Economic, environmental and health impacts of aerial spraying of banana plantations: A literature review

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Abstract

Aerial spraying in banana plantations generates significant economic, environmental, and public health impacts. This study presents a critical review of the scientific literature to analyze the effects of this practice in rural contexts, with an emphasis on producing countries such as Ecuador. From an economic perspective, aerial spraying has been shown to increase productivity and pest control efficiency, although it entails external costs, including adverse effects on the health of agricultural workers and nearby communities. Environmentally, reported consequences include soil, air, and water pollution, biodiversity loss, and greenhouse gas emissions. In terms of health, pesticide exposure is associated with respiratory illnesses, genotoxic effects, spontaneous abortions, and low birth weight. The lack of effective regulation, inadequate use of protective equipment, and limited awareness of associated risks exacerbate the issue. The review underscores the urgent need to implement sustainable agricultural practices, enforce stricter regulations, and establish monitoring systems to mitigate risks to human health and the environment.

Keywords: aerial spraying; pesticides; banana; public health; environmental impact; agribusiness; Ecuador.

Impactos de la fumigación aérea de plantaciones bananeras: una revisión de la literatura

Resumen

La fumigación aérea en plantaciones de banano genera impactos significativos a nivel económico, ambiental y de salud pública. Este estudio realiza una revisión crítica de la literatura científica para analizar los efectos de esta práctica en contextos rurales, con énfasis en países productores como Ecuador. Desde una perspectiva económica, la fumigación aérea ha demostrado aumentar la productividad y eficiencia en el control de plagas, aunque con costos externos asociados, como la afectación a la salud de los trabajadores agrícolas y comunidades cercanas. A nivel ambiental, se reportan consecuencias como la contaminación del suelo, aire y agua, pérdida de biodiversidad y emisiones de gases de efecto invernadero. En términos de salud, la exposición a pesticidas está relacionada con enfermedades respiratorias, efectos genotóxicos, abortos espontáneos y bajo peso al nacer. La falta de regulación eficaz, el uso inadecuado de equipos de protección y el desconocimiento de los riesgos agravan el problema. La revisión enfatiza la necesidad de implementar prácticas agrícolas sostenibles, regulaciones y sistemas de monitoreo que reduzcan los riesgos para la salud humana y el ambiente.

Palabras clave: fumigación aérea; plaguicidas; banano; salud pública; impacto ambiental; agroindustria; Ecuador.

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INTRODUCTION

Spraying is defined as the application of smoke, gases, vapors, or dust in suspension, especially to fields or plants, to combat insect pests and other harmful organisms. The impact of spraying is in several areas, including damage to workers' occupational health, including the risk of chronic diseases and acute poisoning; risks to public health, including poisoning of consumers; damage to the environment, including soil and water contamination, deforestation and reduction of biodiversity; poisoning of wild animals, livestock and pollinators; reduction of yields; damage to production costs and export potential [1].

From different fields, it can be indicated that the relationship between the use of pesticides in rural areas and the incidence of respiratory diseases has been the subject of attention and research for decades. As industrial agriculture intensified and the use of pesticides became widespread, concerns arose about the potential negative effects on human health [2]. The use of pesticides in agriculture became more common in the early 20th century to control pests and increase crop yields. However, in the 1960s, people began to pay attention to the effects of pesticides on human health. DDT is one of the most widely used pesticides [3].

One of the products used is Dichlorodiphenyltrichloroethane, a man-made chemical that does not occur naturally in the environment. It is a white crystalline solid, odorless and tasteless. DDE (dichlorodiphenyldichloroethylene) and DDD (dichlorodiphenyldichloroethane) are DDT-like chemicals formed by the breakdown of DDT. DDT is a pesticide that was once widely used to control agricultural insects and insects that transmit diseases such as malaria [4]. It was banned in 1972 because it harmed wildlife, but it is still used in some countries where diseases such as malaria are a major health problem. DDE is not intended for commercial use. DDD has been used for pest control but is also banned. A form of DDD has been used to treat adrenal cancer. With further research, it was discovered that pesticides can have irritant and toxic effects on the human respiratory system [5].

