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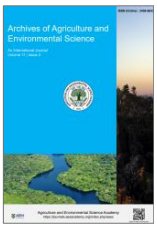

Original Research Article

Bridging the gap between knowledge and practice in pesticide use: Occupational health risks among smallholder farmers in Nepal

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ABSTRACT

Improper use of pesticides poses significant occupational health hazards among smallholder farmers in Nepal who often have limited access to safety information and protective measures. This study aimed to assess pesticide use patterns, farmers' knowledge of health risks, safety practices, and their association with socio-demographic characteristics in Banke district, Nepal. A cross-sectional survey was conducted among 360 farmers selected via multistage sampling process. Data were collected using pretested questionnaires, complemented by 20 key informant interviews, and 10 focus group discussions. Most respondents were male (76.67%), 41.94% had primary level education and, 66.11% cultivated less than one hectare of land. Overall, 97.78% of the respondents reported using pesticides primarily in vegetable farming (86.11%) followed by paddy (66.94%) production. Although 72.78% were aware of the adverse health effects of pesticides, 57.78% of respondents had received no training on pesticide management. The most frequently reported health problems were headache (18.06%) and skin rash (16.94%). Farmers' knowledge of pesticide-related health risks was positively correlated ($r = 0.434$, $p<0.01$) with safety practices. In addition, respondents' safety practices were significantly varied by gender, age, and education level. The findings highlight a clear knowledge-practice gap and underscore the need for practical safety training, affordable personal protective equipment, and behavior-change interventions to promote safer pesticide use among small holder farmers.

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INTRODUCTION

The increasing demand for food and the rise of commercial agriculture have resulted in the widespread cultivation of high-value crops, especially vegetables, in numerous developing nations. Despite increased agricultural output and farmer earnings, this trend has led to a significant dependency on pesticides to combat pests. On one side, their application shows a notable impact on food production and in safeguarding against pests. However, on the other hand, it has turned into a significant risk to health, food safety, and the environment because of the improper use of different chemical pesticides. Proper use of pesticides is crucial for the sustainability of agriculture (Lykogianni *et al.*, 2021). Pesticides are applied to enhance the quality and quantity of agricultural output by

minimizing damage caused by pests (Ahmad *et al.*, 2024; Janaki Rani *et al.*, 2025; Verdadero *et al.*, 2025). Improper pesticide handling, such as mixing, applying, storing, and disposing of waste, can result in the poisoning of farmers and individuals near farms by hazardous substances. Additionally, acute pesticide poisoning may lead to headaches, nausea, dizziness, vomiting, skin irritation, and eye damage, while long-term exposure can lead to neurological disorders, respiratory diseases, reproductive issues, and cancer (Ahmad *et al.*, 2024; Desye *et al.*, 2024; Shekhar *et al.*, 2024; Norvivor *et al.*, 2025). Moreover, pesticide residues are frequently detected in food products, soil, water, and wildlife all around, indicating both direct and indirect exposure risks for farming communities (Tourinho *et al.*, 2025).

Nepal has experienced a notable increase in pesticide use after the commercialization of agriculture and the growth of vegetable cultivation. According to the Plant Quarantine and Pesticide Management Center (PQPMC, 2024), Pesticide imports increased significantly from 454,596 kg in 2013-2014 to 1664,381 kg in 2023-2024. In Nepal, the most commonly imported pesticides are insecticides, fungicides, and herbicides (Plant Quarantine and Pesticide Management Center (PQPMC), 2024). Although the nation's policies encourage the implementation of IPM and the regulation of pesticide usage, farmers still face difficulties in adopting suggested practices for the safe handling and application of these chemicals because of a lack of adequate technical support, training, and personal protective equipment (Karki & Dangol, 2023; Bhandari *et al.*, 2024). Moreover, the detection of pesticide residues in food, including banned pesticides; for example, a recent study found that rice from the Kathmandu valley had residues of eleven different pesticides, such as fungicides, insecticides, and rodenticides, some of which were banned (Bhandari *et al.*, 2025) highlights the necessity for improved pesticide management strategies and the encouragement of responsible pesticide usage practices in Nepal. Although the harmful effects of pesticides are well known, there is still limited information on farmers' level of knowledge of pesticide hazards and their influence on their pesticide-use practices. This knowledge gap limits the proper extension work and appropriate strategies to promote safe pesticide use among commercial vegetable farmers. Hence, this study was conducted to assess the knowledge and practice gap of pesticide use among smallholder farmers in Banke district of Nepal. The findings of this study will contribute to knowledge and create awareness among the farmers regarding the safe use of pesticides to promote IPM activities and develop strategies to minimize pesticide abuse and its adverse implications on human health, food safety, and the environment.

