



Farmers' Awareness on Excessive Pesticide Use in Vegetable Cultivation: A Case Study from Shariatpur District of Bangladesh

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Abstract: Vegetable cultivation is a vital source of income and nutrition in Bangladesh; however, excessive pesticide use poses significant environmental and public health risks. This study examined the socio-economic characteristics of 105 vegetable farmers in Bhedarganj Upazila, Shariatpur District, their awareness of environmental pollution, and the factors influencing such awareness. The findings revealed that most farmers were middle-aged (45%) with a mean age of 48.9 years, had secondary-level education (50%), medium-sized families (55%), and predominantly small farm holdings (76%) with an average size of 0.738 ha. The mean annual income was 299,857 BDT. Farmers generally exhibited moderate extension media contact (66%), medium training exposure (50%), moderate cosmopolitanism (37%), and relatively high organizational participation (49%). Awareness of environmental pollution due to excessive pesticide use was moderate for 46% of respondents and high for 39%, with a mean awareness score of 18.70 (SD = 3.43). Multiple regression analysis indicated that 63% of the variation in awareness was explained by the selected socio-economic variables ($R^2 = 0.6325$; adjusted $R^2 = 0.5934$; $p < 0.001$). Cosmopolitanism, farming experience, organizational participation, and extension media contact were identified as significant positive predictors, whereas age, education, farm size, and income were not statistically significant. The study underscores the importance of information access, social interaction, and experiential learning in enhancing environmental awareness and recommends strengthening extension services, training programs, and farmer organizations to promote sustainable vegetable cultivation.

Keywords: Excessive pesticide; Farmers' awareness; Vegetable cultivation; Socio-economic characteristics; Extension media contact

INTRODUCTION

Modern agriculture depends heavily on synthetic pesticides to protect crops from insect pests and plant diseases and to ensure food security. In Bangladesh, particularly in intensive vegetable production systems, pesticide use has increased rapidly over the last few decades (Islam et al., 2021; Damalas and Koutroubas 2018;

Howlader et al., 2024). While these agrochemicals contribute to higher yields and reduced crop losses, their excessive and indiscriminate application has emerged as a serious environmental and public health concern. This problem is especially evident in vegetable-growing areas such as Bhedarganj upazila of Shariatpur District, where farmers frequently rely on repeated pesticide applications to

secure marketable produce (Akter et al., 2018; Howlader et al., 2025).

The excessive use of pesticides creates a complex ecological and socio-economic paradox. On one hand, farmers aim to maximize production and income; on the other hand, overdependence on chemical control methods leads to long-term environmental degradation and health risks (NASRIN 2017; Atreya et al., 2012, Howlader et al., 2026; Laboni et al., 2024). Continuous and unregulated pesticide application contaminates soil, water, and air, disrupts soil nutrient balance, and alters the biological, chemical, and physical properties of agricultural land. Beneficial soil microorganisms, which play a vital role in nutrient cycling and soil fertility, are particularly vulnerable to chemical exposure. As a result, soil quality and long-term productivity may decline despite short-term yield gains (NguyeN et al., 2018; Karim et al., 2024; Mia et al., 2025; MSI Shumon et al., 2025).

In addition to environmental degradation, excessive pesticide use poses significant risks to human health (Zhou et al., 2009; MIU Hoque et al., 2025; Mou et al., 2025; Nikson et al., 2024). Farmers are often directly exposed to toxic chemicals during mixing and application, frequently without proper protective equipment. Such exposure may result in acute poisoning symptoms as well as chronic health problems, including neurological disorders and other long-term diseases. Consumers are also at risk due to pesticide residues on fresh vegetables, especially when farmers ignore recommended safety measures such as the pre-harvest interval (PHI) (Gurbuz et al., 2014; Rahman et al., 2024; Robi et al., 2025). These health hazards highlight the urgent need to address unsafe pesticide practices at the farm level.