Thus, chronic or acute exposure to pesticides can cause respiratory irritation, pneumonia, occupational asthma, and other respiratory diseases. Over the years, regulations and policies have been developed to regulate pesticide use and reduce negative impacts on human health and the environment. More sustainable agricultural methods are promoted, such as organic agriculture, which limits the use of chemical pesticides [7]. Despite advances in regulation and knowledge of potential hazards, the exact relationship between pesticide use and the incidence of respiratory disease in rural areas is an active research topic. Continued research on long-term exposure to multiple pesticides, cumulative effects, and biological mechanisms to better understand these relationships and take appropriate precautions is needed [8]. Likewise, exposure to pesticides by agricultural workers and producers has also been a cause of respiratory symptoms in Ecuador, where 62% of the rural population is engaged in this activity.

Chemical pesticides also account for 1 to 4% of greenhouse gas emissions. These emissions contribute to climate change. They come from the production and transportation of chemical pesticides. In both cases, they use fossil fuels to a large extent.

The Ministry of Agriculture and Livestock of Ecuador, and agricultural workers of banana farms, exposed to pesticides for their activities such as fertilization, spraying, and harvesting, indicated: a high correlation between exposure to agrochemicals and respiratory diseases such as asthma and wheezing; that workers were not aware of the dangers of handling these chemicals and the use of adequate respiratory personal protective equipment to mitigate the risk; and that filter masks were used by only one-third of the population [9].

Evaluated greenhouse gas emissions (CO_2,

CH_4 and N_2O) following fertilizer application in banana plantations in Brazil, highlighting the significant environmental impact of these practices. The results underline the need for management strategies that minimize emissions and promote sustainability [10]; while the anonymous 2020 study on the banana supply chain in Thailand assessed the environmental impact, suggesting the implementation of more sustainable practices to mitigate the negative effects. This analysis is crucial to understand the impact along the entire supply chain [11]. The purpose of the present study is exposure to pesticides in rural areas contributes to the increase of respiratory diseases in the exposed population.

Evaluation of the use of pesticides in agricultural activity in the department of Putumayo, the Putumayo sector has for many years grown and expanded illegal crops for the production and processing of psychoactive substances, especially cannabis, cocaine, and heroin [12]. While it has been established that this situation causes public order, violence, social, and economic imbalances, which motivates the development of programs and strategies to eradicate the problem, it is necessary to study in detail the issues related to this activity: the use of agrochemicals as organic [13]. Treatment and purification The amount of alkalis and crop maintenance chemicals is a risk factor for the deterioration of health in the affected communities [14].

This research aims to analyze some data obtained from an investigation used in the study "Postulated Effects of Glyphosate on Human Health" conducted by the Clínica de Toxicología Uribe Cualla sponsored by the U.S. Embassy [15]. The objective of the analysis is to determine the types of pesticides used by farmers in the Putumayo province, particularly in the municipalities of Orito, San Miguel, and Valle del Guamuez, and their relevance in the storage, use, waste, and residue management of pesticides and the use of personal protective equipment [16].

A retrospective descriptive observational study was conducted in three municipalities in the province of Putumayo, an important cocaine-producing area. The study was presented and approved by the Ethics Committee of the Universidad del Rosario and approved by the Research Committee of the Clínica Uribe Cualla.

For this purpose, 12 villages were selected, of which 9 were visited because of public order problems due to relocation. To mobilize people, community promoters and radio and television media announced the organization of a 10-day health brigade from June 10 to 20, 2001. A total of 1,244 people, regardless of profession, age, or gender, spontaneously participated in this event; two members of the research team were assigned to complete the survey according to the instructions, and the survey questions were combined in all cases [17]. Of the 501 subjects who received the survey application, 11 left the interview site, leaving 490 subjects to be included in the data analysis. The participation of the subjects in the study is voluntary, and anonymous, after filling out and signing an informed consent form, which takes into account the norms established by the Ministry of Health and Social Protection of Colombia in 1993, published in Resolution no. 008430/93 [18].

Agriculture, one of the main economic activities in Putumayo province, is associated with the use of pesticides; unfortunately, it is possible to point out that the conditions of preparation, use, storage, and solid waste disposal of these products are inadequate: Disposal of these substances The population corresponds to all age groups, including children; they use toxicological class I products with a frequency of up to once a week, using dosing methods, including stationary pumps, without personal protection measures and without an adequate plan for the final disposal of the empty containers [19].

Legal regulation regarding the use, treatment,

and disposal of pesticides and their derived solid wastes is complex and fragmented in various norms; although Decree 1843 of 1991 established the law on this matter, another more specific regulation. The mandates of various government departments are not completely defined, which generates duplication and confusion as to the functions they perform [8].

