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# Evaluation of pesticide contamination risks and sustainable practices in Ecuadorian agriculture

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**Pesticide use is crucial in global agriculture to control pests and increase crop yields. In Ecuador, the use of pesticides, including fungicides and insecticides, is common in crops such as potatoes and tomatoes. However, the indiscriminate use of these products has proven to have negative consequences for human health and the environment. This study investigates these risks in Ecuadorian agriculture, specifically in the Paute canton, where inadequate data exacerbates these issues. Employing a descriptive research design, data were collected through validated surveys administered to 30 farmers (9 women and 21 men) residing in various rural communities. The study also included observational methods to complement survey data. Findings reveal that farmer, predominantly with primary education, face health risks from inappropriate pesticide use. Symptoms reported include eye irritation, headaches, and nasal irritation, which vary based on education level and safety practices. The research highlights the urgent need for improved pesticide management through targeted training and sustainable practices. This study's insights into the extent of health issues and variability in safety measures provide a basis for developing effective interventions to mitigate the health and environmental impacts of pesticide use in Paute and similar regions.**

**Keywords** Pesticide contamination, Ecuadorian agriculture, Farmer health, Sustainable practices, Environmental impact, Safety measures, Paute canton

The widespread use of pesticides in agriculture has become a cornerstone of global efforts to safeguard crop yields and enhance food production[1–5]. However, the excessive and often unregulated use of these chemicals poses considerable risks to both human health and environmental sustainability.[1,6–8] In Latin America, particularly in Ecuador, these challenges are compounded by a lack of comprehensive data on pesticide contamination, as well as insufficient monitoring and regulation[9–12] In the Paute canton, a descriptive study has highlighted that local farmer—primarily men with limited educational backgrounds—are especially vulnerable to the harmful effects of improper pesticide usage. Pesticides, including insecticides and fungicides, have been associated with acute poisoning, long-term chronic diseases, and significant biodiversity loss through the contamination of soil and water resources [13–15].

Prolonged exposure to these agrochemicals can lead to a wide array of adverse health outcomes, ranging from neurological[16] disorders to respiratory and dermatological conditions[17–19]. In Ecuador, pesticides like Chlorpyrifos and Mancozeb are frequently applied in the cultivation of staple crops such as potatoes and tomatoes[20], underscoring their critical role in maintaining agricultural productivity (Universidad Central del Ecuador, 2022[21–23]). However, the indiscriminate use of these chemicals has led to serious repercussions, adversely affecting human health, deteriorating water quality, and undermining the region's biodiversity[24,25]. The lack of consistent monitoring data, inadequate farmer education, and poor safety practices further exacerbate the environmental and public health challenges posed by pesticide contamination across Latin America[12,23].

A detailed analysis of pesticide use in the communities of Paute reveals significant relationships between educational levels, pesticide use patterns and duration of fungicide application[26,27].

The survey data indicate widespread application of pesticides such as Ranger, Forum, Curacron, Conter and Bala 55 at different educational levels, with a notable reliance on certain pesticides in communities with lower

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educational levels, suggesting prolonged reliance that could indicate less access to information or technology to reduce use.

The results underscore the critical need for specific educational programs aimed at promoting safer pesticide practices, especially in regions such as Paute, where agriculture is integral to the local economy and food security. By providing empirical insight into this specific context, the study aims to contribute valuable recommendations to promote safer and more sustainable agricultural practices, striking a balance between agricultural.

By providing empirical insights from this specific context, the study aims to contribute valuable recommendations to promote safer, more sustainable farming practices. In regions like Paute, where agriculture is integral to the local economy and food security, striking a balance between agricultural productivity and the protection of public health and the environment is paramount.

## Materials and methods

### Design of the study

This study is descriptive and exploratory in nature, focused on determining the perceptions and practices related to the use of pesticides among farmers in the Paute canton. The study design combined mixed methodologies (quantitative and qualitative). The quantitative approach allowed obtaining measurable data through surveys, while the qualitative approach deepened the perceptions and attitudes of farmers through open questions.

