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Research article

Adoption status of integrated pest management (IPM) practices among vegetable growers of Lamjung district of Nepal

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A R T I C L E I N F O

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A B S T R A C T

The widespread use of highly toxic pesticides for agricultural purposes has raised concerns about their hazardous impact on both human health and the environment. Integrated pest management (IPM) is a strategy designed to tackle pest problems and reduce pesticide use, with the aim of protecting both human health and the environment. This study was conducted in Besishahar, Sundarbazar, Rainas, and Madhyenepal municipalities of the Lamjung district of Nepal in the year 2023 with a sample of 100 vegetable-growing farmers to assess the adoption of IPM practices in vegetable cultivation. Descriptive and inferential statistics were used to analyze the data, and the logit model was used to identify the factors affecting the adoption of IPM practices in vegetable cultivation among farmers. Respondents were grouped into two categories, adopter and non-adopter, based on the extent of adoption of IPM practices. The findings revealed that only 37 % of the total respondents adopted IPM practices for vegetable cultivation. The easy availability of chemical pesticides and lack of bio-pesticides were the major constraints for the adoption of IPM practices in the study area. The output of the binary logit model indicated that greater participation in training, higher education levels, and increased contact with extension agents significantly influence the adoption of IPM practices in vegetable cultivation. The findings could be used to formulate better policies towards increasing the adoption of sustainable approaches in agriculture and regulation.

1. Introduction

Nepal is an agricultural country where almost 66 % of its population, directly or indirectly, is involved in agriculture, and it contributes 23.95 % to the national GDP, with vegetables contributing 13.44 % to the agricultural GDP [1]. Insect pests are a major problem in vegetable crops, causing plant damage and reducing crop production [2]. Commercial cultivation of vegetables heavily depends on chemical pesticides to manage pests [3]. Pesticides are indeed a remarkable innovation for modern agriculture, as they help reduce crop losses caused by pest infestation [4]. However, frequent and excessive use of pesticides can lead to the development of

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pesticide resistance in pests, resulting in the emergence of new pests [5]. Besides, the frequent use of pesticides leads to environmental pollution through contamination of soil, groundwater, and surface water [6]. Thus, while chemical pesticides have contributed to increased agricultural production, they simultaneously pose risks to both human health and the environment [7].

One way to improve the lives of farmers in most developing countries is through the adoption of innovative agricultural technologies. Among these technologies, Integrated Pest Management (IPM) stands out as an environmentally sustainable and socio-economically appropriate approach for addressing insect pests, diseases, and weeds [8]. In vegetable cultivation, IPM integrates various techniques and strategies to efficiently manage pests and diseases while promoting economic viability, sustainability, and environmental friendliness. It aims to minimize the reliance on chemical inputs by combining multiple pest control methods—such as cultural practices, mechanical approaches, biological controls, and the judicious use of pesticides [9]. IPM, as a holistic approach, takes into account the life cycle of pests and diseases as well as their interaction with the environment to provide effective and economical pest control while minimizing hazards to humans and the environment [10].

IPM was initiated in Nepal in 1997 through the Community IPM Support Program. IPM was initiated in Nepal in 1997 through the Community IPM Support Program. Various NGOs/INGOs have played a crucial role in promoting IPM practices across the country. Organizations such as FAO, the Integrated Pest Management Innovation Lab (IPM IL), KISAN, Caritas Nepal, iDE Nepal, Winrock International, and USAID have been instrumental in disseminating IPM technologies. These organizations have supported the implementation of farmer field schools (FFS), field days, group dissemination through market planning committees (MPC), demonstrations, training sessions, and written media like pamphlets [11].

In order to increase the likelihood of IPM adoption, policymakers should focus on building irrigation schemes, strengthening research-extension-farmers (R-E-F) linkages, making credit services more accessible, providing training and workshops for development agents, empowering the educational sector, and making information accessible to farmers [12]. Participatory approaches are needed for the development and extension of these technologies, as farmers often require external support in terms of knowledge, technique, and supportive policies [13]. Additionally, farmers' perceptions of risk and cost and their access to extension information, training, and experience are key determinants of technology adoption [14]. The principal objective of this study is to investigate the current status of IPM practices adoption among vegetable farmers and uncover the influential factors and constraints for the adoption of IPM practices, which will help create awareness among farmers and assist stakeholders in developing strategies to address issues related to pest management.