Despite growing scientific evidence and awareness campaigns highlighting these risks, many farmers continue to apply pesticides excessively. This persistence suggests the presence of a substantial knowledge practice gap (Shahidullah et al., 2023; Rahman et al., 2025). In many cases, farmers lack access to effective Integrated Pest Management (IPM) alternatives, receive limited extension support, or possess insufficient understanding of the long-term environmental consequences of pesticide misuse (Ntow et al., 2006). In the context of Bhedarganj upazila, the actual level of farmers' awareness regarding environmental pollution caused by excessive pesticide use remains largely unexplored. Understanding this awareness is essential for designing effective interventions (Nishantha et al., 2016; Sultana et al., 2025; Yesmin et al., 2-2023).

Farmers' socio-economic characteristics are widely recognized as key factors influencing their knowledge, attitudes, and practices. Variables such as education level, farm size, income, farming experience, training exposure, and extension contact may significantly affect how farmers perceive environmental pollution and pesticide-related risks (Sharafi et al., 2018; Umar et al., 2021). Identifying the relationships between these factors and farmers' awareness can help explain why certain groups are more vulnerable to unsafe pesticide practices than others. Such insights are crucial for developing targeted extension and policy strategies (Yang et al., 2024).

The justification for this study is strongly supported by national agricultural trends. Bangladesh has achieved remarkable success in vegetable production, reaching nearly 19.7 million tons in 2020–21 (BBS 2020). However, this achievement has been accompanied by a sharp rise in pesticide consumption, with imports increasing from about 3,000 metric tons in 1990 to approximately 45,000 metric tons in 2021 (BBS 2020). Alarming, farmers may apply pesticides 17–50 times in a single growing season, often ignoring safety guidelines. Only a small proportion of farmers receive formal training on safe pesticide handling, further intensifying the problem (Rahman et al., 2003).

This study contributes scientifically by providing a localized and quantitative assessment of farmers' environmental awareness, rather than focusing solely on contamination levels. By identifying socio-economic determinants of awareness, the research moves beyond description to explain the underlying causes of pesticide misuse. From a policy perspective, the findings will support government agencies, extension services, and non-governmental organizations in designing targeted awareness programs, improving monitoring systems, and strengthening regulatory enforcement.

Several assumptions underlie this study. It is assumed that the selected respondents possess adequate knowledge to provide reliable information, that they responded honestly, and that the sample reflects the broader farming population of the study area. It is also assumed that the researcher's familiarity with the local context minimized interviewer bias and that the data followed regular and independent distributions. The study acknowledges limitations, including its focus on a specific geographic area, reliance on verbally reported data, and examination of a limited number of socio-economic variables.

In view of these concerns, this study takes a farm-level approach to examine pesticide use practices in vegetable cultivation in Bhedarganj upazila of Bangladesh. The specific objectives of the study were to: (i) identify the socio-economic characteristics of vegetable farmers using pesticides, (ii) evaluate farmers' level of awareness regarding environmental pollution resulting from excessive pesticide application, and (iii) analyze the influence of selected socio-economic factors on farmers' environmental awareness.

The findings of the study may contribute to promoting sustainable vegetable production by improving farmers' understanding of the effects of excessive pesticide use and supporting the design of effective extension and policy interventions.

MATERIALS AND METHODS

Experimental Site

The study was carried out in Bhedarganj Upazila, Shariatpur District, situated in south-central Bangladesh. This area was purposively selected due to its strong relevance to the research problem. Bhedarganj Upazila is well known locally for its intensive vegetable cultivation, a factor that is important because high-value, intensive production systems

often involve greater dependence on, and potentially excessive use of, chemical pesticides-the main focus of this study.

To further narrow the study population, one union, Mohishar, was specifically chosen due to its high density of vegetable growers. Within this union, the study included all vegetable

farmers from four villages: Mahisar, Arshinagar, Digar Mahishkhali, and Sokhipur. Figure 1a presents a map of Shariatpur District highlighting Bhedarganj Upazila, while Figure 1b shows a detailed map of the study area within the Upazila.