### Sampling and selection

This study is part of a broader research effort that builds on previous findings regarding agricultural practices and pesticide use in the Paute canton. Our sample consisted of 30 farmers, including 9 women and 21 men, aged between 28 and 67 years, residing in rural communities such as Bulán, El Cabo, Paute Centro, Pirincay, San Juan, Sumac, Tuntac, Yumacay, and Zhumir. The selection of participants was based on the diversity of agricultural practices and the representativeness of pesticide use in the region.

Previous studies, such as that of[28], have highlighted that the most widely grown crops in the area are potatoes, tomatoes, and vegetables such as carrots, our study was designed to reflect the variability of pesticide use across these crops, with a focus on those pesticides used most frequently, as well as their correlation with the farmers' educational levels and changes over time.

The data collected provides insights into the prevalence of pesticide use and its association with educational attainment among farmers. This is crucial for understanding the impact of pesticide use on public health and the environment, as discussed in[28] in their analysis of pesticide residues and their potential effects. Data Collection Plan.

Data collection was conducted through a prevalidated survey, which collected quantitative and qualitative information on pesticide practices and perceptions. The survey included specific questions on the types of pesticides used, phytosanitary practices, farmers' level of education, time of pesticide use, and safety measures during preparation and application.

Data Analysis.

Data analysis combined quantitative and qualitative methods. Descriptive statistical analyses were carried out to identify patterns in the use of pesticides and farmers' perceptions of their environmental and health impacts. In addition, correlation analysis was used to explore possible relationships between demographic variables and pesticide use practices. As for the qualitative analysis, the open responses were codified to identify recurring themes and narrative patterns in the perceptions of farmers. The heterogeneity of the sample was addressed by evaluating the differences between subgroups (gender, age, type of crop), which allowed us to identify variations in practices and perceptions related to the use of pesticides.

Justification of the Exploratory and Pilot Nature of the Study.

This study is defined as exploratory and pilot with the purpose of identifying initial trends in farmers' perceptions and practices regarding the use of pesticides in the Paute canton. The results obtained in this pilot will serve as a basis for the development of broader study that allows a more in-depth analysis of the observed dynamics. The preliminary conclusions will allow us to adjust the methodological design of future studies and formulate more precise and contextualized recommendations.

Compliance with Ethical Standards

All methods were carried out in accordance with the guidelines and regulations relevant to research involving the collection of data through surveys of human populations. The experimental protocols of this study were approved by the Committee of the Research Group in Biotechnology and Environment (INBIAM) of the Salesian Polytechnic University.

Informed consent was obtained from all participating in subjects and/or their legal guardians before administering the surveys. Participants were informed about the purpose of the study, the confidentiality of their answers, and their right to participate voluntarily.

## Results

### Key findings summary

**Demographics:** Most respondents are male (65%), with females accounting for 35%. The average age is 48 years. Most respondents are married (95% of men, 86% of women), and the predominant education level is primary education (65% of men, 57.2% of women).

**Health Symptoms**: The most reported health issues related to fungicide use are eye irritation and headaches.

**Safety Practices**: Safety practices vary considerably, with parishes such as Paute Centro and San Juan displaying greater diversity in the use of protective measures.

**Demographic Characteristics**: Table 1 summarizes the key demographic characteristics.

| Respondents | Gender | Average Age | Marital Status | Education Level | Average Years Working in Agriculture by Education and Gender |
|---|---|---|---|---|---|
| Men | 65% | 48 | Married 95% | Primary 65% | Primary: 15.16 years |
| | | | Free Union 5% | Secondary 25% | Secondary: 18.67 years |
| | | | | Higher 10% | Higher: 11.71 years |
| Women | 35% | 48 | Married 86% | Primary 57.2% | Primary: 14.11 years |
| | | | Divorced 14% | Secondary 42.8% | Secondary: 13.17 years |
| **Total** | **27** | | | | |

**Table 1**. Main demographic characteristics of farmers in the rural communities of Paute.

## Health symptoms and safety practices

Perception of Health Symptoms.

- Eye Irritation: Predominantly reported by farmers with primary education levels engaged in plant production and sales.
- Headaches: Mainly reported by farmers involved in plant sales and crop supervision, especially those with secondary education.
- Nasal Irritation: Observed to a lesser extent among farmers with secondary education involved in crop care.
- No Symptoms: A subset of farmers involved in greenhouse care reported no significant symptoms.