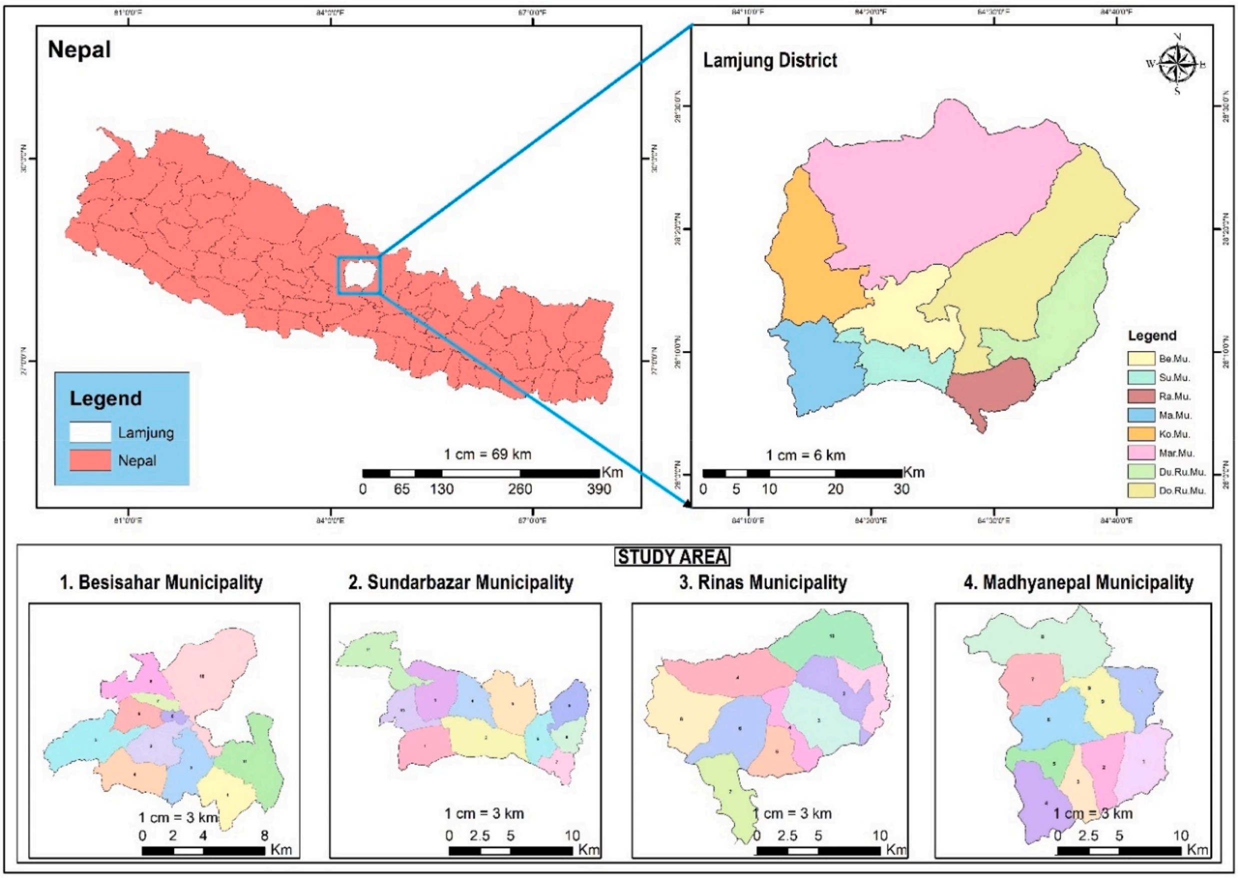

Fig. 1. A map of Nepal showing the study site, Lamjung district of Nepal.

2. Methodology

2.1. Study site

The highly potential areas of Lamjung district—Besishahar, Sundarbazar, Rainas & Madhyenepal Municipalities (Fig. 1)—were purposively selected for the study as there were plentiful numbers of vegetable growers, extensive area covered by vegetables, good production of vegetables, and better access to road facilities in the district. The main vegetable crops cultivated in these areas include tomatoes, cauliflower, cabbage, cucurbits, beans, okra, and leafy greens, providing a diverse context for assessing the application of IPM practices.

2.2. Selection of vegetable growers

A total of 100 vegetable growers, 35 from Besishahar, 25 from Sundarbazar, and 20 from each Rainas and Madhyenepal municipalities, were selected by random sampling technique to draw a representative sample.

2.3. Survey design and data collection

The primary data for this study was collected directly from farmers at the selected site through semi-structured face-to-face interviews. Prior to the main data collection, a pre-testing was carried out to assess the validity and effectiveness of the interview schedule. Verbal consent was obtained from all the participants before their involvement in the study. Additionally, secondary information was gathered by reviewing both published and unpublished documents, including annual reports from the Agriculture Knowledge Center (AKC) in Lamjung, journal articles, records from the Center Bureau of Statistics (CBS) and the Ministry of Agriculture and Livestock Development (MoALD), and farmers' group records.

2.4. Data analysis

Data analysis was conducted using a combination of statistical tools and software. The primary and secondary data collected from the field survey were coded, organized, and tabulated using the IBM SPSS Statistics (Version 25) [15]. For further data analysis, STATA (Version 14) [16] and Microsoft Excel 2019 [17] were employed. Inferential statistical techniques used in the analysis included Garrett ranking, Relative Importance Index, Chi-Square test, *t*-test, and the binary logit model. Prior to conducting regression analysis, diagnostic tests were performed to assess the possibility of multicollinearity among the independent variables.

