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RESEARCH

# What Factors Influence Farmer's Behavior in Adopting Integrated Pest Management Practices in Mountains of Nepal?

Anisha Sapkota [1,*], Kishor Atreya [2], Subodh Khanal [3] and Kanchan Kattel [4]

[1] Department of Agricultural Botany and Ecology, Institute of Agriculture and Animal Science (IAAS), Tribhuvan University, Kathmandu 44618, Nepal
[2] School of Forestry and Natural Resource Management, Institute of Forestry, Tribhuvan University, Kathmandu 44618, Nepal
[3] Institute of Agriculture and Animal Science (IAAS), Gauradaha Agriculture Campus, Tribhuvan University, Jhapa 57200, Nepal
[4] Department of Nutrition and Public Health, University of Agder, Kristiansand 4630, Norway
[*] Author responsible for correspondence; Email: ansa.sapkota41@gmail.com.

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## Abstract

Farmers who have attended the season-long integrated pest management-farmers' field school (IPM-FFS) are more likely to adopt IPM practices but significant knowledge gaps persist regarding the extent of IPM adoption among farmers in Nepal and the factors influencing their practices. This study thus looks at factors influencing farmers' decisions to adopt IPM practices in Kavrepalanchok district of Nepal. It focuses on six components of the health belief model (HBM): benefits, severity, susceptibility, barriers, self-efficacy, and cues to action. We interviewed both IPM-FFS-trained and other non-trained farmers. Poisson's regression and bootstrapping were used to analyze the relationship between HBM components (independent variables) and the adoption of IPM practices (dependent variable). The analysis was done separately for "IPM-FFS farmers," "other farmers," and both groups combined. Findings show increased adoption of IPM practices by the IPM-FFS trained farmers, driven mainly by the benefits (IRR 1.32, $p<0.01$). However, HBM components did not show a substantial impact on enhancing the adoption of IPM practices among "other farmers." When combined, perceived benefits (IRR 1.35, $p<0.01$), self-efficacy (IRR 1.41, $p < 0.01$), and cues to action (IRR 1.34, $p<0.01$) significantly enhanced the adoption of greater IPM practices. Findings are similar between normal and bootstrap Poisson regressions. This study shows the importance of improving farmers' confidence through targeted training programs in promoting sustainable agricultural practices.

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**Statement of Sustainability:** The present work supports sustainability by promoting sustainable agriculture practices such as IPM. The adoption of IPM can help reduce pesticide overreliance and safeguard human health and ecosystems. By promoting eco-friendly practices, IPM enhances biodiversity conservation, encourages optimal resource usage, and improves crop quality ensuring responsible consumption and production.

## 1. Introduction

Since World War II, pesticides have become essential in modern agriculture for food security (Damalas and Koutroubas, 2018; Tudi et al., 2021), however, its use is increasing rapidly with approximately 3 billion kilograms of pesticides applied annually worldwide (Hayes and Hansen, 2017; Sharma et al., 2020). Only about 1% of these pesticides effectively target insect pests, leaving the majority to infiltrate the environment, ecosystems (Pathak et al., 2022), and the food chain (Bernardes et al., 2015; Sharma et al., 2019). Such infiltration increases health risks to humans (Hernández et al., 2013), environmental pollution, pest resistance, and pest resurgence (Ahmad et al., 2024; Watts and Williamson, 2015). These challenges warrant the urgent need for sustainable alternatives, such as integrated pest management (IPM) (Chandler et al., 2011), which apply ecological principles and employ a variety of pest control methods to reduce chemical pesticides (Green et al., 2020; Hayes and Hansen, 2017; Pretty and Bharucha, 2015).

In Nepal, the misuse of pesticides is a growing concern, where usage has reached 1.6 kg a.i./ha in vegetable production, despite the national average being relatively low at 396 g a.i./ha (Aryal et al., 2021; Nyaupane, 2021). This excessive and irrational use of pesticides has resulted in immediate and long-term health consequences, environmental pollution (Sharma et al., 2013), and decline in beneficial insects (GC and Neupane, 2019; Gyawali, 2018; Paudel et al., 2024; Paudel et al., 2020; Thakuri et al., 2022). Recognizing these issues, the Nepal Government promotes the production and use of organic pesticides, strictly prohibits the reckless use of pesticides that result in residue levels exceeding specified limits, and bans the sale of low-quality or adulterated pesticides (Plant Quarantine and Pesticide Management Center, 2019). Initially, the Nepal government adopted the IPM program in the early 1990s as part of its plant protection initiatives (Tiwari, 2012). Despite initial challenges such as financial constraints and a shortage of trained personnel, the program was reintroduced in 1997, with the first Farmers' Field School (FFS) in 1998 to address a brown planthopper outbreak in rice (Kafle et al., 2014; Tiwari, 2012). The IPM-FFS model, which involves hands-on, season-long learning, has helped farmers adopt and apply IPM practices to reduce pesticide misuse (Nyaupane, 2021). However, the adoption of IPM in Nepal has been slow, partly because of financial constraints, a shortage of trained personnel, farmers' reluctance to change established practices, and insufficient knowledge and availability of alternative methods (Ghimire and Kafle, 2014; Tiwari, 2012). The long-term effectiveness of these IPM programs in promoting sustainable practices remains under-monitored (Thapa, 2017), and studies on farmers' adoption behaviors on theoretical grounds are limited (Khanal et al., 2020; Nyaupane, 2021).