Safety Measures in Pesticide Handling.

- Use of Masks: Although farmers engaged in plant production and sales report wearing masks, they still report experiencing eye irritation. This suggests that improper use or inadequate mask types might contribute to these symptoms.
- Following Product Instructions: Farmers involved in crop supervision and plant sales who report the following product instructions tend to experience headaches.
- Use of Gloves and Eye Protection: The use of gloves and eye protection is associated with fewer health issues, but their use is less common among farmers.

Education Level and Risk Perception.

- Primary Education: Farmers with primary education most often report symptoms such as eye irritation.
- Secondary Education: Those with secondary education levels tend to report more headaches.
- Higher Education: Fewer symptoms are reported by farmers with higher education levels.

(Refer to Fig. 1 for an illustration of the health risk perceptions.)

## Pesticide use in Paute communities by education level

Pesticide use patterns vary significantly by educational level and community. In the study, the most commonly used pesticides were identified, such as Ranger, Forum, Curacron, Conter and Bala 55. Communities such as Zhumir and San Juan show consistent use of these products at all levels of education, with farmers with primary and secondary education making more intensive use compared to those with higher education. This finding highlights a worrying trend in communities with less access to education, as shown in Fig. 2.

According to the study by[28], the crops that use pesticides the most in the Paute region, Ecuador, are potatoes (Solanum tuberosum) and tomatoes (Solanum lycopersicum). This fact justifies the focus of the present analysis, since these two crops are the most affected by the use of pesticides. The results of the study show that potato and tomato production predominate in different communities, reinforcing the need to further investigate the effects of pesticides on these particular crops[28,29].

## Disposal of fungicide containers by gender and education

Disposal methods for fungicide containers vary by education and gender, as shown in Fig. 3. Farmers often prioritize cost when selecting fungicides, neglecting safety recommendations. Respondents with only primary or secondary education, especially those with limited guidance on safe fungicide use, tend to dispose of containers improperly, such as discarding them in the trash. Conversely, those who consider both cost and efficacy are more likely to employ safer practices like puncturing or triple-rinsing containers. Men with primary or secondary education are particularly more likely to follow these safer disposal methods, as illustrated in Fig. 3.

## Statistical analysis

This analysis examines the relationships between education level, safety practices, and perceived health risks related to fungicide use among farmers in Paute. Pearson correlation and Chi-square tests revealed significant patterns, as detailed in Table 2 and Table 3. Figures 1 and 2 depict the perception of health risks and the adoption of safety measures, highlighting the influence of education and gender. Farmers with lower education levels more frequently report symptoms like eye irritation and headaches, likely due to inadequate use of personal protective equipment.