The situation is aggravated by the lack of real institutional coordination between national and regional units. The cases mentioned in this study are just one example of the issues related to the use, management, and disposal of pesticides and hence the efforts of academic units, research institutes, social security, agriculture and rural development, environment, housing, and territorial development and their related or relevant agencies: to assess the effects of the use and disposal of these chemicals on human health and the environment [20].

State, autonomous, and environmental authorities must fully comply with their functions related to the surveillance, control, and monitoring of the use, treatment, disposal, and destruction of pesticides and all the elements to be treated in the field. Despite the official publication of laws, decrees, and resolutions on the use and handling of pesticides and training in trade unions and agrochemical industry magazines [21], the availability and proper interpretation of such information by common people and farmers is still low, and the level of education is quite irregular. Use unregistered products and unknowing the rules for their use, handling, and final disposal, as well as measures to protect workers [23].

In this regard, various agencies visit certain areas to disseminate the latest situation and published pesticide application procedures; it is recommended to develop training programs aimed at informing local communities and institutions about the safe handling of pesticides and their toxic effects from a technical and scientific point of view [24]. Continuing education programs are also needed for health professionals in the industry to properly diagnose and treat pesticide poisonings. An epidemiological surveillance system coordinated by the Administrative Department of Health needs to be developed and implemented to comply with the mandatory reporting and investigation requirements for all pesticide poisoning cases established by Law No. 1991 of the Ministry of Health and Social Protection. Law of 1843 [25].

The remainder of this paper is organized as follows: Section 2 provides an overview of the context of the economic impact of aerial spraying in banana plantations, Section 3 provides information on the environmental and health impact of aerial spraying, and Section 4 describes the methodology used. Section 5 presents the results obtained and finally, the last section presents the conclusions.

ECONOMIC IMPACT OF AERIAL SPRAYING IN BANANA PLANTATIONS

Aerial spraying in banana plantations has been found to have positive effects on crop productivity and yield. The use of agrochemicals, including aerial spraying, can effectively control pests and diseases that can damage banana crops [26]. By eliminating or reducing the impact of these threats, aerial spraying helps ensure healthy and abundant yields. This, in turn, has a positive economic impact on banana plantations, as higher yields translate into higher profits for farmers.

The cost-effectiveness and profitability of aerial spraying in banana plantations are also important considerations. A study conducted by the International Fertilizer Association (IFA) in 2004 showed that the use of aerial spraying in banana plantations resulted in significant cost savings compared to other pest control methods [27]. The efficiency and effectiveness of aerial spraying make it an economically viable option for banana

growers, contributing to the overall economic sustainability and profitability of the industry. In addition, the use of aerial spraying allows for larger-scale operations, further increasing productivity and profitability.

However, it is essential to consider the potential negative consequences of aerial spraying on the environment and human health. The intensive use of agrochemicals, including aerial spraying, can lead to soil, water, and air pollution, posing a risk to ecosystems and biodiversity [29]. In addition, exposure to these chemicals can have adverse effects on human health, both for workers involved in spraying activities and for nearby communities [30] It is crucial to carefully manage and regulate the use of aerial spraying to minimize these negative impacts and ensure the long-term sustainability of banana plantations.

It can be noted that the study by Prescott-allen [4] provides a basis for spraying practices for foliar disease control in banana plantations, highlighting the importance of leaf retention in the efficacy of disease control. Although this study predates the date range considered, it is still relevant to understanding the evolution of spraying practices [31].

Analysis focuses on social struggles in the Philippines over aerial spraying risk regulation, highlighting how social movements and counter-expertise have influenced government policies. This study illustrates the economic and social complexities surrounding aerial spraying in banana plantations [32].

One of the economic impacts on banana production is the accompanying growth of labor markets that are flexible and feminized, but the marginalization of sectors of the working class, and women in particular, is not an inexorable ingredient of globalization. However, the marginalization of sectors of the working class, and women in particular, is not an inexorable ingredient of globalization. How, then, are social relations within the labor market constructed? Markets and their institutional arrangements, such as labor standards, are not passive or benign processes that simply reflect pre-existing social relations. Instead, I argue that markets are social constructions and that actors use institutions strategically to promote certain interests and preferences [33].