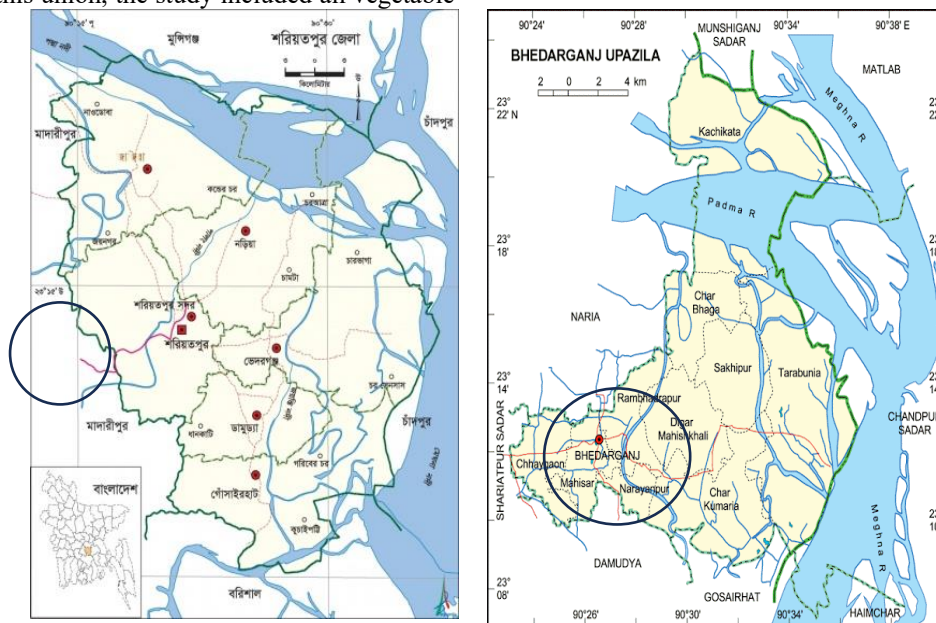


Figure 1. a. Map of Shariatpur District showing the location of Bhedarganj Upazila. b. Map of Bhedarganj Upazila highlighting the study villages in Mohishar Union (Source: www.websshariatpur.gov.bd).

Experimental Design and Sample Selection

The study employed Umar and Wachiko (2021) simplified formula to determine an appropriate sample size. The total registered population of vegetable growers in the selected areas of Bhedarganj Upazila, Shariatpur District, was 2,635. Using a 95% confidence level and a margin of error of 8.5%, the required sample size (n) was calculated as follows:

$$n = \frac{N}{1 + N(e)^2}$$

Where:

n = sample size

N = population size (2,635)

e = margin of error (0.0858)

Substituting the values:

$$n = \frac{2635}{1 + 2635 (0.0858)^2} \approx 105$$

The calculated margin of error is approximately 8.58%. Although a conventional margin of error is 5%, it can be increased depending on the study’s objectives and available resources (Chowdhury et al., 2017). The slight increase in the margin of error remains within an acceptable range for social science research. The final sample of 105 respondents was proportionally allocated among the selected villages based on the size of the farming population. Respondents were chosen using a random sampling technique to ensure representativeness and minimize selection bias.

Data Collection and Data Processing

This study examined how different socio-economic characteristics of vegetable farmers influence their

awareness of environmental pollution caused by excessive pesticide use. Ten key variables were considered: age, education, family size, farm size, annual family income, farming experience, Cosmopolitanism, training on vegetable cultivation, extension media contact, and participation in agricultural organizations.

Age was recorded in full years, as it may influence farmers’ attitudes and behaviors regarding pesticide use and environmental pollution. Education included years of formal schooling as well as non-traditional learning. Farmers who could read and write were scored accordingly, while those with informal or adult education were assessed equivalently. Family size was determined by counting all household members involved in agricultural activities, including the head of household, spouse, children, and other dependents.