MATERIALS AND METHODS

Study area

The study site was the Banke District (28° 02' 60.00" N, 81° 36' 59.99" E) situated in the Lumbini Province of Nepal. The district covers an area of 2,337 km^2 and is inhabited by 129,307 households as per the National Population and Housing Census (2021). The study was carried out in Nepalgunj submetropolitan city, Duduwa rural municipality, and Khajura rural municipality, which are major commercial vegetable-producing areas where pesticide use is widespread.

Study design and sampling

The study utilized a cross-sectional framework and implemented a multistage sampling approach. In the first stage, the Banke district was chosen as the focus of the study based on recommendations from the Agriculture Knowledge Center and local municipality agriculture departments, emphasizing a commercially viable agricultural production area. In the second stage, three local entities, Nepalgunj Sub-Metropolitan City, Duduwa Rural Municipality, and Khajura Rural Municipality, were incorporated. In these municipalities and wards, specific study sites were chosen through simple random sampling to ensure equitable representation. In the third stage, cluster sampling was employed for choosing respondents. The study included households and stakeholders involved in agricultural production, input supply, marketing, and associated services. Furthermore, a total of 360 household surveys, 20 Key informant interviews, and 10 Focus group discussions were conducted. Participants were chosen based on ease of access, closeness to the district headquarters, availability of roads and market access, and the general practicality of travel routes in the field.

Data collection

Both primary and secondary data were collected. Primary data were collected through household surveys using a pre-tested structured questionnaire. In addition, key informant interviews, focus group discussions with local authorities, agrovets, cooperatives, and agricultural technicians, as well as field observations, were conducted (Thapa *et al.*, 2021). Secondary data were collected from government reports, relevant institutional publications, and scientific literature.

Ethical considerations

Participation in the study was voluntary. Respondents were informed about the purpose of the study and provided verbal informed consent before participation. During the study, the privacy and anonymity of the respondents were maintained.

Statistical analysis

The data were analyzed using SPSS Statistics software version 29. Before analysis, the data were screened for completeness and consistency. Descriptive statistics, such as frequencies and percentages, were used to summarize respondents socio-demographic characteristics, cropping patterns, pesticide use practices, and other study variables. Statistical tests of inference were employed to examine possible relationships among the variables.

A chi-square test was performed to evaluate the relationships between categorical variables and determine whether two variables were independent or significantly correlated, as shown in Eq. (1).

$$\chi^2 = (O_ij - E_ij)^2/E_ij \quad (1)$$

Where O_ij represents the observed frequency and E_ij represents the expected frequency.

The relationship between farmers' safety practices and their level of knowledge was examined using Pearson correlation analysis. The correlation coefficient (r) was used to illustrate the direction and strength of the relationship, as shown in Eq. (2).

$$r = \frac{\sum(x - \bar{x})(y - \bar{y})}{\sqrt{\sum(x - \bar{x})^2 \sum(y - \bar{y})^2}} \quad (2)$$

Where x and y represent the variables under study, and $\bar{x}$ and $\bar{y}$ denote their respective means.

RESULTS AND DISCUSSION

Socio-demographic and farming characteristics

A total of 360 farmers participated in the study. The respondents' socio-demographic and farm characteristics are represented below in Table 1. The data showed that male farmers accounted for the highest percentage of the participant sample (76.67%). The age distribution of the farmers indicated a predominance of respondents aged 30-45 years (42.50%) and above 45 years (41.39%), with a mean age of 43.59 years (SD ±12; range: 19-72 years). Most of the respondents had attained elementary education (41.94%) and were literate but without formal education (26.11%). Less than 1% of respondents (0.83%) had a bachelor's degree. Furthermore, most of the respondents (66.11%) cultivated in less than 0.5 ha land, and 68.33% had more than ten years of experience. Most farmers (75.28%) also practiced both subsistence and commercial farming. The high proportion of men (76.67%) among smallholders cultivating less than 0.5 ha is consistent with earlier work showing that pesticide application in South Asia is predominantly undertaken by men, likely reflecting their greater involvement in agricultural labor, mobility, and farm-level decision- making (Thapa *et al.*, 2021; Jyoti *et al.*, 2023; Aye *et al.*, 2024; Karki *et al.*, 2025).

Table 1. Socio-demographic and farming characteristics of respondents (n = 360).