The economic impact of banana production, which involves the use of pesticides through aerial spraying, not only mentions productivity concerning income in terms of foreign exchange earnings for the country but it should be considered that, in the determinants, the insertion of women in this labor field increases the risk within the triple burden that they fulfill in society, such as the reproductive function, which is affected, as well as being a wife and a worker [34].

The implications of the economic impact of spraying, not only banana crops, but also other crops such as corn, as stated in the study [1], whose result states that the aggregate cost of externalities generated by pesticides was estimated at about MXN $24 million per year, and the most notable economic impacts were reflected in consumers, workers, and aquatic life [4]

The economic impact of pests has become a challenge for the local and global economy because they can cause damage to crops, properties, and businesses; one of the most obvious ways in which pests affect the economy is through damage to crops and agriculture, one of the most obvious ways in which pests affect the economy is through damage to crops and agriculture, as insects, fungi and diseases can decimate crops, thus decreasing food production and increasing food prices [33]. The impact on business depends on the repair of the damage they cause, which represents a significant expense for households and businesses, which often must invest in pest control measures and repair of damaged structures, and can have an impact on international trade by affecting the quality and quantity of agricultural

products that are exported and imported. This makes pest prevention and control a necessary investment in agriculture to obtain more and better products [7].

The economic impact is related to several aspects, including the human talent that manages it, when their health is affected, having to access fumigations for pest control, and the decrease in food production, a situation that shows concern on the part of farmers.

ENVIRONMENTAL AND HEALTH IMPACT OF AERIAL SPRAYING IN RURAL AREAS

The rapid increase in chemical exposure during industrialization has greatly increased chemical risks, with devastating consequences for local communities. The number of victims of pesticide poisoning among Ecuadorian farmers is increasing year after year [35].

Ecuador's rural sector has suffered serious consequences without the government developing adequate health policies for chemical risk assessment, patient care, and prevention. April 24 marked another anniversary of World Toxicology Day. This brief essay aims to shed light on issues that are rarely discussed in Ecuadorian health. The countries we know as "developed countries" are plagued by chemicals that are harmful to human health [36]. Especially since industrialization has taken the reins of economic production and the bourgeoisie has taken over society, exposure to chemicals harmful to health has increased exponentially, giving rise to, as they colloquially call it, 'globalization'. It is industrial workers who are most at risk from chemicals, and this not only affects economically dependent countries like ours but, in Spain as of 2010, chemicals 4,000 deaths, 33,000 illnesses, 4,444 deaths, and 18,000 deaths each year from exposure to the risks of Industrial Accident [37].

Aerial spraying in banana plantations can harm banana quality due to exposure to pesticides and pesticides used in aerial the process. Pesticide and its residues can remain on the fruit, which can affect banana quality. In addition, exposure to pesticides used in aerial spraying may affect the health of workers and communities near banana plantations, which may also affect banana quality [38]

In the study of Alvarado et al. 2024, about the incidence of aerial spraying on banana crops in the Bella Union farm of the Colombian Union Site of Machala canton, whose results establish that the presence of serious environmental impacts in the study area, however, through the analysis of samples only the variation of soil electrical conductivity is established, therefore, it is determined that the socio-environmental impacts of aerial spraying are minor, being necessary a more in-depth study [39]. Adopted a scalar narrative approach to map explanatory narratives about pesticides and health in El Oro province, Ecuador. The study revealed that structural explanations, such as uncontrolled aerial spraying, were common among workers, while individualized narratives attributed health problems to personal behaviors, thus stabilizing inequitable social structures [39].

Aerial spraying in banana plantations can affect both banana production and quality. Some of the effects of aerial spraying on banana production and quality are presented below:

Effects on production: Aerial spraying can reduce crop losses due to pests and diseases, which can increase banana production. However, excessive use of pesticides in aerial spraying can affect soil quality and biodiversity, which can reduce banana production in the long term [40].

Effects on quality: Aerial spraying can improve banana quality by reducing crop losses due to pests and diseases. However, excessive use of pesticides in aerial spraying can affect banana quality by leaving pesticide residues on the fruit [41].