Understanding psychological factors that influence farmers' decisions—such as their beliefs, perceptions, and attitudes towards health risks of pesticide use and the benefits of IPM—is crucial for promoting sustainable agricultural practices (Sarma, 2022). The health belief model (HBM) offers valuable insights into these factors and can help identify effective strategies to enhance farmers' adoption of IPM practices (Ataei et al., 2021). The HBM suggests that people's beliefs and perceptions can influence their motivations and actions (Ahmadipour and Nakhei, 2024; Ataei et al., 2021; Zafarzadeh et al., 2019). Theoretically, the HBM contains six key components (Figure 1): (i) perceived benefits of adopting IPM practices, (ii) perceived severity of pesticide toxicity, (iii) perceived susceptibility to pesticide toxicity, (iv) perceived barriers to the adoption of IPM practices (Hochbaum, 1958), (v) self-efficacy—added to the model in 1988 (Bandura, 1997)—representing a person's belief in their ability to adopt IPM practices, and (vi) cues to action, catalysts encouraging behavior change (Champion and Skinner, 2008), such as observing neighbors successfully adopting IPM practices and emulating them to reduce pesticide use (Ataei et al., 2021; Zafarzadeh et al., 2019).

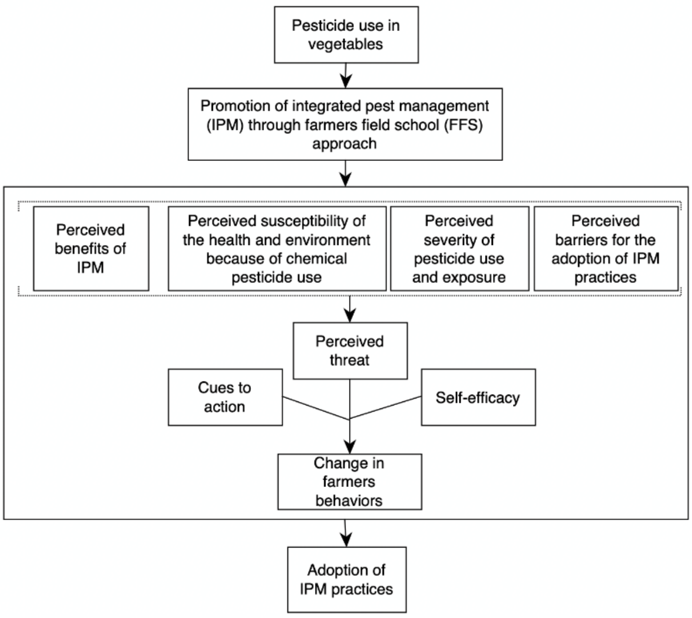

Figure 1. An application of the health belief model on IPM-FFS induced behavior change (Source: Champion and Skinner, 2008).

Although various psychological theories, such as the Theory of Planned Behavior (Fishbein and Ajzen, 1975), the Theory of Reasoned Action (Fishbein, 1967), Social Learning Theory (Bandura, 1977), and Social Cognitive Theory (Bandura, 1986), have been proposed to understand behavioral change, they may not fully capture the unique factors and perceptions related to health and environmental concerns within the context of agroecology (Glanz et al., 2008). For this reason, the HBM is valuable for studying the adoption of IPM practices globally, providing insights that can inform strategies to overcome barriers and enhance self-efficacy among farmers. Many prior studies have used the HBM as a theoretical model to describe behavioral change related to pesticide use (Ahmadipour and Nakhei, 2024; Ataei et al., 2021; Mahyuni and Harahap, 2020; Yazdanpanah et al., 2015; Zafarzadeh et al., 2019). These studies have shown the model's utility in understanding how perceptions of health risks and benefits influence farmers' adoption of sustainable practices, including IPM (Ataei et al., 2021; Zafarzadeh et al., 2019). However, in Nepal, only Bhandari et al. (2018) used the HBM model to explore farmers' safety practices in pesticide use, emphasizing the need for better education and awareness to promote safer and more sustainable agricultural practices.

This study thus aims to fill these gaps by identifying the various IPM practices employed by farmers in the Kavrepalanchok district, particularly those who have received IPM-FFS training, and by evaluating their adoption behavior using HBM. By examining the factors that influence IPM adoption in Nepal, especially through the HBM framework, we can offer valuable insights for policymakers, extension services, and educational programs to promote food security, environmental sustainability, and farmers' well-being. For this study, we hypothesize that:

- H1: Perceived benefits increase the adoption of several IPM practices.
- H2: Perceived severity and perceived susceptibility of pesticide use increase the adoption of several IPM practices.
- H3: Perceived barriers reduce the adoption of several IPM practices.
- H4: Self-efficacy and cues to action increase the adoption of a greater number of IPM practices.

## 2. Materials and Methods

### 2.1. Study Area

The Kavrepalanchok district, located 30 km east of Nepal's capital, Kathmandu, is well-known for its intensive use of chemical pesticides in commercial vegetable production. The district lies at latitude 27°32′44.52′′ north and longitude 85°38′00.96′′ east, with an altitude range from 1007 to 3018 meters above sea level, covering an area of 1396 square kilometers. The specific study area for this research was the former Mahadevsthan Village Development Committee (VDC), now known as Mandan Deupur Ward 2, within the district. Previous studies (Karmacharya, 2012; Sapkota and Sapkota, 2019; Thapa et al., 2015) have documented the excessive and improper use of chemical pesticides in this area. Pesticides are applied in particularly high quantities in the cultivation of vegetables such as potatoes, tomatoes, cauliflower, eggplant, chilies, beans, and cucurbits (Karmacharya, 2012). This heavy pesticide use has led to contamination of soils, as well as ground and surface water, and has increased health risks for farmers (Atreya et al., 2012). In response to these challenges, some farmers in the area have used 'jholmal,' a homemade biopesticide, as an alternative to chemical pesticides, for controlling pests in vegetable crops (Bhusal et al., 2022). Jholmal used in rice also showed a higher crop yield compared to traditional practices (Subedi et al., 2019).