2.5. Categorization of farmers as IPM adopter or non-adopter

The level of adoption was categorized based on the farmers' knowledge and the extent to which they adopted IPM practices. A set of 10 standards was established in consultation with senior officers from AKC and IPM extension agents. These practices included record keeping, use of traps and barriers, use of resistant varieties, selective pesticide use, threshold-based action, use of botanicals, biological control, mixed cropping, crop rotation, and manual cleaning. Respondents who complied with 7 or more of these standards were classified as IPM adopters. Conversely, those who failed to meet this threshold were classified as non-adopters of IPM. This approach allows for a clear distinction between adopters and non-adopters, facilitating further analysis and understanding of IPM adoption patterns.

Record Keeping: Documenting pest occurrences, control actions, and crop conditions to make informed management decisions.

Use of Traps and Barriers: It involves deploying physical devices or structures to manage pest populations. Traps attract and capture pests, helping monitor and reduce their numbers. Barriers are physical obstructions that prevent pests from reaching crops or entering specific areas, thereby protecting plants from damage. For example, use of light traps (3/acre) for Diamondback Moths (DBM), pheromone traps (5/ha) for *Helicoverpa armigera*, delta and yellow sticky traps for whiteflies, and nursery netting to protect against whitefly infection [18].

Use of Resistant Varieties: Planting crop varieties that are naturally resistant to certain diseases or pests. For instance, tomato varieties such as Arka Vikash, Pusa Gaurav, and Pusa Early Dwarf are resistant to fruit borer (*Helicoverpa armigera*). Similarly, cauliflower varieties like KW-5, KW-8, and Kathmandu Local show resistance to stem borer (*Hellula undalis*) [18].

Selective Pesticide Use: Applying pesticides targeted at specific pests to minimize harm to beneficial organisms and the environment.

Threshold-Based Action: A certain level of insect pests and minor damage is generally tolerable. The point at which the pest population and damage level require intervention is called action threshold. This concept is vital in Integrated Pest Management (IPM) as it prevents overusing pesticides and lowers costs by ensuring that pesticides are used only when absolutely necessary [19].

Use of Botanicals: Botanical pesticides can be made at home using pesticidal plants like neem or pyrethrum, making them affordable and accessible for farmers with limited resources. While they are not as potent as synthetic chemical pesticides, frequent application can keep insect pest populations below harmful levels [20]. Effective botanical compounds identified against pests include pyrethrin from pyrethrum (*Tanacetum cinerariifolium*), azadirachtin from neem (*Azadirachta indica*), as well as compounds from garlic (*Allium sativum*), turmeric (*Curcuma longa*), rosemary (*Rosmarinus officinalis*), ginger (*Zingiber officinale*), and thyme (*Thymus vulgaris*) [21].

Biological Control: Biological control involves utilizing living organisms or substances derived from them to manage pests. This includes employing parasitoids, predators, and pathogens to keep insect pest populations at levels that do not cause economic damage

[9].

Mixed Cropping: Growing different types of crops together to enhance biodiversity and reduce pest infestations. For example, growing basil alongside tomatoes can help deter pests like the tomato hornworm and aphids due to the strong aroma of basil that repels these insects [22]. The traditional Three Sisters method intercrops maize, beans, and squash, creating a symbiotic relationship. Maize provides a structure for beans to climb, while beans fix nitrogen in the soil, benefiting maize. Squash acts as ground cover, suppressing weeds and conserving soil moisture, promoting a healthier environment for all three crops [23].

Crop Rotation: Alternately planting different crops in the same field to disrupt pest life cycles and improve soil health. Crop rotation of tomatoes with legumes is vital in IPM as it reduces insect pests by breaking their life cycles and improves soil health through nitrogen fixation. This practice leads to fewer pests, better seedling emergence, and higher yields [24].

Manual Cleaning: Removing pests and weeds by hand to reduce their impact on crops.

2.6. Garrett's ranking technique

The problems in vegetable cultivation and the constraints perceived by farmers regarding the adoption of IPM technologies were ranked using Garrett's ranking technique. The respondents gave these problems and constraints to rate them on a five-point continuum from very severe, quite severe, severe, not so severe, and least severe. The collected data were analyzed using the following formula:

$$\text{Percent position} = \frac{100 - \text{Rij}}{\text{Nj}}$$

where, Rij = Rank given for the ith variable by jth respondents.

Nj = Number of variables ranked by jth respondents.

The percent position for each rank was then converted to scores by referring to tables given by Ref. [25]. Then, for each factor, the scores of individual respondents were summed up and divided by the total number of respondents to calculate the mean score. The mean scores for all the factors were ranked.

2.7. Binary logistic regression model

The binary logistic regression model was used to analyze the factors affecting awareness of IPM among vegetable growers. Eleven different factors, hypothesized as factors affecting awareness of IPM, were taken as independent variables, taking IPM awareness use as the dependent variable. Table 1 describes the variables used in the binary logistic regression model.

$$Y_i\ (\text{adoption} = 1) = b^0 + b^1X^{1i} + b^2X^{2i} \ldots\ldots\ldots + b^kX^{ki} + e^i$$

where,

Y_i = ith observation of the dependent variables, Y_i = Adoption (dummy): 1 if adopter and 0 for non-adopter.

X_1 …. X_{11} = explanatory variables explained as below

b_0 = intercept term (constant)

b_j = coefficient for each of the independent variables

e_i = error term.