Farm size was measured in hectares and included all land under ownership, leased land, and sharecropped land. The formula considered homestead land, owned cultivated land, land given to or taken from others under sharecropping, and leased land. Income was calculated from all agricultural and non-agricultural sources and expressed in thousand Takas, capturing the household’s overall economic capacity. Experience was measured in years of engagement with vegetable cultivation, with longer experience reflecting greater familiarity with farming practices and challenges. Cosmopolitanism was measured by the frequency of visits to eight external places beyond the local community, scored from 0 (not at all) to 4 (regularly), providing an overall score ranging from 0 to 28.

Training exposure was quantified by the number of days attended in vegetable production programs, including planting, pest management, soil preparation, and harvesting. One point was assigned per training day. Interaction with eight selected extension media outlets was recorded using a scale from 0 (never) to 4 (regularly). Scores were summed to give an overall media contact score ranging from 0 to 32. Participation was measured based on the level of involvement (ordinary member, executive committee member, president/secretary) and duration in years. Scores were computed using the formula:

Participation Score \times Duration (years)

Farmers' awareness of environmental pollution from pesticide overuse was assessed using ten statements related to vegetable cultivation. Responses were scored on a four-point Likert scale (0 = no awareness, 4 = high awareness), yielding a total score ranging from 0 to 40. Higher scores indicated greater awareness of ecological consequences.

Data Collection Instruments, Procedure and Processing

Primary data were collected using a structured interview questionnaire, pre-tested for clarity and relevance. Interviews were conducted face-to-face at farmers' homes or fields. The researcher collaborated with local leaders and field staff to ensure access and build rapport. Data collection was carried out over one month (May–June 2025). Farmers were briefed about the study's objectives, and interviews were conducted in the local language to ensure comprehension and accurate responses. Collected data were carefully reviewed, coded, and organized. Quantitative data were standardized, and qualitative responses were converted into numeric scores. Continuous variables were categorized into meaningful ranges, while training, media contact, and organizational participation were classified into low, medium, and high levels. Completed questionnaires were checked for errors or omissions and corrected as needed. All responses were coded using a pre-determined scheme, and qualitative data were converted into numeric scores for analysis. Data were then tabulated in alignment with the study objectives. Socio-economic variables were grouped

into standard ranges for analysis, while awareness and engagement scores were classified to facilitate comparison.

Statistical Analysis

Descriptive statistics (mean, range, frequency, percentage, standard deviation) were used to summarize socio-economic characteristics and awareness levels. Multiple regression analysis was applied to examine the influence of socio-economic factors on environmental awareness. All analyses were performed using SPSS version 25 (Singh 2009).

RESULTS AND DISCUSSION

In line with the study objectives, the chapter is divided into three sections: farmers' socio-economic profile, their awareness of environmental pollution caused by excessive pesticide use, and the relationship between socio-economic characteristics and awareness levels.

An overview of ten selected socio-economic characteristics of the respondents is summarized in Table 1, with separate tables provided for each characteristic to facilitate clear discussion and interpretation. The age distribution of farmers is presented in Table 2. Results show that most respondents were middle-aged (36–50 years, 45%), followed by older farmers (>50 years, 43%), while only 12% were young (≤ 35 years). The mean age was 48.895 years with a standard deviation of 10.388, indicating that the majority were within their productive working age.

Education plays an important role in farmers' understanding of modern agricultural practices, including safe pesticide use. Table 2 indicates that 50% of the farmers had secondary-level education, followed by 29% with primary education, while only 9% had education above the secondary level. The mean years of schooling was 6.333 (SD = 3.467), suggesting that most farmers had primary to secondary education (Table 2). Family size is an important socio-economic factor affecting labor availability and livelihood strategies. Table 2 shows that the majority of respondents (55%) belonged to medium-sized families, followed by small (24%) and large families (21%). The mean family size was 6.486 (SD = 1.415), indicating that most farmers lived in moderately large households.