### 2.2. Data Collection and Sample Size

The study collected data using a combination of household surveys, two focus group discussions (FGDs), and six key informant interviews (KIIs). Initially, a pilot study was conducted to validate the survey questions and to better understand the issues faced by farmers in the study area. Based on the findings from the pilot study, the questionnaire was revised and finalized for the main survey. Previous research showed that approximately 8% of the farmers in the study area (total population 764) had received IPM training (Atreya, 2007). However, because of the unavailability of a comprehensive list of IPM-FFS trained farmers, a snowball sampling method was employed, which resulted in 52 "IPM-FFS farmers." An equal number of farmers from the same area, who never attended IPM-FFS training ("other farmers"), were randomly chosen. Data was collected through face-to-face interviews, conducted between December 2022 and January 2023, after taking their verbal consent for participation. The survey questions were initially prepared in English and, following the pilot study, were translated into Nepali to facilitate the survey process. Three local women were trained as enumerators to administer the survey using an Android-based Kobo toolbox. The survey instrument included a mix of closed-ended, open-ended, and Likert scale questions to collect data on farmers' practices, perceptions, and attitudes toward pesticide use and various IPM practices. For the focus group discussions, a checklist was developed based on three main themes: (i) health hazards associated with pesticide use, (ii) the use of IPM practices, and (iii) comparisons of IPM-FFS techniques. The pilot study helped us to refine this checklist. Two FGDs were conducted in December 2022—one with IPM-FFS-trained farmers and the other with non-trained farmers. Each FGD lasted approximately 60 minutes and was held in a comfortable and private location. Each FGD had ten participants, with an equal number of male and female farmers. The six key informants were the agro-vet owner, an IPM-FFS trainer, male and female farmers trained on IPM-FFS, a health worker, and an agriculture officer.

### 2.3. Poission Regression

The study used standard Poisson regression to assess the adoption of IPM practices in relation to the six components of the HBM. Because of the small sample size, we also run the regression with the bootstrap function. Three separate Poisson regressions with bootstrapping—one for "IPM-FFS farmers," one for "Other farmers," and one for the combined (pooled) dataset, were conducted. Bootstrapping, a statistical technique that repeatedly (in our case, 1000) sample data from the dataset, was employed to estimate the variability of the statistics (Bhattarai and Bhusal, 2015).

### 2.4. Dependent Variable

The dependent variable is the summation of seven IPM practices listed below. Each farmer was asked whether they had adopted these IPM practices for insect pest and disease control, with responses recorded as "Yes" (adopted) or "No" (not adopted). The study selected eight IPM practices following the conceptual understanding provided by Pretty and Bharucha (2015); however, only seven practices were used in the final data analysis. The use of resistant plant varieties was excluded from the analysis because no farmers in the study area reported adopting this practice. The seven IPM practices included are:

- Animal urine storage and use: Farmers store animal urine for a certain period and then mix it with water for spraying on plants. The urine is kept in a closed container during storage to prevent ammonia loss and pathogen entry.
- Jholmal application: Jholmal is a homemade biopesticide that improves crop health and yield (Bhusal et al., 2022). It is prepared by mixing locally available plant resources such as neem (*Azadirachta indica*), chinaberry (*Melia azedarach*), chilies (*Capsicum annuum*), asuro (*Justicia adhatoda*), and titepati (*Artemisia vulgaris*) with animal urine and water, providing insecticidal and insect repellent properties.
- Seed treatment with local resources: Seed treatment using common salt, turmeric, Nepali pepper, and chilies helps protect seeds from insect/pest damage. Neem, Nepali pepper, and citrus plants are beneficial as they emit pungent smells that repel insects.
- Pheromone and sticky traps: Pheromone traps or lures containing synthetic female sex hormones are used to disrupt pest mating, thereby reducing pest populations and crop damage. Sticky traps, particularly yellow ones, are also used as an effective IPM strategy to monitor and control various insects, mainly aphids (Shrestha and Tiwari, 2021).
- Crop rotation: Rotating different crops on the same land helps break pest cycles and reduce disease incidence. Common practices include planting rice followed by potatoes and seasonal vegetables or mustard, followed by maize and other vegetables.
- Inter-cropping: This involves planting crops with repellent or attractant effects in proximity to main crops to protect them from pests. For example, farmers often inter-crop marigold or garlic with tomatoes, cauliflower, and other vegetables.

These IPM practices are often taught in IPM-FFS, but also some of them, for example, the use of urine and crop rotation, are traditional practices. Therefore, other farmers might have adopted these practices on their own. IPM-FFS farmers using these practices in their fields could have also led to their spread among other farmers. We thus added "other farmers" to the study to assess whether their adoption behavior differs from that of the IPM-FFS farmers.

### 2.5. Independent Variables

The independent variables are indices developed for each component of the HBM. Specific questions were carefully selected for each component (Table 1), and indices were calculated accordingly. Except for perceived severity, all questions were binary (1 for "Yes" and 0 for "No"), with values summed to form a single variable. For perceived severity, a Likert scale was used, where farmers rated perceived risks on a scale from 0 (no risk) to 4 (fatal risk). Responses for each question were summed to create the final indices.