In addition, exposure to pesticides used

in aerial spraying can affect the health of workers and communities near banana plantations, which can affect banana quality [42]. Thus, in relation to health and safety, investigated the perception of pesticide risk among local stakeholders in Talamanca, Costa Rica, highlighting the exposure and risks associated with aerial spraying. This study highlights the importance of risk perception in pesticide management and its impact on community health [40]. There is also the study by [43] which explored the effects of aerial spraying on the health of newborns in Ecuador. They found a significant reduction in birth weight and an increase in the probability of low birth weight and preterm delivery, highlighting the health risks associated with pesticide exposure during pregnancy [44].

MATERIALS AND METHODS

The CEE guidelines [45] describe the convention of the systematic review, which breaks down the main research question into definable components known as PICO or PECO. The PICO elements also determine the keywords to formulate the search terms as required by the methodology. The review team agreed on the PICO elements defined in Table 1. Once developed, the team tested on 08/07/23, different search terms, using the three major search engines (PubMed, Scopus, and SAGEPUB,). The review team avoided excessive use of search operators such as wildcards, Booleans, braces, etc., to avoid incompatibilities between the different engines [46].

Table 1. Search strategies used in the different databases

PUBMED	AERIAL AND FUMIGATION AND ECUADOR
	ECONOMIC IMPACT AND BANANA PLANTATIONS
	((ECONOMIC IMPACT) AND (BANANA PLANTATIONS)) AND (SUSTAINABLE ECONOMY)
	((SALIVARY) AND (UNEXPECTED)) AND (PET)
SCOPUS	AERIAL AND FUMIGATION AND ECUADOR
	SUSTAINABLE ECONOMY AND INHABITANTS' HEALTH
SAGEPUB	ECONOMIC IMPACT+ AERIAL FUMIGATION+ BANANA PLANTATIONS

The data presented in Figure 1 show the documents that were investigated by country on fumigation in banana plantations in each territory. This visualization allows us to better understand the distribution of fumigation research in recent years. The country with the highest number of documents, with a total of 12 documents. This indicates that China is the leader in the production of documents on the subject analyzed in this graph. Australia is in second place, with approximately 8 documents, showing a high participation compared to the other countries.

The United States and India, both countries have a similar production, with around 6 papers each, which places them in an intermediate position, highlighting their contribution to academic or scientific production in this context.

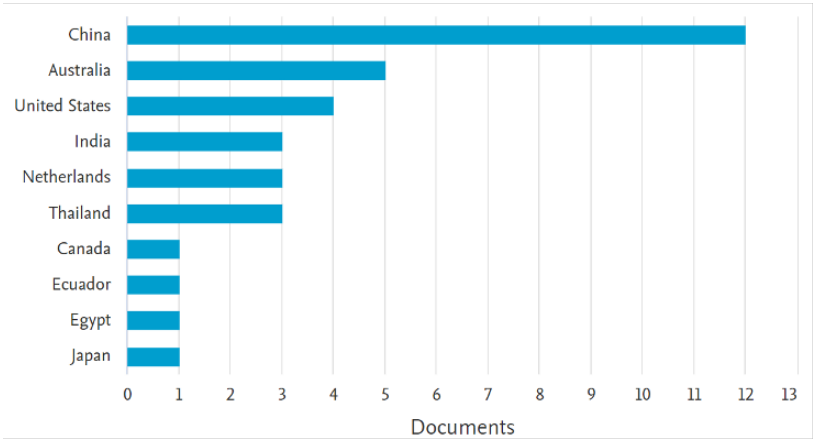

Figura 1. Graphical representation of the distribution of articles by country.

Netherlands and Thailand are also in an intermediate position, with about 5 documents, highlighting their participation in this area. Canada, Ecuador, Egypt, and Japan, these countries have significantly lower production, with 1 or 2 papers each. This indicates a lower participation in the topic or area of research compared to the leaders.

China leads by far in terms of published papers, followed by Australia and then the United States and India. Countries with less production, such as Canada, Ecuador, Egypt, and Japan, have a much more limited representation compared to the others. This graph provides a clear view of the geographic distribution of document production in the subject area analyzed, showing notable leadership by China.

Figure 2 illustrates the proportion of areas of knowledge that researched the impact of aerial spraying. The results show that 42.9% are from the area of Immunology and Agricultural and Biological Sciences, while 10.2% are from Microbiology and 10.2% from the area of Environmental Sciences.