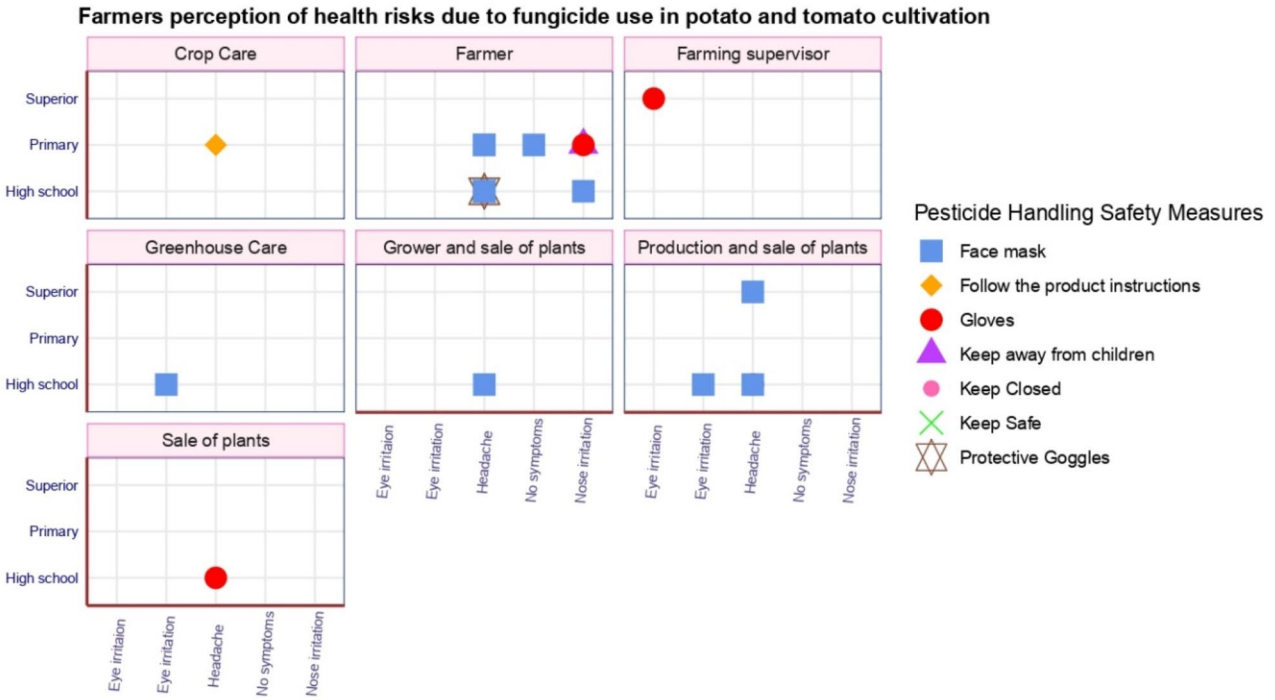


**Fig. 1**. Perception of health risks from Fungicide Use on potato and tomato in Paute Canton.

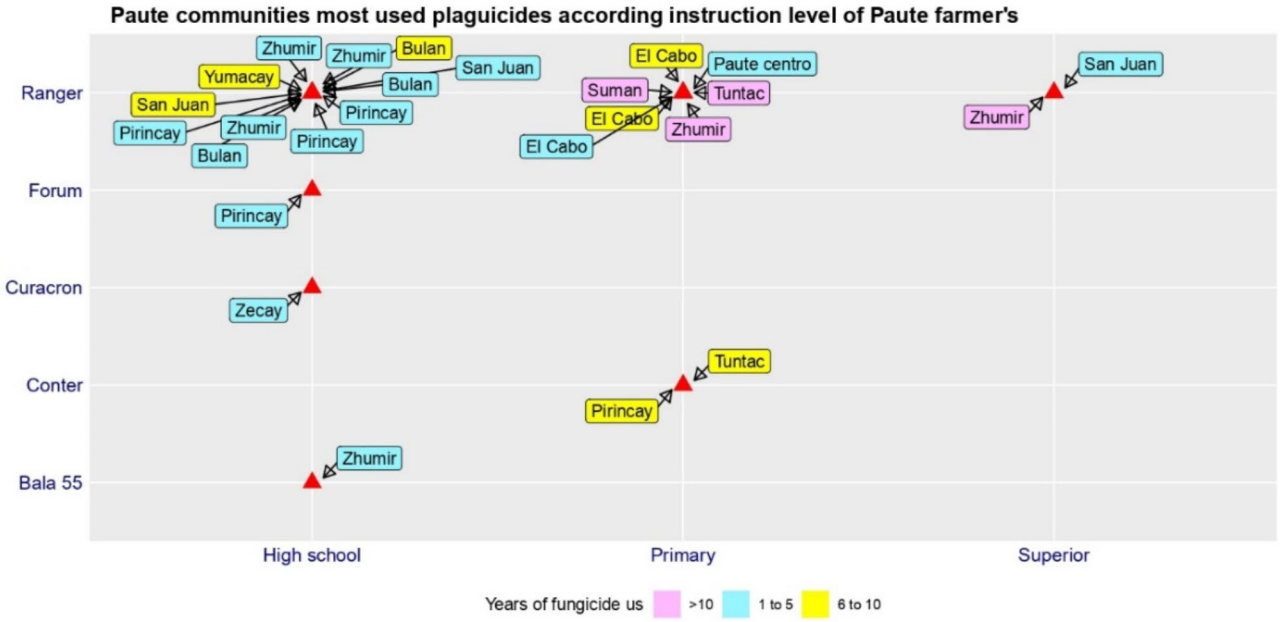


**Fig. 2**. Pesticide use in Paute communities by education level.

### Pearson correlation

## Correlations

The correlation between education and years of farming experience is positive but weak (r = 0.22), indicating a slight trend toward more years of experience with higher education.