Table 1. Indicators accounted for each HBM index and their relationship with dependent variables.

| HBM components | Indicators | Measurement | Expected hypothesis |
|---|---|---|---|
| Perceived Benefits | It refers to the belief about the positive outcomes associated with a behavior.<br>1. IPM guarantees the effectiveness of solving pest/disease problems<br>2. IPM is feasible to practice in both small to large patches of land<br>3. IPM is feasible to practice in both subsistence and commercially cultivated land<br>4. IPM helps to make the soil fertile<br>5. IPM offers good production of vegetables in terms of both quality and quantity | Binary<br>(Yes=1, No=0) | + |
| Perceived Severity | It refers to the seriousness of a risk<br>1. Do chemical pesticides negatively affect your health?<br>2. Do chemical pesticides negatively affect your children's health?<br>3. Do chemical pesticides negatively affect your livestock?<br>4. Do chemical pesticides negatively affect fish in the river?<br>5. Do chemical pesticides negatively affect honeybees? | Likert scale<br>0=no risk at all<br>1=little risk<br>2=moderate risk<br>3=large amount of risk<br>4=fatal risk | + |
| Perceived Susceptibility | It refers to the perception of being at risk.<br>1. Insects can grow resistant due to excessive chemical pesticide application<br>2. New harmful insects/pests are seen in the field due to heavy pesticide use?<br>3. Beneficial organisms are lost in the environment after chemical pesticide use?<br>4. Women are at higher health risk than men due to pesticide use?<br>5. I am unaware of the waiting period for vegetable harvest after pesticide spray? | Binary<br>(Yes=1, No=0) | + |
| Perceived Barrier | It refers to the perceived barriers to the adoption of IPM.<br>1. Ineffective IPM training<br>2. No projects are working currently for IPM [lacks demonstration]<br>3. No easy access to IPM training<br>4. Immediate result of pest control from the chemical pesticide use<br>5. Easy availability of chemical pesticides in the markets | Binary<br>(Yes=1, No=0) | - |
| Self-Efficacy | This refers to the personal belief in the ability to do something.<br>1. Do you prefer to use biopesticides over chemical pesticides?<br>2. Do you understand the meaning of toxic labels (color) in the pesticide containers?<br>3. Chemical pesticides should be used only if the pest population is greater than the natural enemies.<br>4. Are you motivated to reduce excessive chemical pesticide use?<br>5. Self-realization to reduce chemical pesticide use after health check-ups? | Binary<br>(Yes=1, No=0) | + |
| Cues To Action | This is a factor that triggers behavior change.<br>1. Do you or your family members attend a pesticide reduction program?<br>2. Did you receive safety precaution advice?<br>3. Have you heard about IPM's importance from fellow farmers?<br>4. Did you receive information about pesticide exposure health problems in training?<br>5. Have you received specific advice from health care providers to reduce pesticide use? | Binary<br>(Yes=1, No=0) | + |

Note: '+' indicates positive relation and '-' negative relation

# 3. Results and Discussion

## 3.1. Socio-demographic Characteristics

The farmer's socio-demographic details are shown in Table 2. The sample comprised 54% IPM-FFS women and 46% other women. Ethnicity-wise, a significant difference was observed between the groups ($p < 0.001$). A vast majority (92.3%) of IPM-FFS farmers belonged to the so-called privileged (Brahmin, Chhetri, Thakuri) group, whereas only 30.8%

of other farmers were from this group. Conversely, Janajati/Adibasi and Dalits were significantly underrepresented among IPM-FFS farmers, with only 3.8% each, compared to 32.7% and 36.5% among other farmers, respectively. Education level differed between groups ($p < 0.001$). During focus group discussions, Dalit/Janajati stated they were unaware of such programs and non-Dalit groups have access to much of the agriculture-related trainings.

Table 2. Socio-demographic characteristics of farmers.

| Characteristics | IPM-FFS farmers | Other farmers | Significance | |
|---|---|---|---|---|
| | | | Chi-square test | T-test |
| Gender % | | | .278 | - |
| Male | 46.2 (24) | 53.8 (28) | | |
| Female | 53.8 (28) | 46.2 (24) | | |
| Mean age (in years) | 47.58 | 45.13 | - | 0.106 |
| Ethnicity % | | | <0.001 | - |
| BCT (Brahmin, Chhetri, Thakuri) | 92.3 (48) | 30.8 (16) | | |
| Janajati/Adibasi (Danuwar, Gurung, Magar, Tamang, Newar, others) | 3.8 (2) | 32.7 (17) | | |
| Dalits (Sarki, Damai, Kami, Chamar, Dom, and others) | 3.8 (2) | 36.5 (19) | | |
| Family type % | | | 0.500 | - |
| Nuclear | 42.3 (22) | 44.2 (23) | | |
| Joint | 57.7 (30) | 55.8 (59) | | |
| Average family size | 5.81 | 5.63 | - | 0.333 |
| Education (highest enrolled Grade) | 8 | 6 | - | <0.001 |

Note: Figures in parentheses are in numbers.

### 3.2. Risk Perception of Pesticide Use

The graph (Figure 2) shows that there is no significant variation in risk perception among IPM-FFS farmers and other farmers. Both groups mostly recognized that there is a moderate to high risk associated with pesticide use, but they did not change their practices or attitudes toward safe pesticide use. This shows that despite being aware of the risks, farmers persisted in using pesticides because of their effectiveness in managing insect pests, minimizing crop losses, and ultimately boosting production and economic returns (Athukorala et al., 2023; Fan et al., 2015; Mahyuni and Harahap, 2020). Studies done elsewhere argue that farmers frequently engage in risky behavior for higher financial returns from their crops than on their health (Athukorala et al., 2023), mainly because of poor education and lack of understanding of safe pesticide practices (Bhandari et al., 2018; Jallow et al., 2017; Mahyuni and Harahap, 2020).