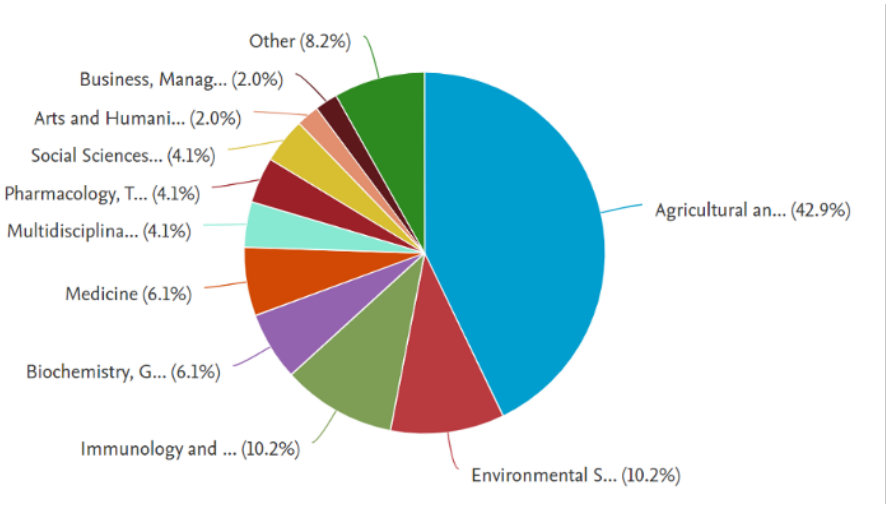

Figure 2. Article by area of knowledge
Source: Own elaboration based on data from the Scopus database with the keywords 2023.

Of the total area, 5.2 million hectares are under agricultural use (permanent, transitory, cultivated, and natural pastures) and 7.0 million hectares are not under agricultural use (forests, woodlands, moorlands, rest, and other non-agricultural uses). This graph

shows the distribution of the area planted with different crops in the country, with cocoa occupying the first place. The key data that stands out is that the area planted with cocoa represents 41.3% of the national total. The cocoa crop occupies the largest planted area with 591,557 hectares, making it the most representative crop in terms of area within the country. This figure highlights the importance of cocoa in the agricultural sector, being a strategic crop for the country's economy and agriculture.

African palm is the second largest crop in terms of planted area, with 196,082 hectares. Although it occupies a significant place, its area is considerably smaller compared to that of cocoa. Bananas follow African palm with 172,653 hectares. It is another important crop, especially for export, but with less planted area than cocoa and African palm.

Plantain has 133,145 hectares, ranking below bananas, but it is still a relevant crop in the agricultural panorama. Sugarcane occupies 116,515 hectares, showing that it is also an important crop, although in a smaller proportion than the others mentioned. Finally, other perennials, which includes several crops not detailed in the graph, occupies 223,002 hectares, indicating a diversity of crops in the country, but each with less area than cocoa.

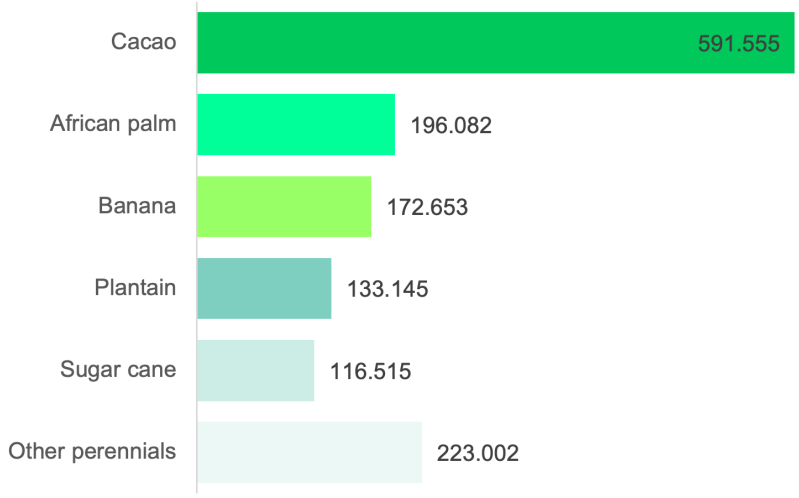

Figure 3. Planted area of permanent crops (ha)
Source: Data from the ESPAC Continuous Agricultural Surface and Production Survey 2023

In 2022, the banana harvested area was 167,544 hectares, registering a growth of 2.1 % compared to 2021. Export bananas are mainly located in the Ecuadorian Coast Region, three provinces account for 91.2% of the national banana harvested area. These are Los Ríos, Guayas, and El Oro, while in the Andes region, there is an 8.8% share.