The correlation between education and perception of health risks is moderate (r = 0.45), suggesting that farmers with higher education tend to report fewer health symptoms related to fungicide use.

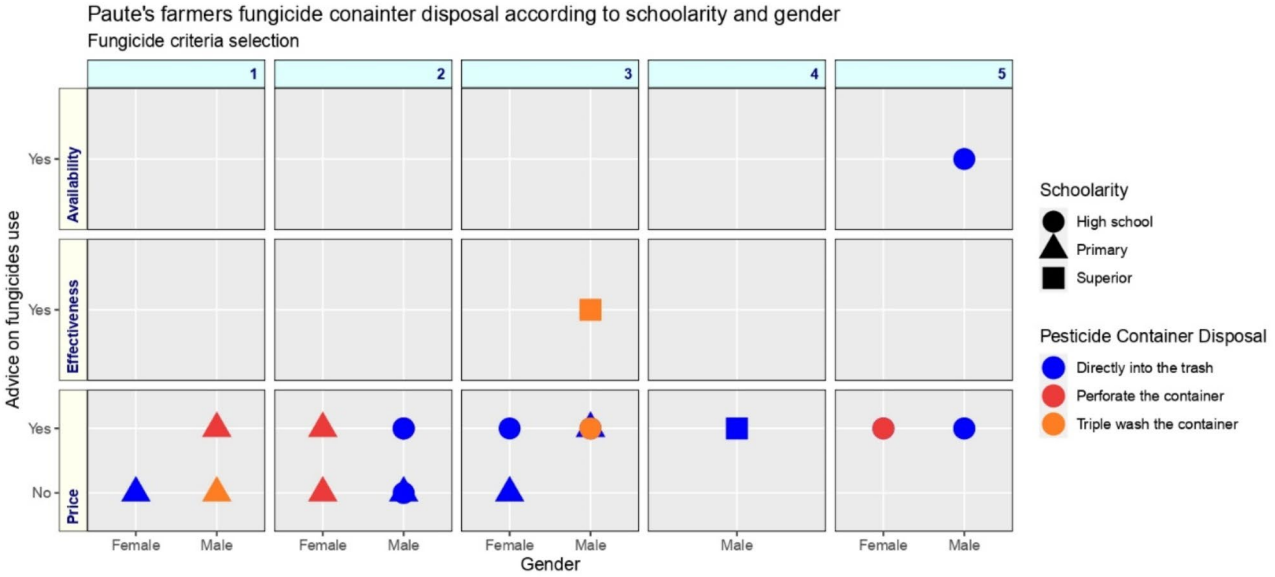


**Fig. 3**. Fungicide container disposal by gender and education level.

| Variable 1 | Variable 2 | Correlation Coefficient (r) | Interpretation |
|---|---|---|---|
| Education and Years of Experience | 0.22 | Weak positive relationship | |
| Education and Risk Perception | 0.45 | Moderate relationship | |

**Table 2**. Correlaciones entre Variables.

| Comparison | Chi-square | value p | Value Significance |
|---|---|---|---|
| Education and marital status | 3.58 | 0.17 | Not significant |
| Education and use of safety measures | 7.89 | 0.02 | Significant |
| Education and method of container disposal | 6.24 | 0.04 | Significant |

**Table 3**. Resultados de la Prueba Chi-cuadrado.

## Chi-square tests

The relationship between education and marital status shows no significance ($p = 0.17$), indicating that marital status is not significantly related to educational level in this sample.

The relationship between education and use of safety measures is significant ($p = 0.02$), indicating that farmers with higher education level adopt more safety measures.

The relationship between education and method of container disposal is also significant ($p = 0.04$), showing that farmers with higher education use safer methods to dispose of fungicide containers.

Education and Safety Practices: The results suggest that education has a significant impact on the adoption of safety practices and the perception of health risks associated with fungicide use.