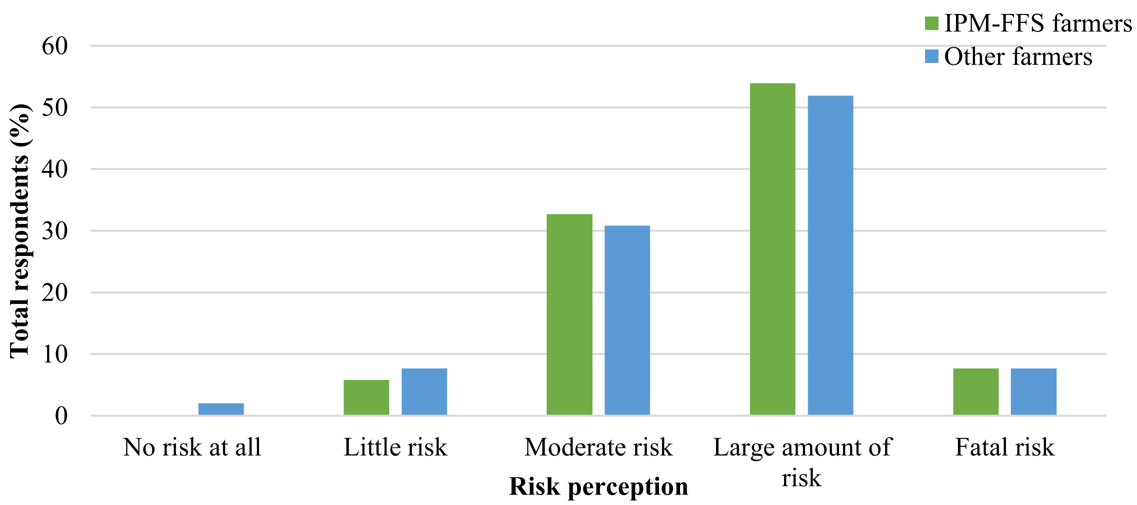


Figure 2. Perception of the risk of pesticide use between IPM-FFS and other farmers.

### 3.3. Adoption of IPM Practices Between IPM-FFS and Other Farmers

The number of IPM practices adopted varied greatly between the two groups (IPM-FFS versus other farmers), as shown in Figure 3. IPM-FFS farmers commonly used biopesticides such as urine (85%) and homemade jholmal (67%), while less than 20% of other farmers primarily relied on urine and intercropping only.

### 3.4. Factors influencing adoption of IPM practices – Poisson regression

Table 3 below summarizes the summary statistics for the dependent and independent variables. IPM-FFS-trained farmers adopted between zero and three IPM practices, whereas other farmers adopted a maximum of one practice. On average, IPM-FFS farmers perceived two benefits of IPM, whereas other farmers perceived less than one. IPM-FFS farmers, on average, identified three key factors for self-efficacy and cues to action, while other farmers identified only one for each.

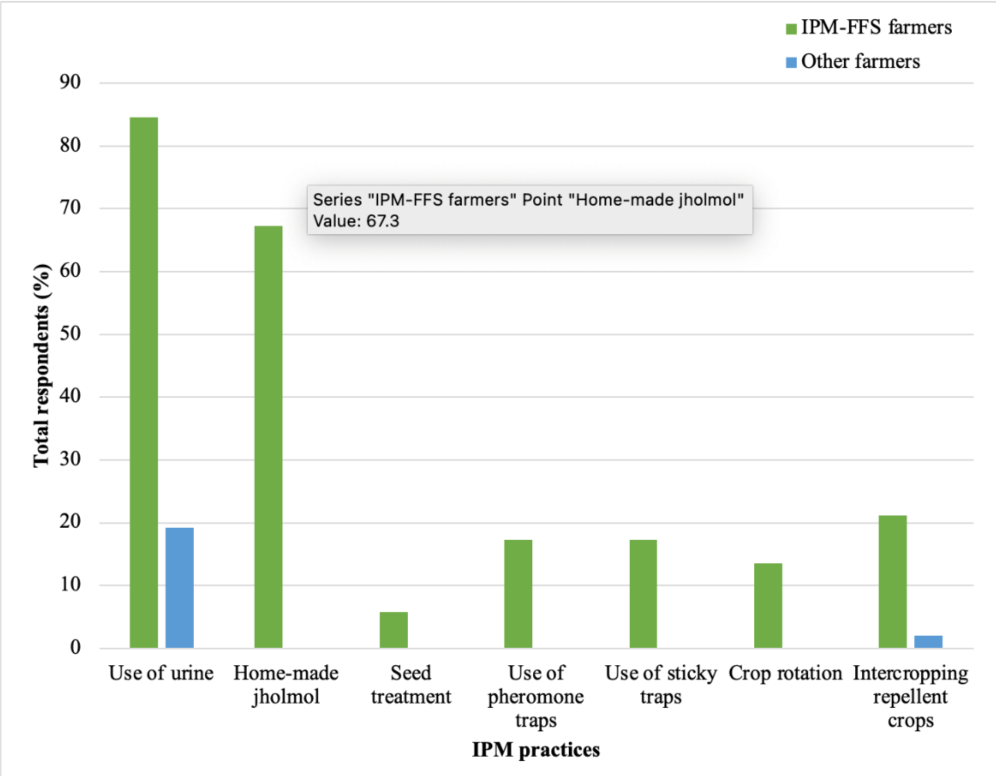


Figure 3. IPM practices adopted by IPM-FFS and other farmers.