X_{ji} = ith observation of jth independent variables

i = n = number of observations = 120.

2.7.1. Age—respondent's age

Age is expected to have a negative impact on adoption. Farmers who are older and more experienced might be less inclined to try out new technologies, whereas younger farmers, being less cautious about risks, are more open to embracing new methods [26].

Table 1

Description of variables used in the binary logistic regression model.

Variable	Description	Value	Type
Age	Age of respondent	Years	Continuous
Sex	Sex of respondent	1 if male, 0 if female	Dummy
Education	Education status of respondent	Years	Continuous
Family labor	Total family labor of respondent	Persons	Continuous
Livestock owned	Total livestock owned by respondent	Livestock Standard Unit (LSU)	Continuous
Off farm income	Off farm income of respondent	1 if any occupation other than agriculture, 0 if agriculture	Dummy
Farm size	Total farm size by respondent	Area in ha	Continuous
Experience	Experience in vegetable cultivation of respondent	Years	Continuous
Extension agents	Contact of respondents with extension agents	1 if Yes, 0 if No	Dummy
Training	Whether the respondent attended IPM related training	1 if attended, 0 if not attended	Dummy
Membership	Whether the respondent is members of Farming association	1 if Yes, 0 if No	Dummy

2.7.2. Sex—respondent's sex (male = 1, female = 0)

It is expected that male respondents are more likely to adopt IPM practices than the female. Women often have lesser access to critical resources such as land, cash and labor which makes it more difficult for them to carry out expensive and labor-intensive agricultural practices [27].

2.7.3. Education – level of respondent's education

Farmer's education level positively affects the adoption of new technology. Households where members have secondary or higher education levels are more likely to adopt new agricultural [28]. Studies have shown that farmers with lower level of education are less capable of adopting professional knowledge, recognizing pests and diseases, and understanding the risks associated with pest residues [29].

2.7.4. Off farm income

Farmers with additional income from non-agricultural sources are more likely to participate in IPM practices. This supplementary income provides the financial resources needed to adopt new technologies, including IPM practices, by ensuring the necessary liquidity [30].

2.7.5. Family labor

The size of the household, particularly the availability of family members to work on the farm, significantly influences the adoption of new practices. Family laborers can contribute to farm activities, even if they have other jobs, reducing the need for hiring external workers and saving costs [31].

2.7.6. Experience in vegetable cultivation

Experience in vegetable cultivation is positively related to the likelihood of adoption. With more experience, there is more crop related information available to the farmer. Experience may provide the farmer with general farming knowledge as well as specific farming knowledge about his or her own farm [28].

2.7.7. Livestock unit

Studies have found a correlation between higher livestock units and a greater likelihood of adopting new agricultural practices. Farmers with more livestock may have better financial stability and resources, enabling them to invest in and implement innovative techniques [32].

2.7.8. Farm size

[33] noted that the variation in adoption might be attributed to the characteristics of IPM technology. Larger farms are anticipated to embrace technologies that require more capital, whereas smaller farms are likely to adopt technologies that demand more labor.

2.7.9. Participation in IPM-related training

Participation in training helps farmers increase their knowledge through formal and informal education and apply this information in their own fields. This is expected to positively impact adoption [34].

2.7.10. Contact with extension agents

Technical advice and extension services play a significant role in farmers' willingness to adopt environmentally friendly practices. Farmers who participated more frequently and in diverse extension activities were more likely to adopt organic farming [35].

2.7.11. Membership of farming association

In most developing countries where information asymmetry is common, group membership or organizational membership plays an

Table 2
Distribution of the demographic and socio-economic characteristics (continuous variables) of the sampled household with farmer's category.

Variables	Overall (n = 100)	Farmers' category		t-value
		Adopter (n = 37)	Non-adopter (n = 63)	
Age	44.45 (8.61)	43.62 (8.19)	44.94 (8.88)	−0.74 NS
Family size of HH	5.50 (2.51)	5.73 (2.45)	5.37 (2.56)	0.7 NS
Male members of HH	3.05 (1.84)	3.41 (1.8)	2.84 (1.84)	1.49 NS
Female member of HH	2.45 (1.26)	2.32 (1.27)	2.52 (1.26)	−0.76 NS
Economically active members	3.75 (1.74)	4.11 (1.49)	3.54 (1.85)	1.59**
Total land holdings (ha)	0.66 (0.58)	0.88 (0.72)	0.53 (0.43)	3.03**
Total operational land (ha)	0.11 (0.07)	0.15 (0.09)	0.09 (0.05)	3.81**
Livestock holdings (LSU)	5.8 0 (5.72)	6.88 (8.29)	5.17 (3.35)	1.46**
Experience in vegetable production	7.78 (4.5)	8.92 (4.82)	7.11 (4.19)	1.97*

Note. Figures in parentheses indicate standard deviation; p-values are the result of *t*-test, NS indicates non-significant, **, * indicates 5 %, 10 % level of significance respectively.

important role in technology adoption. Farmers involved in the community have a higher probability of IPM adoption compared to farmers who were not [36].