RESULTS AND DISCUSSION

Aerial spraying in banana plantations can affect banana quality due to exposure to pesticides used in the process. It is important to carefully evaluate these effects before deciding to use aerial spraying in the banana industry. In addition, integrated pest and disease management practices should be adopted to reduce reliance on pesticides and pesticides and to protect the health of workers and the environment [48].

It is known that toxic agriculture causes cancer and other diseases in adults. A large scientific literature is currently available on the specific effects of pesticides on children's health. However, pediatricians and their patients will benefit greatly from a document that summarizes the most recent and scientifically documented

knowledge [49]. The document may also stimulate them to acquire relevant scientific knowledge based on their daily experience or clinical observations in their field [50]. Cytogenetic monitoring of agricultural workers in the province of Cordoba exposed to the pesticides glyphosate, cypermethrin and atrazine showed a higher frequency of chromosomal abnormalities compared to controls, demonstrating the risks presented. The effects of these pesticides on their population health [51].

Further research can establish other population effects of pesticide exposure, as cited by [52]explored the effects of pesticides on rates of miscarriage and infant deaths among women farmers in South Africa. The results indicated that pesticide exposure during the first three months of pregnancy was significantly associated with an increase in miscarriages. This study underscores the need for interventions to improve pesticide safety and reduce reproductive health risks [52]. A situation that uncovers a situation that was not visualized, as it only focused on intoxications and cancer, which has to be considered to not only address human health but also, according to [53] the evaluation of the sustainability of 48 arable farming systems in France, including conventional, integrated and organic systems. It was found that integrated systems, which combine a variety of management techniques, showed a reduction in the use of pesticides and nitrogen fertilizers, consuming less energy and often being more energy efficient. The results suggest that promoting crop rotation diversity and combining diverse management techniques can contribute significantly to the economic and environmental sustainability of agricultural systems. This situation should not only be observed but also applied to reduce risks to the population and the environment [54].

Around the world, more than 5 billion pounds of pesticides are used annually; they represent a diverse group of chemical and physical agents that have varying toxicity to plants and animals. Exposure to these chemicals is common in both agricultural and residential settings; 15.0% of insecticides and 8.0% of herbicides used in the United States are for residential use 1,2. The primary function of pesticides is to prevent or reduce pest losses, given their high degree of toxicity as they are designed to kill certain organisms; they create risks of harm to human health, wildlife, and sensitive ecosystems. The main risk for agricultural workers is exposure to pesticides during preparation, chemical application, handling, and tasks in recently sprayed fields from residues in food and drinking water for the general population [55].

The risk to agricultural workers or the surrounding communities increases due to multiple exposures and re-exposure of the individual before full recovery [56] investigated the genotoxic effects on workers in conventional and organic banana plantations in Ecuador. Using the micronucleus assay in buccal cells, they found a significant increase in the frequency of micronuclei and other nuclear abnormalities in workers from conventional plantations compared to those from organic plantations. These results indicate that organic farming could be a viable alternative to reduce cancer risks associated with intensive pesticide use [57]. This occurs in these workers because, unlike laborers, applicators and day laborers can be exposed, successively or simultaneously, to pesticides of different classes and this can cause the following affectations in the human body.

It has been estimated that 25 million agricultural workers worldwide experience unintentional pesticide poisonings each year. In Chile, between 2006 and 2015 the Toxicological Information Center of the Catholic University (CITUC for its Spanish acronym) received a total of 22,951 cases of pesticide poisoning. The main routes that enter the human body are: dermal, oral, ocular, and respiratory (inhalation) and their danger

increases depending on the concentration and toxicity of the pesticide [58]. The use and exposure of pesticides may be related to various diseases such as cancer, leukemia, Parkinson's, asthma, neuropsychological and cognitive disorders, etc. In Chile, the presence of pesticides (organophosphate: chlorpyrifos and fungicides: diphenylamine (banned in EU), thiabendazole pyrimethanil) in the population due to the consumption of vegetables was evidenced [59]. Pesticide use in rural areas can have respiratory health implications Pesticides that come into use are chemicals designed to kill or control pests, such as insects, weeds, and fungi. Although pesticides can be effective in protecting crops and increasing agricultural production, they also pose risks to human health and the environment, whether through aerial or ground spraying, they can be dispersed into the air and inhaled by people living or working nearby.