Variable	Category	Frequency (n)	Percentage (%)
Gender	Male	276	76.67
	Female	84	23.33
Age (years)	<30	58	16.11
	30–45	153	42.50
	>45	149	41.39
Education	Illiterate	32	8.89
	Read & Write	94	26.11
	Primary	151	41.94
	Secondary	58	16.11
	Higher Secondary	22	6.11
	Bachelor's & above	3	0.83
Landholding (ha)	<0.5	238	66.11
	0.5–1.0	103	28.61
	>1.0	19	5.28
Farming experience	<5 years	62	17.22
	5–10 years	52	14.44
	>10 years	246	68.33
Purpose of farming	Home consumption	86	23.89
	Business only	3	0.83
	Both	271	75.28

Pesticide use patterns and exposure

The use of pesticides was widespread among the respondents, as 97.78% of them currently used pesticides for agricultural purposes, mainly for controlling pests (Table 2). The most commonly treated crops with pesticides include vegetables (86.11%), paddy (66.94%), and maize (57.50%). Most farmers (44.72%) had used pesticides for 5-10 years, while 58.05% of them applied pesticides at a frequency of between 1-3 times per month. Farmers mostly (59.72%) applied pesticides in the afternoon. Farmers relied mostly on informal sources of information on pesticide use, including friends (25.83%) and family members (24.44%), compared to formal sources such as government agencies (4.72%) and pesticide dealers (2.78%). The major sources of supply of pesticides included agro-vet shops (61.67%), cooperatives (28.33%), and purchases from India (34.44%). This study assessed the use of pesticides, safety practices, and their socio-demographic determinants among vegetable and cereal growers in the Banke district of Nepal. The high prevalence of pesticide application (97.78%) was reported in this study from the vegetable, paddy, and maize farming systems. The current study's findings are consistent with the increasing trends of commercial farming in Nepal and elsewhere, where farmers are more concerned about pests and yields, and therefore they are more likely to adopt pesticides than alternative pest management measures (Atreya *et al.*, 2022; Moreira & Da Silva, 2023).

Protective equipment, precautionary practices, and container disposal

Table 3 presents the use of personal protective equipment, the implementation of precautionary measures, and the way of disposal of pesticide containers by the respondents. It shows that the largest number of respondents (75.00%) used masks as an individual protection means. The use of other forms of protection was less common, including gloves (28.33%) and full body covers (16.94%), while about 16% of the respondents did not use any protective equipment while working with pesticides. As for the precautionary measures, about 97% of the farmers washed their hands after mixing concentrates, and almost 93% did it after spraying. Meanwhile, only 60% of the respondents followed the instructions on the packaging while using the chemicals. In relation to the methods of disposal of empty containers, about 48.33% of the respondents threw them in the trash, 37.78% gave them to rag pickers or left them at collection zones, while 28.61% burned or buried the containers of pesticides. In addition, 16.94% of them threw the packages in the fields or near them, and 3.61% did not take any measures. Use of personal protective equipment was inconsistent among respondents. While 75% farmers reported wearing masks, these measures were taken primarily to avoid unpleasant odors rather than to prevent chemical exposure, while only 28.33% used gloves when handling pesticides. It is corroborated with other studies showing that farm workers often have low protective equipment adoption due to factors such as cost, discomfort, and insufficient information on

occupational health risks (Kangavari *et al.*, 2024; Nguyen & Tsai, 2024; Tsakiris *et al.*, 2025). In combination with the fact that more than a quarter of respondents (26.11%) used pesticides more than three times per month, this suggests frequent occupational exposure to pesticide related health hazards, consistent with studies showing that repeated exposure to pesticides without adequate protection can increase the risk of occupational health issues (Desye *et al.*, 2024; Shekhar *et al.*, 2024).

Table 2. Pesticide use patterns, exposure, and sources among farmers (n = 360).

Category	Indicator	Frequency	Percentage (%)
Pesticide use	Yes	352	97.78
	No	8	2.22
Crops treated	Vegetables	310	86.11
	Paddy	241	66.94
	Maize	207	57.5
	Wheat	16	4.44
	Fruits	10	2.78
	Others	4	1.11
Duration of use	<5 years	62	17.22
	5–10 years	161	44.72
	>10 years	75	20.83
	Unaware	54	15.00
	Not used	8	2.22
Frequency of use (past month)	1–3 times	209	58.05
	>3 times	94	26.11
	Not used	57	15.83
Time of application	Morning	80	22.22
	Afternoon	215	59.72
	Evening	65	18.06
Source of information	Fellow farmers	93	25.83
	Family members	88	24.44
	Government services	17	4.72
	Pesticide retailers	10	2.78
	Digital apps/SMS	4	1.11
Source of pesticides	Agro-vet shops	222	61.67
	India (cross-border)	124	34.44
	Cooperatives	84	28.33
	Other/local shops	13	3.61

Table 3. Personal protective equipment use, precautionary practices, container disposal and training (n = 360).