3. Results and discussion

3.1. Socio-economic and demographic characteristics

About 37 % of total respondents have adopted IPM practices in vegetable cultivation. Despite continuous efforts by various organizations to promote IPM, the majority of the farmers remain non-adopters, indicating a need for additional efforts. Understanding the factors influencing farmers' adoption decisions could improve the effectiveness of IPM dissemination programs.

The average age of IPM adopters was 43.62 years, slightly younger than the non-adopters, who averaged 44.94 years. The adopters also had more experience, averaging 8.92 years compared to the non-adopters' 7.11 years (Table 2). The average household (HH) size for IPM adopters and non-adopters was 5.73 and 5.37, respectively which was higher than the national average of 3.53 in 2021 [37] (National Statistics Office, 2023). The average number of male and female members in the households of IPM adopters was 3.41 and 2.32, respectively, while non-adopters had an average of 2.84 male and 2.52 female members. The average number of economically active members was higher among IPM adopters (4.11) compared to non-adopters (3.54). This difference was found to be statistically significant at a 5 % level of significance (Table 2). In terms of landholding, IPM adopters had an average of 0.88 ha (ha), with 0.15 ha dedicated to vegetable cultivation. In contrast, non-adopters had a smaller average landholding of 0.53 ha, with 0.09 ha used for vegetable cultivation.

The gender distribution among IPM adopters was 59.5 % males and 40.5 % females, whereas among non-adopters, 54 % were males and 46 % were females, with no statistically significant difference (Table 3). In terms of ethnicity, 48.6 % of adopters were Janajati, 27 % were Brahmin, and 24.3 % were Chhetri. Among non-adopters, 44.4 % were Janajati, 39.7 % were Chhetri, and 15.6 % were Brahmin, reflecting the major ethnic groups in the Lamjung district [37]. Education levels varied significantly between adopters and non-adopters. None of the adopter respondents were illiterate, 5.5 % were literate (non-formal education), 40.5 % had primary education, 45.9 % had secondary education, and 8.1 % had higher education. In contrast, among non-adopters, 9.5 % were illiterate, 30.2 % were literate (non-formal education), 34.9 % had primary education, 23.8 % had secondary education, and only 1.7 % had higher education. This difference was statistically significant at the 1 % level, supporting the findings by Ref. [38] that farmers' education levels significantly impact IPM adoption behavior.

Agriculture was the predominant source of income for both groups, with 67.6 % of IPM adopters and 74.6 % of non-adopters engaged in this sector. Business was less common, involving 5.4 % of adopters and 1.6 % of non-adopters. Civil service and foreign employment sectors had similar patterns in both groups, with minor percentage variations. Additionally, having multiple sources of income was quite common, with 21.6 % of adopters and 14.3 % of non-adopters having more than one income source.

Similar socio-economic factors influence IPM adoption in other regions globally. For instance, studies in Asia and Africa have shown that younger, more educated farmers with larger landholdings and more family labor are more likely to adopt IPM practices [39,40]. Younger farmers often exhibit greater openness to new technologies and practices, and their higher education levels enable them to better understand and implement IPM techniques. Larger landholdings provide the necessary space for experimenting with and integrating multiple pest management strategies, while more family labor allows for the labor-intensive aspects of IPM, such as manual pest control and monitoring [33]. Additionally, access to resources, information, and training further supports the adoption of IPM practices in these regions.

Table 3
Distribution of the demographic and socio-economic characteristics (categorical variables) of the sampled households with farmer's category.

Variables	Category	Overall (n = 100)	Farmers' Category		Chi-square
			Adopter (n = 37)	Non-adopter (n = 63)	
Gender	Male	56	22 (59.5)	34 (54)	0.593^{NS}
	Female	44	15 (40.5)	29 (46)	
Ethnicity	Bramhin	20	10 (27)	10 (15.9)	0.206^{NS}
	Chhetri	34	9 (24.3)	25 (39.7)	
	Janajati	46	18 (48.6)	28 (44.4)	
Education	Illiterate	6	0 (0)	6 (9.5)	0.002***
	Literate (non-formal)	21	2 (5.5)	19 (30.2)	
	Primary level	37	15 (40.5)	22 (34.9)	
	Secondary level	32	17 (45.9)	15 (23.8)	
	Higher level	4	3 (8.1)	1 (1.7)	
Primary source of income	Agriculture	72	25 (67.6)	47 (74.6)	0.615 ^{NS}
	Business	3	2 (5.4)	1 (1.6)	
	Civil service	3	1 (2.7)	2 (3.2)	
	Foreign employment	5	1 (2.7)	4 (6.3)	
	More than one	17	9 (21.6)	9 (14.3)	

Note. Figures in the parentheses indicate percent, NS indicates non-significant, *** indicates 1 % level of significance.

3.2. Livestock holding characteristics of the households

Household livestock holding was assessed using the Livestock Standard Unit (LSU) as defined by Ref. [41]. The study found that the overall average LSU per household was 5.80. Notably, the average LSU per household for IPM adopters (6.88) was higher than that of non-adopters (5.17), as illustrated in Table 4. This finding suggests that IPM adopters might have better overall farm management practices, which include maintaining higher livestock holdings.