Table 3. Summary of the dependent and independent variables for IPM-FFS farmers, other farmers, and pooled

| Variables | IPM-FFS farmers (N=52) | | | Other farmers (N=52) | | | Both farmers (N=104) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Min | Max | Mean (SD) | Min | Max | Mean (SD) | Min | Max | Mean (SD) |
| Total IPM Adopt | 0 | 3 | 1.67 (1.08) | 0 | 1 | 0.21 (0.41) | 0 | 3 | 0.94 (1.09) |
| Perceived Benefits | 0 | 5 | 2.00 (1.56) | 0 | 3 | 0.33 (0.73) | 0 | 5 | 1.16 (1.48) |
| Perceived Severity | 1 | 4 | 2.62 (.69) | 0 | 4 | 2.65 (0.84) | 0 | 4 | 2.63 (0.76) |
| Perceived Susceptibility | 2 | 5 | 3.23 (0.83) | 1 | 5 | 3.52 (1.02) | 1 | 5 | 3.38 (0.94) |
| Perceived Barrier | 0 | 4 | 2.46 (1.31) | 1 | 5 | 2.75 (1.08) | 0 | 5 | 2.61 (1.20) |
| Self-Efficacy | 1 | 5 | 3.19 (0.89) | 0 | 4 | 1.10 (1.01) | 0 | 5 | 2.14 (1.42) |
| Cues To Action | 1 | 5 | 2.69 (0.92) | 0 | 5 | 1.15 (1.35) | 0 | 5 | 1.92 (1.38) |

Note: Figures in parentheses are standard deviations

The standard Poisson regression (Table 4) and the Poisson regression with bootstrapping (Table 5) both show no significant differences between the two methods. The impact of HBM indices on the adoption of IPM practices was not significant for farmers who had never participated prior to IPM-FFS. However, IPM-FFS farmers' adoption of IPM practices was significantly influenced by their perceived benefits. The incident rate ratio (IRR) for perceived benefits ($p < 0.001$) for the IPM-FFS farmer is 1.32, meaning that each additional unit increase in perceived benefits results in a 1.32 times higher adoption of IPM practices. Similarly, in the combined group, for each unit increase in perceived benefits, farmers were 1.35 times more likely to increase the adoption of additional IPM practices. The more farmers know about these benefits, the more likely they are to increase IPM practices. However, the perceived benefits of IPM did not significantly enhance IPM practices for those farmers who never attended prior IPM-FFS.

The result suggests the need to increase farmers' awareness of the benefits of IPM for better adoption. There are several IPM benefits already established in the literature. For example, Paudel, Sah et al. (2020) argue that IPM practices not only reduce insect/pest damage but also improve soil fertility by increasing nitrogen content. Similarly, Bolivian farmers considered IPM products as 'superior' in terms of taste and texture, despite their less attractive appearance (Jørs et al., 2017). During FGDs in our study, the IPM-FFS farmer expressed their higher satisfaction with IPM practices, particularly emphasizing the positive impact of Jholmal on soil health. They attributed any perceived ineffectiveness to a lack of knowledge about the proper application of Jholmal. In contrast, other farmers expressed doubts about IPM effectiveness, viewing it as unsuitable for large-scale farms. This aligns with findings by Timprasert et al. (2014), who observed that non-IPM farmers perceived IPM as complex, time-consuming, and less effective for larger farms. Regarding our hypothesis H1, it has been determined that an increase in perceived benefits results in a higher rate of adoption of IPM practices. This finding has been validated for the IPM-FFS and combined pool sample, however, it does not hold true for the other farmers.

Table 4. Factors influencing adoption of IPM practices.

| Indicators | IPM-FFS farmer | | | | Other farmers | | | | Both (pooled) farmers | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | IRR | Std. Err | z | P>\|z\| | IRR | Std. Err | z | P>\|z\| | IRR | Std. Err | z | P>\|z\| |
| Perceived Benefits | 1.32 | 0.100 | 3.65 | 0.000 | 1.88 | 0.770 | 1.55 | 0.121 | 1.35 | 0.096 | 4.25 | 0.000 |
| Perceived Severity | 1.08 | 0.177 | 0.46 | 0.645 | 0.65 | 0.448 | -0.62 | 0.533 | 0.99 | 0.157 | -0.03 | 0.973 |
| Perceived Susceptibility | 1.02 | 0.182 | 0.13 | 0.896 | 0.79 | 0.377 | -0.49 | 0.624 | 0.90 | 0.141 | -0.70 | 0.481 |
| Perceived Barrier | 0.95 | 0.104 | -0.49 | 0.623 | 1.88 | 1.041 | 1.14 | 0.255 | 1.04 | 0.099 | 0.41 | 0.678 |
| Self-Efficacy | 1.00 | 0.158 | 0.02 | 0.983 | 1.16 | 0.616 | 0.28 | 0.781 | 1.41 | 0.184 | 2.63 | 0.009 |
| Cues to Action | 1.08 | 0.144 | 0.55 | 0.583 | 1.61 | 0.467 | 1.63 | 0.102 | 1.34 | 0.144 | 2.72 | 0.007 |
| _cons | 0.61 | 0.528 | -0.57 | 0.571 | 0.03 | 0.072 | -1.47 | 0.142 | 0.14 | 0.102 | -2.65 | 0.008 |

Table 5. Factor influencing adoption of IPM practices (Bootstrap Poisson regression).