Category	Item/Practice	Frequency	Percentage (%)
PPE use	No PPE used	60	16.67
	Mask	270	75.00
	Long-sleeved shirt	157	43.61
	Spectacles/eyewear	134	37.22
	Hat	121	33.61
	Gloves	102	28.33
	Trousers	81	22.5
	Full-body cover	61	16.94
Precautionary practices	Wash hands after mixing	349	96.94
	Wash hands after spraying	326	90.56
	Wash hands before eating	337	93.61
	Wash hands before smoking	231	64.17
	Change clothes after spraying	187	51.94
	Bath after spraying	225	62.5
	Follow product label before spraying	215	59.72
Container disposal	Discarded in waste bins	174	48.33
	Given to rag pickers/collection zones	136	37.78
	Burned or buried		
	Left in fields/nearby locations	103	28.61
	No action taken	61	16.94
Training regarding pesticide use, safety practices	Yes	152	42.22
	No	208	57.78

Table 4. Farmers' knowledge of pesticide risks, exposure pathways, and health symptoms (n = 360).

Category	Indicator	Frequency	Percentage (%)
Perceived risks of pesticides	Health effects	262	72.78
	Environmental effects	245	68.06
	Livestock effects	240	66.67
Safe application awareness	Avoid cloudy days	270	75.00
	Attention to wind direction	249	69.17
	Consider rainfall timing	124	66.67
Exposure pathways recognized	Inhalation	278	77.22
	Oral intake	252	70.00
	Skin contact	236	65.56
	Eye exposure	213	59.17
Label color awareness	Yellow	312	86.67
	Blue	281	78.06
	Red	267	74.17
	Green	238	66.11
Common health symptoms (of 33.33% affected)	Headache		
	Skin irritation	65	18.06
	Extreme tiredness	61	16.94
	Excessive sweating	32	8.89
	Muscular weakness	27	7.5
	Abdominal pain	19	5.28
	Respiratory difficulty/ back pain	12	3.33
	Vomiting/dry mouth	11	3.06
	Others	5	1.39
	Salivation/speech difficulty	4	1.11
	Headache	3	0.83
Health-seeking behavior	Self-treatment	62	17.22
	Hospital visit	29	8.06
	Rest, no treatment	27	7.50
	No action	3	0.83

Knowledge, exposure pathways, and health outcomes

Farmers showed a moderate level of knowledge of pesticide hazards (Table 4). More specifically, farmers identified potential health hazards (72.78%), environmental hazards (68.06%), and livestock hazards (66.67%). Farmers had a much more varied knowledge level when asked about safe use of pesticides. For example, farmers avoided spraying pesticides on cloudy days (75.00%) and 69.17% considered wind direction. However, farmers were less knowledgeable when asked about avoiding application of pesticides before rainfall (34.44%). Farmers were more knowledgeable about exposure routes for pesticide poisoning, with 77.22% being aware of inhalation as a major exposure pathway, followed by oral routes (70%), skin penetration (65.56%), and eye contact (59.17%). Farmers were most familiar with yellow warning labels on pesticide packages (86.67%). It was found that (33.33%) of farmers who used pesticides without protection reported experiencing health symptoms, with headaches (18.06%) and skin irritation (16.94%) being the most prevalent ones. Additionally, most farmers (17.22%) sought treatment at home following pesticide exposure compared to those who visited hospitals (8.06%). A significant observation from this study is the disparity between farmers' awareness and behavior. While many respondents (72.78%) recognized that pesticides could be hazardous to human health, this knowledge did not translate into appropriate safety measures, corroborated with findings from the reviewed literature on farmers' knowledge, attitudes, and practices (Istriningsih *et al.*, 2022; Sapbamrer & Thammachai, 2020). This was mainly attributed to the lack of training, reported by 57.78% of respondents, which may have constrained farmers' ability to interpret pesticide hazards and properly use protective equipment (Desye *et al.*, 2024). Moreover, farmers rarely considered environmental conditions when spraying, with only 34.44% and 69.17% considering rainfall and wind, respectively (Koju *et al.*, 2020). These observations indicates that the issue may stem less from lack of awareness than from inadequate technical training. Similarly, the frequent use of bare hands for mixing pesticides (51.9%) was consistent with the findings from Nepal, where this practice has been identified as a common contributor to acute pesticide poisoning (Atreya *et al.*, 2020). The heavy use of fungicides and insecticides observed in this study, suggests that fungal diseases and insect pests are major constraints for these farmers, contributing a strong reliance on chemical control rather than integrated pest management, consistent with findings from other studies conducted in Nepal (Paudel *et al.*, 2020; Khanal *et al.*, 2022). Interestingly, farmers showed high compliance with hygiene practices, with 96.94% reporting handwashing after pesticide application. However, hygiene measures alone are not sufficient to prevent pesticide related health risks, particularly when the use of personal protective equipment is neglected (Lari *et al.*, 2023; Desye *et al.*, 2024). This may explain why approximately one-third of the participants (33.33%) reported experiencing adverse pesticide effects, such as headache and skin irritation, which are commonly associated with occupational pesticide user (Keleb *et al.*, 2024; Robinson *et al.*, 2024; Sapbamrer *et al.*, 2024).