3.3. Farmers adoption of IPM practices in vegetable cultivation

In terms of the adoption rate of ten IPM practices, manual cleaning, and the use of traps and barriers are more widely adopted, with 73 % and 63 % adoption rates, respectively (Fig. 2). Conversely, the use of resistant varieties and record keeping have lower adoption rates of 19 % and 9 %, respectively. Meanwhile, strategies such as crop rotation (42 %), biological control (41 %), use of botanicals (31 %), and threshold-based action (30 %) show moderate adoption rates. A significant number of farmers (54 %) used selective pesticides as an IPM practice in vegetable cultivation. They used only targeted pesticides based on economic thresholds and the consideration of factors regulating pest populations. Selective pesticides are preferred in IPM programs to minimize the impact on beneficial organisms and reduce pesticide resistance [42]. Studies have shown that vegetables grown using IPM practices with selective pesticides have lower pesticide residues compared to those grown using conventional cultivation practices [43]. The number of farmers using botanicals was lower compared to those using other IPM practices. Neem, derived from the Azadirachta indica tree, is a commonly used botanical by vegetable growers. It is prepared by mixing the extracts from the seeds, leaves, and bark of the tree. Neem has a bitter taste that deters insects from feeding on it, making it an effective method for controlling harmful insects [44].

3.4. Control methods for insect pests

Among the adopters, mechanical methods were the most employed control strategy (84 %), followed by cultural methods (78 %) and biological methods (65 %) (Fig. 3). However, chemical methods were used less frequently (41 %) by adopters. This preference is supported by the notion that the use of durable, reliable tools is crucial for maintaining efficiency and minimizing downtime, further enhancing the appeal of mechanical methods among farmers [45]. Educational programs and access to high-quality equipment are essential to support the broader adoption of these sustainable pest management practices [33].

In contrast, among the non-adopters, a higher proportion relied on chemical methods (87 %), while the utilization of cultural (48 %), mechanical (48 %), and biological methods (32 %) was comparatively lower. This reliance on chemical methods by non-adopters may be attributed to the immediate and visible effects of pesticides, which can be more convincing to farmers who are less familiar with IPM techniques [33].

On a global scale, the preference for chemical methods among non-adopters is also observed in various regions where awareness and access to IPM practices are limited. For example, in many parts of Africa, the lack of access to IPM training and resources leads farmers to default to chemical pest control [40]. Conversely, in regions with robust IPM training programs and legislative support, such as parts of Europe, there is a higher adoption rate of non-chemical pest control methods [46]. This underscores the importance of continuous education and support for farmers to encourage the adoption of more sustainable pest management practices.

3.5. Problems related to vegetable production

The problems encountered by farmers in vegetable production were analyzed and are presented in Table 5. The study revealed that the most significant challenge was environmental problems, which ranked first with a Garrett score of 63.64. These issues included insect pests, diseases, fluctuating weather conditions, and soil fertility concerns. Marketing problems, such as perishability, price fluctuations, middlemen, and transportation, ranked second with a Garrett score of 53.42. Technical problems, including issues with inputs, extension support, and storage, followed with a score of 48.69. Economic problems, notably the high costs of inputs and credit

Table 4
Livestock holding characteristics of the households.

Livestock	Overall (n = 100)		IPM adoption			
			Adopter (n = 37)		Non-adopter (n = 63)	
	Number	LSU	Number	LSU	Number	LSU
Cattle	17	17	4	4	13	13
Buffalo	92	138	40	60	52	78
Oxen	22	22	9	9	13	13
Pig	11	6.6	1	0.6	10	6
Goat	631	252.4	209	83.6	422	168.8
Poultry	720	144	487	97.4	233	46.6
Total		580		254.6		325.4
Average		5.80		6.88		5.17

Note. LSU of individual animal (buffalo = 1.5, cow/bull = 1, swine = 0.6, sheep/goat = 0.4, poultry = 0.2).

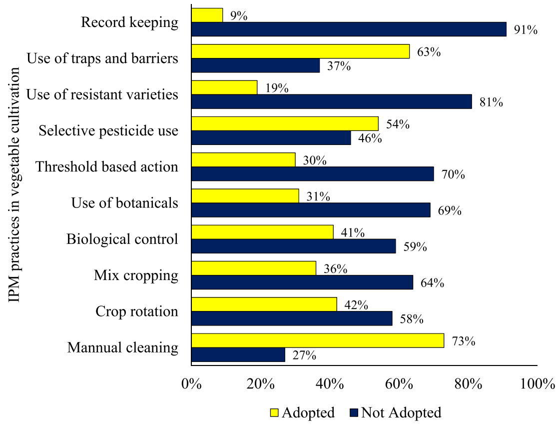

Fig. 2. Overall adoption of IPM practices in vegetable cultivation.