| Indicators | IPM-FFS farmers | | | | Other farmers | | | | Both (pooled) farmers | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | IRR | Std. Err | z | P>\|z\| | IRR | Std. Err | z | P>\|z\| | IRR | Std. Err | z | P>\|z\| |
| Perceived Benefits | 1.32 | 0.071 | 5.13 | 0.000 | 1.88 | 3.181 | 0.38 | 0.707 | 1.35 | 0.078 | 5.24 | 0.000 |
| Perceived Severity | 1.08 | 0.119 | 0.68 | 0.494 | 0.65 | 1.242 | -0.22 | 0.822 | 0.99 | 0.134 | -0.04 | 0.968 |
| Perceived Susceptibility | 1.02 | 0.128 | 0.19 | 0.852 | 0.79 | 0.598 | -0.31 | 0.757 | 0.90 | 0.103 | -0.96 | 0.337 |
| Perceived Barrier | 0.95 | 0.071 | -0.72 | 0.470 | 1.88 | 4.429 | 0.27 | 0.789 | 1.04 | 0.076 | 0.54 | 0.591 |
| Self-Efficacy | 1.00 | 0.145 | 0.02 | 0.982 | 1.16 | 1.076 | 0.16 | 0.873 | 1.41 | 0.172 | 2.82 | 0.005 |
| Cues to Action | 1.08 | 0.112 | 0.71 | 0.479 | 1.61 | 1.076 | 0.66 | 0.506 | 1.34 | 0.107 | 3.65 | 0.000 |
| _cons | 0.61 | 0.401 | -0.75 | 0.456 | 0.03 | 0.309 | -0.34 | 0.732 | 0.14 | 0.098 | -2.77 | 0.006 |

Perceived severity, susceptibility, and barrier did not show any significant impact in deciding the adoption of a number of IPM practices in IPM-FFS farmers, other farmers, and combined pooled samples. Contrary to our initial assumptions, with other farmers, perceived severity and perceived susceptibility had a negative relationship with the adoption of IPM practices, while perceived barriers had a positive relationship, although non-significant. This may be attributed to the farmers' perception of pesticide use as a customary and indispensable practice for achieving high crop yields, despite the latent risks that may not be immediately apparent (Mahyuni and Harahap, 2020). This could further show that the relationship between farmers' severity and susceptibility to chemicals and the adoption of IPM practices is more complicated than previously understood (Abdollahzadeh et al., 2024). Likewise, our initial assumption of a negative relationship between perceived barriers and the adoption of IPM practices was not supported by this study, especially among other farmers. This is probably because of their severe lack of knowledge of IPM practices and their adoption barriers (Shojaei et al., 2013; Thakuri et al., 2022). These farmers have a minimal adoption rate of IPM practices. In summary, our analysis did not find any evidence to suggest that perceived severity and perceived susceptibility of pesticide use have a positive impact on the adoption of IPM practices (H2), or that perceived barriers have a negative impact on the adoption of these practices (H3) among IPM-FFS farmers, other farmers individually, or when considering both groups together.

Similarly, in the combined group, self-efficacy ($p < 0.01$), and cues to action ($p < 0.01$) were significant positive predictors of adopting IPM practices, showing that higher confidence in using IPM practices and external triggers like training and safety advice for general farmers may lead to increased adoption, although their impact was not significant when analyzed separately for IPM-FFS and non-IPM-trained farmers. Specifically, a unit increase in self-efficacy made farmers 1.41 times more likely to increase additional IPM practices, while a unit increase in cues to action resulted in a 1.34 times greater likelihood of increased number of IPM adoption. Confidence in using biopesticides, knowledge of pesticide labels, and responsible pesticide application are crucial aspects of self-efficacy that significantly impact IPM adoption among farmers. Most farmers still preferred chemical pesticides over biopesticides because of the limited accessibility and availability of biopesticides (Atreya et al., 2012; Bhandari et al., 2020) and the higher efficacy of chemicals (Constantine et al., 2020). Similarly, other farmers lack knowledge regarding pesticide toxicity color code compared to IPM-FFS farmers, for a number of reasons such as illiteracy, lack of awareness, and disinterest in reading labels (Sapkota et al., 2020). Therefore, implementing awareness and training programs on safe pesticide handling could empower farmers to improve their self-efficacy in reducing pesticide misuse (Sapkota and Sapkota, 2019). In the same way, the adoption of IPM practices can be influenced by training programs related to pesticides, peer discussions, and receiving health advice.

Research shows that implementing educational interventions and community engagement results in a higher adoption rate of safer agricultural practices (Ataei et al., 2021; Khanal et al., 2020). In our study, participants in the focus group discussion also reported that attending pesticide reduction programs led to decreased pesticide use. Shrestha et al. (2010) argue that peer learning among farmers emphasized community interactions as motivators to reduce pesticide use. However, our research findings show that self-efficacy and cues to action were successful in encouraging the adoption of IPM among the general population. But, when analyzed separately, they did not have a significant influence on the IPM adoption. This suggests that IPM-FFS farmers who had already received structured season-long training may rely more on their formal education and hands-on experience rather than external cues (Damalas and Koutroubas, 2018). In contrast, other farmers may require more targeted and intensive interventions to translate awareness into practice, as they might lack sufficient exposure to or trust in these cues (Kafle et al., 2021). Accessible and relatable information delivered through media campaigns, peer discussions, and awareness programs can effectively bridge knowledge gaps and encourage safer practices (Abdollahzadeh and Sharifzadeh, 2021; Gautam et al., 2017). This highlights the imperative for training programs to concentrate on fostering farmers' confidence through focused education, experience sharing, and support, in order to enable the wider acceptance of IPM practices. Consequently, our final assumption (H4) remains true for the combined pooled sample but is not substantiated when considering IPM-FFS and other farmers separately.