Recommendations: It is critical to develop specific training programs to improve safe fungicide handling, especially in less educated communities.

Although this study is based on self-reports of symptoms, we recommend that future research include detailed medical evaluations to confirm the long-term effects of pesticide exposure, especially in farmers with more than 20 years of experience.

## Discussion

The results of this study demonstrate a significant correlation between education level and the perception of risks associated with fungicide use ($r = 0.45$, $p < 0.05$). This aligns with prior research showing that farmers with higher educational attainment are generally more aware of the health hazards posed by prolonged pesticide exposure (Jones et al., 2019; Pérez et al., 2021)[30–32]. However, while knowledge can influence risk perception, socioeconomic pressures, limited access to appropriate personal protective equipment (PPE), and cultural barriers remain key factors that hinder the adoption of safer agricultural practices (Smith et al., 2020). Therefore,

it is critical that intervention programs not only focus on knowledge transfer but also address these broader systemic challenges.

Consistent with earlier studies in Latin American agricultural regions, our findings further highlight the pivotal role of education and training in mitigating pesticide-related risks[33,34]. For instance, research conducted in Peru found that farmers with lower educational backgrounds were more likely to report health issues related to pesticide use, a trend that mirrors the outcomes observed in Paute[35–37]. This correlation underscores the urgent need to develop targeted educational interventions that cater specifically to farmers with limited formal education.

However, caution must be exercised when generalizing these results to other agricultural regions. The specific dynamics of Paute canton, such as the small sample size (n=30) and the targeted selection of participants, limit the broader applicability of these findings. Moreover, factors such as access to education, economic resources, and governmental policies differ significantly across regions, potentially influencing both pesticide practices and health outcomes. As such, the patterns observed in Paute may not be directly transferrable to other agricultural contexts without careful consideration of these variables.

To address the deficiencies in pesticide training, we recommend the implementation of continuous education programs that encompass both theoretical and practical aspects of pesticide management. These programs should be accessible, culturally adapted, and designed to overcome linguistic and economic barriers. Additionally, local governments should develop policies that incentivize the use of biological control methods and the adoption of sustainable farming practices. Future research should prioritize assessing the effectiveness of these interventions, with a particular focus on their impact on farmer health and environmental outcomes.

Despite the important insights provided by this study, there are several limitations that should be acknowledged. First, the relatively small sample size constrains the generalizability of the findings. Second, the purposive sampling approach may introduce bias, as those farmers more willing to participate in the study may not fully represent the broader community. Finally, reliance on self-reported data could result in the underreporting or overreporting of health symptoms and safety practices, which should be accounted for in future investigations.

The findings of this study reveal concerns trends in pesticide use and management among farmers in the Paute canton. The demographic profile of most respondents—primarily men with primary education—indicates potential gaps in access to essential information and training on safe pesticide practices. This demographic is also associated with a higher likelihood of exposure to health risks, including eye irritation, headaches, and nasal irritation, which were frequently reported by the respondents.

An important aspect identified in this study is the perception of health risks among farmers, particularly those cultivating potatoes and tomatoes. While some protective measures, such as masks and gloves, were reportedly used, these appear insufficient to fully mitigate the observed health impacts. This underscores the need for enhanced training and the broader adoption of safer and more effective pesticide management practices.

The variability in safety measures and the disposal of fungicide containers further reflects the inconsistent implementation of good agricultural practices across different communities. Parishes like Paute Centro and San Juan exhibited greater diversity in safety practices, likely due to higher levels of education and improved access to information. In contrast, communities such as El Cabo and Yumacay showed fewer safety measures, making them ideal candidates for targeted interventions aimed at improving pesticide safety education.

The prevalence of primary education among farmers reporting health symptoms suggests a direct relationship between education level and risk perception, as well as the use of safety measures. This is a critical finding, indicating that intervention strategies must be tailored to the educational background of the farming population to be effective. Additionally, risk perception and the adoption of safe practices are influenced by socioeconomic factors, such as the cost of fungicides and the availability of PPE, which need to be addressed in any comprehensive intervention strategy.

