The three-dimensional structure of the index reflects an important feature of agriculture-human-wildlife conflict, households are affected not only by the frequency of wildlife encounters but also by the consequences of those encounters and the resources available to manage them. This interpretation is consistent with the vulnerability framework of IPCC (2007), in which exposure, sensitivity and adaptive capacity represent distinct but related aspects of vulnerability. Similar applications of this framework have been reported in livelihood studies by Hahn et al. (2009) and Pereira et al. (2024).

The exposure dimension represents the circumstances that bring farming households into contact with wildlife-related risk. Crop raiding, livestock predation, proximity to forest areas and repeated conflict events are especially relevant in farming systems situated close to wildlife habitats. Meena et al. (2022) reported comparable crop and livestock losses around Ranthambore Tiger Reserve, while Pereira et al. (2024) showed that repeated human-wildlife interactions can influence livelihood vulnerability across protected-area landscapes. The retained exposure indicators extend assessment beyond the occurrence of a single loss and account for the setting and recurrence of conflict.

Sensitivity captures the extent to which wildlife conflict affects farm production and household livelihood. Yield reduction, livestock loss and protection expenditure represent direct effects, whereas time spent guarding fields and dependence on crop and livestock income reflect burdens that may persist beyond an individual conflict event. Barua et al. (2013) similarly described opportunity costs and other indirect effects of human-wildlife conflict. Including these aspects is useful because households exposed to similar wildlife pressure may experience different levels of livelihood disruption depending on their dependence on affected farm enterprises.

Adaptive capacity represents the means available to prevent losses, cope with conflict and recover afterwards. The retained indicators cover farm-level protection, access to extension and institutional support, financial coping, compensation, community cooperation and conflict awareness. These elements are relevant to agricultural extension because farmers' responses to wildlife conflict depend not only on individual practices but also on access to information, services and institutional support. Nyhus (2016) and Pereira et al. (2024) likewise emphasize the role of management and institutional arrangements in shaping responses to human-wildlife conflict. Verma et al. (2026) also highlighted adaptive coexistence behaviour as an important aspect of farmer's wildlife-conflict tolerance.

The reliability coefficients obtained for the three dimensions indicate satisfactory internal consistency, and the overall coefficient supports the use of the items as parts of a common livelihood-vulnerability instrument. Similar expert-based screening followed by reliability assessment has been used in tool-development studies (Shitu et al., 2018; Gupta et al., 2023; Vijayan et al., 2022; Vijayan et al., 2023; Mallappa & Gadde, 2025; Sahu et al., 2026). The present validation establishes content relevance and internal consistency of the instrument, its performance across different ecological and institutional settings remains to be examined through wider field application.

CONCLUSION

The developed index represents livelihood vulnerability arising from agriculture-human-wildlife conflict through 57 sub-indicators covering exposure, sensitivity and adaptive capacity. Its structure recognizes that households facing similar wildlife pressure may differ in the losses they experience and, in the resources, available to cope with those losses. The satisfactory reliability obtained for the overall instrument and each dimension supports its use for household-level field assessment. The index can help extension personnel, researchers and agencies identify whether vulnerability is associated mainly with repeated exposure, livelihood sensitivity or limited capacity to cope and recover. Such information can guide locally appropriate measures related to crop and livestock protection, advisory support, compensation access, financial coping and community action. Further application in different conflict settings can examine its wider usefulness.

DECLARATIONS

Ethics approval and informed consent: The study was conducted in accordance with principals laid out in Helsinki Declaration 1964 and its modifications. The ethical issues were taken care by Departmental Advisory Board of Department of Agricultural Extension, BUAT, Banda. Informed consent was obtained from the experts and farming households before data collection. The confidentiality and anonymity of participants were strictly maintained throughout the research process.

Conflict of interest: The authors declare no conflict of interest.

Consent for publication: All authors approved the final manuscript and consented to its publication.

Data availability statement: The data supporting the findings of this study are available from the corresponding author on reasonable request.

Authors' Contribution: Gyanendra Singh: Investigation, data collection, analysis and manuscript preparation; A. P. Verma: Conceptualization, supervision and manuscript review; B. K. Gupta: Methodology, supervision and review; Gaurav Shukla: Statistical analysis and validation; Rohit Chaudhary: Wildlife-domain inputs and manuscript review. All authors read and approved the final manuscript.

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