Since there are multiple factors that impact the adoption of IPM (Figure 3), we recommend considering these factors in future research and data analysis. The adoption of IPM may be influenced by distinct socioeconomic and cultural factors, which can lead to uncertainty in the IPM-FFS programs within the region (Khanal et al., 2020). Take, for instance, farmers in most developing nations are heavily reliant on agriculture as their main source of income. In these countries, farmers prioritize increasing production and economic gains, often overlooking the potential health and environmental risks of pesticide use (Jallow et al., 2017; Wilson and Tisdell, 2001). Other relevant psychological and social factors, such as farmers' agencies, access to resources, and service providers, can also contribute to farmers' decisions about pesticide use and the adoption of IPM practices (Sarma, 2022; Sharifzadeh et al., 2023).

Henceforth, we suggest that future IPM-FFS training programs and interventions should prioritize a comprehensive evaluation of various factors, with particular attention to the core elements shown in Figure 4. The focus should be on the elements in the inner circle, which involve promoting the long-term benefits of IPM practices, enhancing self-efficacy, and reinforcing cues to action. While outer factors such as the severity and susceptibility to pesticide use, barriers to IPM, and broader contextual factors like society, culture, and policy are still important, they should be secondary to the core elements. In those countries, tailored training programs that consider the local context can be highly effective in addressing the contextual cultural and economic factors that contribute to farmers' hesitance in adopting IPM practices. The future adoption of IPM practices can be expanded by enhancing support for local extension agents, promoting peer learning opportunities, and offering financial incentives or subsidies for biopesticides. Ensuring that these support services and interventions are not only effective but also sustainable is crucial for the long-term success of IPM-FFS. To ensure long-term effectiveness and sustainability, it is essential to continuously improve and support these programs based on thorough, evidence-based research.

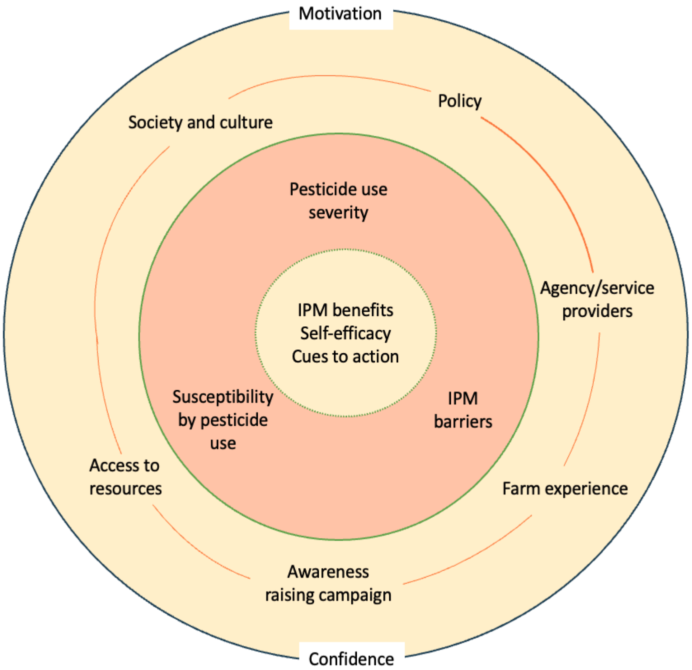


Figure 4. The IPM-FFS training program should consider many factors, with a greater emphasis on the inner circle, to bolster individual confidence and motivation for the adoption of IPM practices.

There are a few limitations to note in this study. The small sample size led us to use bootstrapping, a method that improves the reliability of our estimates by simulating the sampling distribution. In the pooled analysis, we observed that self-efficacy and cues to action were significant predictors of IPM adoption. However, when we looked at the separate analyses for IPM-FFS and non-IPM-trained farmers, we did not see the same significance. This difference is likely because the combined population had a wider range of confidence levels and external triggers. The larger and more diverse sample size in the pooled analysis gave us greater power to detect significant effects. Separate analyses for homogeneous groups may have had baseline differences in IPM adoption or lower variability, which made it harder to detect the impact of these factors within each subgroup. Finally, our study is cross-sectional and cannot capture the temporal evolution of IPM-FFS farmers' behavior. To better understand the long-term effects of IPM-FFS and farmers' adoption of IPM practices, future research should conduct larger longitudinal studies.

## 4. Conclusion

The study emphasizes a clear distinction in the factors that influence the adoption of IPM practices between IPM-FFS and other farmers. IPM-FFS farmers exhibit a significantly higher rate of adoption, driven by their recognition of benefits such as enhanced soil fertility, yield and quality, suitability for commercial farming, and effectiveness. In contrast, other farmers show minimal adoption, with no significant factors motivating their commitment. Perceived benefits, self-efficacy, and cues to action increased adoption rates among the general population. This highlights the critical importance of targeted education and support in promoting sustainable agricultural practices. Therefore, the study strongly argues for the ongoing implementation of the IPM-FFS programs combining education with practical behavioral support for the change. IPM-FFS trainers can enhance the perceived benefits of IPM and the self-efficacy of farmers while addressing barriers through improved access to resources. Policymakers may consider these psychological factors when designing future interventions to promote sustainable agriculture. By enhancing farmers' understanding of intervention benefits, boosting their self-efficacy, and providing clear behavioral triggers, adoption rates can be significantly improved. Such holistic approaches, grounded in psychological and practical frameworks, are vital for advancing eco-friendly farming and ensuring long-term agricultural sustainability.

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