Table 1. Salient features of the selected characteristics of farmers

Characteristics	Measuring unit	Range		Mean	SD
		possible	observed		
Age	Years	-	21-68	48.9	10.39
Education	Year of schooling	-	00-18	6.33	3.46
Family Size	Person	-	3-9	6.49	1.41
Farm Size	Hectare	-	0.17-4.68	0.738	0.412
Annual family income	('000' tk)	-	94-955	299.85	136.92

Farming experience	Years	-	5-50	19.6	7.59
Cosmopolitaness	Score	0-32	10-29	16.23	4.37
Training on vegetable cultivation	Days	-	0-10	11.72	5.95
Extension media contact	Score	0-24	11-24	6.09	1.60
Agricultural organizational participation	Score	-	0-17	4.21	2.33

Farm size influences resource availability, technology adoption, and farm productivity. Based on the DAE (1999) classification, farmers were grouped according to their landholding size. Table 3 shows that most respondents were small farmers (76%), followed by medium farmers (20%), while only 4% were marginal farmers. The mean farm size was 0.738 ha (SD = 0.412), indicating the predominance of small-scale farming in the study area. This finding is consistent with the national agricultural structure of Bangladesh, where small farms dominate (BBS, 2023). Small landholdings often encourage intensive input use, including pesticides, which may have environmental implications.

Annual income reflects farmers' economic status and their capacity to adopt improved farming practices. Based on the mean \pm SD classification, Table 4.6 shows that 46% of

respondents belonged to the medium-income group, followed by high-income (39%) and low-income groups (15%). The mean annual income was 299,857 BDT (SD = 136,924), indicating that most farmers had medium to relatively high income, which may enable greater investment in agricultural inputs (Table 3). Similar observations were reported by Rahman et al. (2020).

Farming experience plays a key role in decision-making, technology adoption, and environmental awareness. Based on the mean \pm SD classification, Table 3 shows that 54% of respondents had high farming experience, followed by medium (27%) and low experience (19%). The mean farming experience was 19.6 years (SD = 7.591), indicating that most farmers were highly experienced. Greater experience may enhance problem-solving ability and awareness of pesticide use and its environmental impacts.

Table 2. Distribution of the farmers according to their age, education and family size.

Age	Frequency	Percentage	Mean	Standard Deviation
Young (≤ 35)	13	12%		
Middle ($>35-50$)	47	45%	48.895	10.388
Old (>50)	45	43%		
Education	Frequency	Percentage	Mean	Standard Deviation
Illiterate (0)	1	1%		
Can sign only (0.5)	12	11%		
Primary (1-5 class)	30	29%	6.333	3.467
Secondary (6-10 class)	53	50%		
Above secondary (above 10)	9	9%		
Family size (person)	Frequency	Percentage	Mean	Standard Deviation
Small family (≤ 4)	25	24%		
Medium family (5 -7)	58	55%	6.486	1.415
Large family (above 7)	22	21%		

Cosmopolitanism reflects farmers' exposure to external communities and information sources, influencing their knowledge and attitudes toward agricultural innovations and environmental protection. Based on the mean \pm SD classification, Table 4 shows that 41% of respondents had high cosmopolitanism, followed by medium (37%) and low levels (22%). The mean cosmopolitanism score was 16.229 (SD = 4.368), indicating generally moderate to high exposure. Higher cosmopolitanism may enhance interaction with extension services, NGOs, and fellow farmers, thereby improving awareness of safe pesticide use.

Training plays a crucial role in improving farmers' knowledge, skills, and practices related to sustainable crop production and safe pesticide use. Based on the mean \pm SD classification, Table 4 shows that 50% of respondents had medium training exposure, followed by high (31%) and low levels (18%). The mean training duration was 11.724 days (SD = 5.953), indicating moderate training opportunities among farmers. Adequate training enhances farmers' technical capacity to adopt Good Agricultural Practices (GAP) and environmentally safe cultivation methods.

Table 3. Distribution of the farmers according to their farm size, annual income and farming experience.