Finally, the analysis of fungicide container disposal practices by gender and education level reveals that most farmers make decisions based on price and effectiveness, with inadequate attention to safe disposal methods. Improper practices, such as discarding containers in the trash or puncturing them, point to a lack of awareness regarding environmental hazards and safe disposal protocols. This emphasizes the need for educational campaigns that focus not only on pesticide application but also on the safe handling and disposal of chemical residues and containers to minimize environmental contamination.

## Conclusions

This study provides a comprehensive overview of perceptions and practices in pesticide use among farmers in the Paute canton, identifying critical areas for intervention and improvement. Based on the results, the following conclusions can be drawn:

Lack of Training and Education: The predominance of farmers with primary education and their correlation with health symptom perception indicates an urgent need for specific training programs in safe pesticide management.

Insufficient Safety Measures: Although some farmers use protective measures like masks and gloves, these are not sufficient to prevent the reported symptoms, suggesting the need to improve pesticide management practices and adopt more effective safety measures.

Variability in Management Practices: The difference in safety practices and container disposal among communities highlights the importance of implementing educational strategies that address the specific needs of each community, considering their demographic characteristics and education levels.

Socioeconomic Impact: The cost and availability of fungicides and PPE significantly influence pesticide management and disposal practices. Interventions must consider these factors to be effective and sustainable.

Public Policy Recommendations: The findings suggest the need to develop public policies that promote continuous education and training in safe pesticide management, as well as the implementation of technical assistance programs and subsidies for PPE acquisition.

In summary, this study provides a solid foundation for designing interventions that improve agricultural practices and reduce health and environmental risks in the Paute canton. Collaboration between local authorities, agricultural organizations, and the community is crucial to implement these recommendations and achieve a positive and sustainable impact.

The study offers a comprehensive perspective on the risks associated with the use of pesticides in the canton of Paute, Ecuador. Through a descriptive analysis, inadequate practices in the management of pesticides and a lack of awareness of health and environmental risks have been identified. However, it is essential that concrete measures be taken to address these problems.

Detailed Recommendations: We propose the implementation of specific training programs focused on:

- Safe handling of pesticides: Practical workshops on the proper use of personal protective equipment (PPE) and the reading of product labels.
- Waste management: Courses on the correct disposal of pesticide containers, promoting triple washing technique and safe recycling.

In Ecuador, the use of pesticides, including fungicides and insecticides, is common in crops such as potatoes and tomatoes.

However, the indiscriminate use of these products has proven to have negative consequences for human health and the environment.

Integrated Pest Management (IPM): Introduction of IPM programs that include alternative and biological techniques to reduce dependence on chemical pesticides.

Prioritization of Actions: It is recommended to prioritize the following interventions:

- Training farmers on safe practices, since deficiencies in the use of PPE are critical to public health.
- Improvement in the management of pesticide waste, given the direct impact on environmental pollution.
- Promotion of MIP to reduce the use of pesticides, starting with communities with greater use of chemicals.

Study Limitations: This study has certain limitations, such as the small size of the sample, which may limit the generalization of the results. In addition, data collection was based on farmers' perceptions, which could be subject to memory biases or willingness to share information. Therefore, it is important to interpret the findings with caution and conduct broader studies to confirm the observed trends.

## Availability of Data and/or Code

The data generated and analyzed during the current study are available in the public repository [https://orcid.org/0000-0002-6293-0735/] and [https://inbiam.blog.ups.edu.ec/investigadores/geovanna-zea] (https://inbiam.blog.ups.edu.ec/investigadores/geovanna-zea), and can be requested from the corresponding author via institutional mail at azea@ups.edu.ec. No specific code was generated for this stud.

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## Author contributions

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## Declarations

## Conflict of interest

"The authors have no relevant financial or non-financial interests to disclose. There are no conflicts of interest relevant to the content of this article. All authors certify that they have no affiliations with or involvement in any organization or entity with any financial or non-financial interest in the subject matter or materials discussed in this manuscript. Furthermore, the authors have no financial or proprietary interests in any material discussed in this article.

**Ethics Approval**
This study did not involve research with human participants or animals, so ethical approval was not required.
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Not applicable, as this study did not involve human participants.

## Additional information

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