Relationship between knowledge and precautionary practices

A statistically significant moderate positive correlation was found between farmers' knowledge scores and their precau-

tionary practice scores (r = 0.434, *p<0.01*), which suggests that farmers who demonstrated a better understanding of pesticide hazards applied more precautionary measures (Figure 1). Farmers' gender was found to be significantly associated with their safety practices; male farmers were more likely to use personal protective equipment and wash hands after spraying (*p<0.001*), while female farmers were more involved in knapsack spraying (p = 0.019). Farmers with literacy had a higher likelihood of adopting precautionary practices, compared to illiterate farmers (87.2% vs. 58.8%), although the association was not statistically significant (χ^2 = 38.87, p = 0.083; trend, p = 0.014). The likelihood of adopting precautionary practices decreased with farmers' age; it was highest among farmers aged 30 years or below and lowest among farmers older than 50 years (85.2% vs. 74.7%, respectively; *p<0.001*). The moderate positive correlation between knowledge and precautionary practice scores (Figure 1) suggests that more knowledgeable farmers tend to adopt safer practices. However, the occurrence of hazardous practices among many farmers with adequate knowledge indicates that awareness alone is insufficient to ensure safe pesticide handling. Similar findings were reported by (Atreya *et al.*, 2022; Karki *et al.*, 2025), who emphasized the need to address structural barriers, particularly the availability and accessibility of resources needed to support safer pesticides practices. Taken together, the results highlight the need for practical training, affordable protective equipment and targeted behavioral change communication to reduce the occupational and environmental risks associated with pesticide use in the study area.

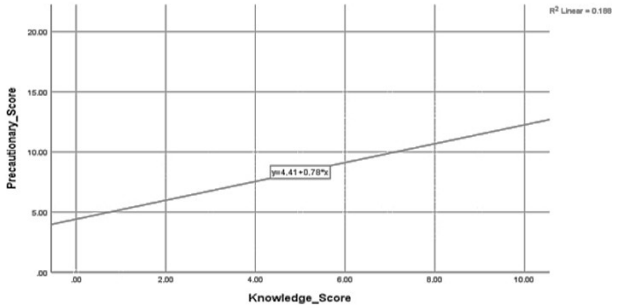

Figure 1. *Correlation between knowledge score and precautionary practice score.*

Conclusion

The study found widespread pesticide use among smallholder farmers in the Banke District, particularly in vegetable and paddy production. Although many farmers are aware of the potential health risks associated with pesticide use, unsafe handling and application practices remained common, highlighting a clear knowledge-practice gap. Safety practices also varied by gender, age, and education, indicating that these variables should be considered when developing intervention strategies. In general, the study emphasizes a distinct disparity between understanding and actual practice. Strengthening practical training to farmers, improving access to low-cost PPE, and promoting behavior-change communication are crucial for minimizing occupational and environmental risks and support safer, more sustainable pesticides use in the study area.

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DECLARATIONS

Author contribution statement: Conceptualization: M.C., N.O., N.R.P. and B.P.; Methodology: M.C.; and N.R.P. Formal analysis: M.C. and S.B.; Investigation: M.C. and S.K.; Resources: M.C.; Data curation: M.C., S.K., A.R., S.B., B.A., D.C. and PA; Writing-original draft preparation: M.C.; Writing-review and editing: B.P., N.R.P and A.R.; Visualization: A.R. and P.A.; Supervision: M.C., N.O., B.P., N.R.P. and D.C.; Project administration: B.A., and D.C.

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Ethics approval: This study was conducted in view of the institutional ethical guidelines and does not harm the human participants.

Consent for publication: All co-authors gave their consent to publish this paper in AAES.

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