Farm size (ha)	Frequency	Percentage	Mean	Standard Deviation
Marginal (up to 0.2 ha)	4	4%		
Small (>0.2 to 1.0 ha)	80	76%	0.738	0.412
Medium (>1.01 to 3.0 ha)	21	20%		
Annual Income ('000' tk)	Frequency	Percentage	Mean	Standard Deviation
Lowest (Up to 165)	16	15%		
Medium Medium (>165-300)	48	46%	299.857	136.924
Highest (above 300)	41	39%		
Farming experience (years)	Frequency	Percentage	Mean	Standard Deviation
Low (Up to 12)	20	19%		
Medium (>12-19)	28	27%	19.6	7.591
High (above 19)	57	54%		

Extension media contact reflects farmers' exposure to information sources that influence their knowledge and awareness. Based on the mean \pm SD classification, Table 4 shows that 66% of farmers had medium extension media contact, followed by high (23%) and low levels (11%). The mean score was 6.095 (SD = 1.602), indicating moderate engagement with extension services. This level of exposure suggests that farmers receive some guidance on pesticide use, though there is scope for strengthening communication. Participation in agricultural organizations enables farmers to share experiences, receive technical guidance, and adopt sustainable practices. Based on the mean \pm SD classification,

Table 5 shows that 49% of respondents had high organizational participation, followed by low (34%) and medium levels (17%). The mean participation score was 4.210 (SD = 2.332), indicating that farmers were moderately to highly involved in agricultural organizations.

The study assessed farmers' awareness of environmental pollution caused by excessive pesticide use (Table 5). Based on the mean \pm SD classification, 46% of respondents had a medium level of awareness, followed by high (39%) and low levels (15%). The mean awareness score was 18.695 (SD = 3.431), indicating an overall moderate level of awareness among farmers.

Table 4. Distribution of the farmers according to their cosmopolitanism, training on vegetable and extension media.

Cosmopolitanism (Score)	Frequency	Percentage	Mean	Standard Deviation
Low (Up to 12)	23	22%	16.229	4.368

Medium (13-17)	39	37%
High (above 17)	43	41%

Training on vegetable (days)	Frequency	Percentage	Mean	Standard Deviation
Low (Up to 6)	19	18%		
Medium (7-13)	53	50%	11.724	5.953
High (above 13)	33	31%		

Extension Media (score)	Frequency	Percentage	Mean	Standard Deviation
Low (Up to 4)	12	11%		
Medium (5-6)	69	66%	6.095	1.602
High (above 7)	24	23%		

Although most farmers were aware of the harmful effects of indiscriminate pesticide use on soil, water, biodiversity, and human health, a notable proportion lacked sufficient knowledge or practices to reduce environmental risks. These findings highlight the need for strengthened awareness programs, extension services, and training to promote sustainable pesticide management in vegetable cultivation. The contribution of farmers' awareness of environmental pollution due to excessive pesticide use was analyzed using

multiple regression (Table 6). The regression model was highly significant ($p < 0.001$), with an R^2 of 0.6325 and an adjusted R^2 of 0.5934, indicating that approximately 63% of the variation in awareness was explained by the selected socio-economic variables. While the overall model showed strong explanatory power, the effects of individual variables varied. A variable-wise interpretation is presented below.

Table 5. Distribution of the farmers according to organizational participation and awareness level

Agricultural Organizational Participation (score)	Frequency	Percentage	Mean	Standard Deviation
Low (Up to 2)	36	34%		
Medium (3-4)	18	17%	4.210	2.332
High (above 4)	51	49%		

Awareness (score)	Frequency	Percentage	Mean	Standard Deviation
Low awareness (Up to 15)	16	15%		
Medium awareness (16-19)	48	46%	18.695	3.431
High awareness (Above 19)	41	39%		

The contribution of farmers' awareness of environmental pollution arising from excessive pesticide use was examined using multiple regression analysis (Table 6). The overall regression model was highly significant at the 0.1% level ($p < 0.001$), with an R^2 value of 0.6325 and an adjusted R^2 of

0.5934. This indicates that approximately 63% of the variation in farmers' awareness was explained by the combined effects of the selected socio-economic characteristics, demonstrating strong explanatory power of the model.