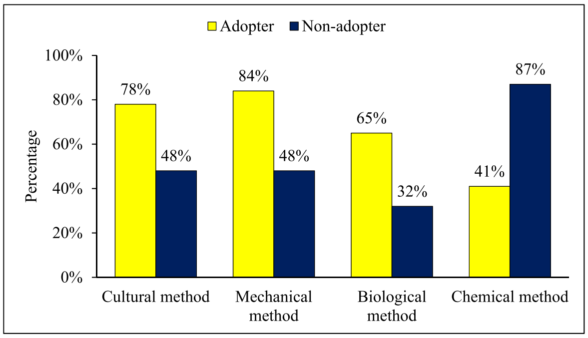

Fig. 3. Control methods for insect pests management.

Table 5
Ranking of different problems related to vegetable production by the respondents.

Problems	Garrett score	Ranking
Environmental problems (Insect pests, disease, fluctuation of weather conditions, soil fertility)	63.64	I
Marketing problems (Perishable, price fluctuation, middleman, transportation)	53.42	II
Technical problems (Inputs, Ext. support, storage)	48.69	III
Economic problems (High costs of inputs, credit facilities)	45.67	IV
Labor problems (Unskilled, high cost, unavailability)	37.58	V

facilities, scored 45.67, while labor problems, characterized by unskilled labor, high costs, and unavailability, ranked last with a score of 37.58 [47]. also identified disease and insect attacks, price fluctuations, and the high cost of inputs as significant challenges faced by farmers in vegetable cultivation.

Comparing these findings to other regions, similar challenges are reported globally. For instance, studies in Southeast Asia highlight environmental and marketing problems as significant barriers to vegetable production [48]. In African regions, technical and economic constraints are more pronounced due to limited access to inputs and financial resources [49]. This suggests that addressing these issues through policy interventions and support programs is critical for improving vegetable production across different regions.

Table 6
Constraints in the adoption of IPM technology (n = 63).

Constraints of adoption of IPM	Garret score	Rank
Easy availability of chemical pesticides	63.81	I
Lack of Bio-Pesticides	51.75	II
Lack of technical support	46.75	III
Lower effectiveness compared to chemical pesticides	46.43	IV
No separate price for organic vegetables	41.27	V

3.6. Constraints perceived by farmers in the adoption of IPM technologies

Table 6 presents the adopters' ranking of the perceived constraints in adopting IPM technologies. The majority of the respondents ranked the easy availability of chemical pesticides as the primary constraint, with a Garrett score of 63.81. This was followed by the lack of bio-pesticides (51.75), insufficient technical support (46.75), lower effectiveness compared to chemical pesticides (46.43), and the absence of a separate price for organic vegetables (41.27) [19]. also reported that the easy availability of chemical pesticides and the limited availability of bio-pesticides were barriers to the adoption of IPM technology.

Similar constraints were observed globally. For example, in Latin America, the availability of chemical pesticides and lack of bio-pesticides were major barriers to IPM adoption [50]. In contrast, regions with strong regulatory support and well-developed markets for organic produce, such as parts of Europe, showed higher adoption rates of IPM practices [46]. These findings underscore the importance of strengthening bio-pesticide availability, providing technical support, and creating market incentives for organic produce to enhance IPM adoption.

3.7. Factors affecting adoption of IPM among vegetable growers

IPM adoption is influenced by a range of factors (independent variables), encompassing socio-demographic and extension-related aspects. The study examined the impact of these independent variables on IPM adoption. From the result of the diagnostic tests—carried out to assess the potential for multicollinearity among independent variables—the average Variance Inflation Factor (VIF) was determined to be 1.29, with no variable exceeding a value of 1.7, indicating the absence of multicollinearity among the independent variables. Table 7 depicts the results of a binary logit regression model aimed at identifying the key determinants influencing farmers' knowledge of IPM. The study found that education, contact with extension services, and participation in IPM-related training emerged as statistically significant factors at the 1 % level of significance. Membership in a farming association was significant at the 5 % level. These results align with the findings of [11]. Similarly [38], also found significant influence of gender, education level, training, landholding size, and contact with extension agents on adoption behavior of farmers. Significance is observed at the 1 % level, where the binary logistic regression's Chi-square value (χ^2) of 68.72 and the corresponding log-likelihood ratio of −31.53 indicate that all the variables in the model have a significant influence on the likelihood of IPM adoption. The pseudo-R^2 value of 0.522 suggests that the variables included account for approximately 52.2 % of the decision to adopt IPM, underscoring the model's substantial explanatory power for IPM awareness.

The education level of farmers has a significant effect on the adoption of IPM practices in vegetable cultivation at a 1 % level of significance. The study revealed that with each unit increase in education level, the likelihood of adopting IPM practices increases by a factor of 1.48. This result aligns with the findings of [11], who suggests that a higher level of education provides farmers with the necessary knowledge and skills to comprehend the benefits of IPM practices and make informed decisions regarding their adoption. Educated farmers are more likely to comprehend the long-term advantages of IPM, including environmental sustainability and reduced reliance on chemical pesticides, leading to higher adoption rates.