Among the variables analyzed, age showed a negative but statistically non-significant relationship with awareness ($\beta = -0.092$, $p = 0.350$), suggesting that older farmers tended to be slightly less aware of environmental pollution, although the effect was weak. Education level ($\beta = 0.115$, $p = 0.236$), family size ($\beta = 0.060$, $p = 0.458$), farm size ($\beta = -0.173$, $p = 0.288$), and annual income ($\beta = 0.052$, $p = 0.739$) also exhibited non-significant effects on awareness, indicating that demographic and resource-related factors alone did not strongly influence farmers' environmental consciousness in the study area.

In contrast, several information- and exposure-related variables were found to significantly influence farmers' awareness. Extension media contact had a positive and significant effect ($\beta = 0.202$, $p = 0.042$), highlighting the importance of access to extension services and information channels in improving awareness of pesticide-related

environmental risks. Farming experience also showed a significant positive contribution ($\beta = 0.226$, $p = 0.047$), suggesting that prolonged involvement in farming enables farmers to recognize the adverse impacts of excessive pesticide use through practical experience. Although training had a positive coefficient ($\beta = 0.189$), its effect was not statistically significant ($p = 0.119$), possibly due to limited coverage or effectiveness of training programs.

Cosmopolitanism emerged as the strongest predictor of awareness ($\beta = 0.238$, $p = 0.017$), indicating that farmers with greater exposure to external communities and information sources were more environmentally conscious. Organizational participation also had a significant positive influence ($\beta = 0.218$, $p = 0.038$), emphasizing the role of farmer organizations and collective platforms in facilitating knowledge sharing and environmental learning.

Table 6. The Contribution of Farmers' Awareness on Environmental Pollution

DV	Independent Variable (IV)	β	Sig.	R ²	Adj. R ²	Sig.
Farmers awareness on environmental pollution	Age	-0.092	0.35			
	Education Level	0.115	0.236			
	Family Size	0.06	0.458			
	Farm Size	-0.173	0.288			
	Annual Family Income	0.052	0.739	0.6325	0.5934	0.000***
	Extension Media Contact	0.202	0.042*			
	Farming Experience	0.226	0.047*			
	Training on Vegetable Cultivation	0.189	0.119			
	Cosmopolitanism	0.238	0.017*			
	Organization Participation	0.218	0.038*			

$p < 0.05$ = Significant (*), $p < 0.01$ = Highly Significant (**), $p < 0.001$ = Very Highly Significant (***)

Overall, the findings suggest that farmers' awareness of environmental pollution is shaped more by information access, social interaction, and experiential learning than by basic socio-demographic characteristics. Strengthening extension services, promoting organizational participation, and increasing farmers' exposure to diverse information sources are therefore crucial strategies for enhancing environmental awareness and encouraging sustainable pesticide use in vegetable cultivation in Bhedarganj Upazila.

Discussion

The present study revealed that farmers' awareness of environmental pollution due to excessive pesticide use was largely influenced by information exposure, social interaction, and practical farming experience rather than by

basic demographic factors such as age, education, farm size, or income. The regression model explained 63% of the total variation in awareness ($R^2 = 0.6325$), indicating strong explanatory power of the selected socio-economic variables. The finding that cosmopolitanism significantly influenced environmental awareness ($\beta = 0.238$, $p = 0.017$) is consistent with previous studies. Hasan et al. (2025a), Khan et al. (2010) and Haque et al. (2025) reported that farmers with higher external exposure were more knowledgeable about safe pesticide use and environmental protection practices. Similarly, Hasan et al. (2025b), Gesesew et al. (2016) and Fahim et al. (2025) found that cosmopolite farmers were more likely to adopt integrated pest management (IPM) practices due to better communication networks and access to diverse information sources.

The positive and significant contribution of extension media contact ($\beta = 0.202$, $p = 0.042$) supports the findings of Hasan

et al. (2025c), Philip et al. (2021) and Basunia et al. (2026), who emphasized that frequent interaction with extension agents enhances farmers' environmental awareness and innovation adoption. Lithourgidis et al. (2016) and Bashir et al. (2025) also observed that farmers receiving regular extension support showed higher awareness of pesticide-related health and environmental risks.

Farming experience was another significant predictor ($\beta = 0.226$, $p = 0.047$), suggesting that long-term involvement in agriculture enables farmers to recognize the negative impacts of excessive pesticide use. Similar results were reported by Yilmaz (2015) and Ali et al. (2025), who found that experienced farmers had greater awareness of soil degradation and ecological imbalance caused by chemical inputs.

The significant role of organizational participation ($\beta = 0.218$, $p = 0.038$) aligns with the findings of Mergia et al. (2021) and Al Masum et al. (2025), who reported that collective action and farmer group membership enhance knowledge sharing and environmentally responsible behavior. Rijal et al. (2018) and Ahsan et al. (2025) further explained that farmer organizations improve access to technical knowledge and promote sustainable agricultural practices.

In contrast, variables such as age, education, income, and farm size were not statistically significant in explaining awareness. Similar findings were reported by Mubushar et al (2019) and Abdul Fahim et al. (2025), who noted that formal education alone does not necessarily translate into environmental consciousness unless supported by practical exposure and training.

Overall, the results of this study are consistent with earlier empirical evidence suggesting that information access, social networks, and experiential learning play a more critical role than structural socio-economic characteristics in shaping farmers' environmental awareness. Therefore, strengthening extension services, enhancing farmers' cosmopolitanism through exposure visits, and promoting active participation in agricultural organizations are essential strategies for reducing pesticide misuse and promoting sustainable vegetable cultivation in Bangladesh.

CONCLUSIONS

This study concludes that vegetable farmers in Bhedarganj Upazila possess a moderate level of awareness regarding environmental pollution caused by excessive pesticide use; however, this awareness is not uniformly distributed nor adequately translated into environmentally safe practices. While most farmers are middle-aged, moderately educated, and experienced, traditional socio-demographic and resource-based characteristics such as age, education, farm size, income, and family size do not significantly influence their environmental awareness. Instead, factors related to information access, social exposure, and experiential learning, namely extension media contact, farming experience, cosmopolitanism, and participation in agricultural organizations, play a decisive role in shaping farmers' awareness.

The multiple regression results demonstrate that these communication- and interaction-based variables collectively explain a substantial proportion of variation in awareness, highlighting that awareness is socially constructed rather than merely a function of formal education or economic capacity. Although many farmers recognize the harmful effects of pesticide misuse on human health and the environment, gaps remain in their understanding of soil and water contamination and biodiversity loss, indicating a persistent knowledge–practice disconnect.

Overall, the findings emphasize that strengthening extension services, enhancing farmers' exposure to external knowledge sources, and promoting organizational participation are more effective strategies for improving environmental awareness than relying solely on demographic or economic improvements. Addressing these factors is essential for promoting sustainable pesticide management and environmentally responsible vegetable cultivation in Bangladesh.

Declarations

Consent to publish

All authors have reviewed the manuscript and approved the final version of the manuscript for publication in the Journal of Agroforestry and Environment.

Authorship contribution statement

The research work was conceptualized and supervised by Md Abul Bashar and Dr. Mohammed Shofi Ullah Mazumder who provided overall guidance and ensured the scientific rigor of the study. Md Saleh Chowdhury, a master's student, carried out the primary experimental work, including data collection, observation, and preliminary analysis. The subsequent data processing, statistical analysis, and interpretation were supported by Md. Jony Ali, Mst. Taslima Khatun, Sarmin Islam Sayma, Md. Saifuddin and Robiul Islam who also assisted in organizing the results and preparing the manuscript. Together, all authors contributed to refining the discussion, reviewing the literature, and finalizing the manuscript. All authors have read and approved the final version of the manuscript and agree to be accountable for all aspects of the work.

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