Likewise, contact with extension agents also had a significant effect on the adoption of IPM practices at a 1 % level of significance. The results show that for each unit increase in contact with extension agents, the likelihood of adopting IPM practices increases by a factor of 18.71. This indicates that the efforts of extension agents, who provide information and support to farmers and communities, play a pivotal role in promoting the adoption of IPM practices. This could be attributed to the dissemination of expert knowledge to local farmers and the positive influence and attitude of these experts [51]. The frequency of a farmer's contact with personal local sources of information has a positive and significant impact on the adoption of recommended technology [52]. In Nepal, these extension agents are known as Junior Technical Assistants (JTAs). Despite the availability of various information sources on IPM practices, farmers prefer consulting JTAs due to their local familiarity and accessibility. Farmers can approach JTAs anytime without

Table 7
Key determinants of adoption of IPM among vegetable growers.

Determinants	Coefficient	Std. Err.	Sig.	Odd ratio
Sex	0.388	0.814	0.634	1.474
Education	0.391***	0.131	0.003	1.479
Family labor	0.129	0.209	0.537	1.138
Livestock owned	0.015	0.057	0.788	1.015
Off farm income	0.730	0.746	0.328	2.075
Land owned	0.033	0.040	0.409	1.034
Experience in vegetable cultivation	0.310	0.391	0.428	1.364
Contact with extension agents	2.929***	0.974	0.003	18.710
Participation in IPM related training	3.356***	1.099	0.002	28.667
Membership of farming association	1.724**	0.732	0.019	5.605
Summary Statistics				
Number of observations (N)	100			
LR (χ^2)	68.72			
Log likelihood	−31.53			
Pseudo R^2	0.522			

Note: **, *** indicates significant at 5 %, 1 % level of significance respectively.

hesitation and rely on their technical expertise to navigate complex IPM practices [20]. Consequently, farmers with more frequent contact with JTAs are more likely to adopt IPM practices compared to those with less frequent contact.

Similarly, participation in training significantly influences IPM adoption at a 1 % level of significance. The study revealed that for each unit increase in training participation, the likelihood of adopting IPM practices increases by a factor of 28.67. Training is an effective strategy for enhancing farmers' awareness of innovative technologies. Numerous studies have shown that access to information positively influences adoption [11,20,53]. This impact can be attributed to the comprehensive understanding and skills gained through training programs, which empower farmers to implement IPM practices more effectively. Training sessions often provide hands-on experience, practical demonstrations, and opportunities to engage with experts, making it easier for farmers to grasp and apply new techniques. Consequently, farmers who participate in training are better equipped to adopt and sustain IPM practices compared to those who do not receive such training.

Membership in farming associations also significantly affects the adoption of IPM practices at a 5 % level of significance, indicating that for each unit increase in farming association membership, the likelihood of adopting IPM practices increases by a factor of 5.61. This finding aligns with the study conducted by Ref. [36], which found that membership in organizations plays a crucial role in technology adoption, and farmers involved in the community are more likely to adopt IPM compared to those who are not. Membership in these associations provides farmers with access to shared knowledge, resources, and support networks, facilitating the dissemination and implementation of IPM practices. The collaborative environment within farming associations encourages the exchange of experiences and best practices, further enhancing the adoption of innovative technologies [20]. As a result, farmers who are active members of farming associations are better positioned to embrace and sustain IPM practices.

4. Conclusion

This study revealed that the adoption rate of IPM in vegetable cultivation is 37 %, with the majority of the farmers lagging in the adoption of IPM technology, indicating the need for ongoing dissemination programs. The adoption of IPM was influenced by several factors, including age, sex, education, family labor, livestock ownership, off-farm income, land ownership, experience in vegetable cultivation, contact with extension agents, participation in IPM-related training, and membership in farming associations. The binary logit regression model showed that the farmers with access to training facilities, frequent contact with extension agents, higher education levels, and membership in farming associations exhibited a statistically significant inclination towards adopting IPM, providing them with the necessary knowledge, resources, and support to encourage the adoption of IPM practices. By improving access to training, information, and alternative pest management strategies, farmers can make informed decisions and effectively implement IPM techniques, leading to improved pest control and sustainable agricultural practices. To foster a favorable perception towards IPM, extension agents, mass media, and NGO personnel need to underscore the advantages of IPM and the harmful effects of frequent pesticide use. The study also revealed that most farmers used manual cleaning, traps and barriers, and selective pesticide use, while fewer farmers used record keeping, resistant varieties, threshold-based action, botanicals, biological control, and mixed cropping. The adoption and intensity of IPM technologies in Nepal and other developing countries are influenced by various socio-economic, institutional, and management factors, aligning with Roger's adoption theory and empirical studies. These findings can contribute to the development of more effective policies aimed at increasing the adoption of IPM technologies, particularly in Nepal and other developing countries.

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Data availability statement

The data supporting this study's findings are available from the corresponding author, Shrestha S., upon request.

CRediT authorship contribution statement

Sukraraj Shrestha: Writing – original draft, Visualization, Software, Methodology, Formal analysis, Conceptualization. **Lal Prasad Amgain:** Writing – review & editing, Methodology, Investigation, Conceptualization. **Prem Pandey:** Writing – review & editing, Visualization, Supervision, Methodology, Investigation. **Tarjan Bhandari:** Writing – review & editing, Visualization, Supervision, Software, Data curation. **Sudip Khatiwada:** Writing – review & editing, Visualization, Methodology, Formal analysis.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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