Technological innovations, the identification of disease risks in bananas, as well as the reduction of risk in plantations, reducing environmental impact, as well as the optimization of plantation management, such as monitoring for yellow Sigatoka in banana plantations, should be considered. This study shows how advanced technology can improve the early detection and management of diseases, reducing the need for intensive aerial spraying [59] developed a method to detect banana plantations using neural networks and aerial photography. Their study achieved an accuracy of over 95%, showing how technology can optimize plantation management and reduce environmental impact [59]. In this sense, it is also the improvement of water management, optimizing water use with the improvement of productivity, as stated in the study of [60] identified opportunities to improve the management of water stress in banana production, highlighting the importance of efficient irrigation practices. This study is relevant for developing strategies to optimize water use and improve productivity without compromising the environment [61].

The negative impact on banana quality due to exposure to pesticides used in aerial spraying has been recognized, however, the burden of disease has not been given the importance it deserves, in fact, studies, monitoring, and surveillance of workers, with important results, since chromosomal abnormalities thus evidencing the risks to which people are exposed [62], This situation is evidenced when the cytogenetic monitoring of agricultural workers exposed to glyphosate, cypermethrin and atrazine pesticides showed a higher frequency of chromosomal abnormalities compared to controls, which demonstrates the risks involved [63]. In addition, there are studies conducted on women farmers exposed to pesticides, whose effect is a function in the rates of spontaneous abortions and infant deaths, it is also evidenced in the investigation of the genotoxic effects in workers of conventional and ecological banana plantations in Ecuador, found a significant increase in the frequency of micronuclei and other nuclear anomalies in workers of conventional plantations [64].

Integrated cropping systems combining a variety of management techniques showed a reduction in the use of pesticides and nitrogen fertilizers, consuming less energy and often being more energy efficient, indicating that organic farming could be a viable alternative to reduce the cancer risks associated with intensive pesticide use [65].

CONCLUSIONS

In conclusion, aerial spraying in banana plantations can have several economic effects, both positive and negative. It is important to carefully evaluate these effects before deciding to use aerial spraying in the banana industry. In addition, integrated pest and disease management practices should be adopted to reduce reliance on pesticides and to protect the health of workers and the environment.

Agriculture-associated respiratory diseases encompass a wide range of clinical manifestations, from mild illness to severe respiratory failure, including occupational asthma. Various organic aggregates carry bacteria, mold, toxins, and pesticides, which can be transported into the airways and cause more serious lung problems.

Workers may be exposed to high concentrations of allergenic dust when working in confined agricultural spaces such as nurseries and silos. Gases used as pesticides or released in response to pesticide use (hydrogen sulfide, phosgene, chlorine, etc.) directly affect the lining of the airways and present a risk of triggering hyperbronchitis, which can cause inflammation and asthmatic reactions in people. Asthma can be triggered by exposure to specific antigens in agricultural environments, such as pollen, dust mites, and grain dust.

Mucositis is a common reaction to airborne dust in patients with a history of allergic rhinitis or atopy. Plant particles in grain dust appear to mechanically irritate the eyes, but exposure to endotoxins and mycotoxins can also irritate the eyes, nasal passages, and throat.

Figure 3 highlights the dominance of cocoa, which represents more than 40% of the country's total agricultural area, being the main crop in terms of extension. It is followed by other relevant crops such as African palm, banana, plantain, and sugarcane, but none of them come close to the predominance of cocoa. This underlines the importance of cocoa in national agriculture, both in terms of planted area and economic impact.

The entire population is indirectly exposed to pesticides through water and air pollution caused by the use of these products in agriculture and public health. The amount and type of pesticides used are not adequately controlled because the food was grown to contaminate it or because deadlines were not met before marketing (withdrawal period). When food is used that has been disinfected during storage and transport, or when it is stored or transported in premises or vehicles that have been disinfected (before or at the same time) or have been used for storage or transport of pesticidal food. Finally, humans are exposed to food contamination caused indirectly by soil and water contamination.

Author Contributions: For research articles with several authors, a short paragraph specifying their individual contributions must be provided. The following statements should be used “Conceptualization, Mauricio Alfredo Guillen Godoy and , Juan Tarquino Calderón Cisneros; methodology, Mariana Esperanza Guadalupe Vargas and Imelda Arias-Montero; software, , Juan Tarquino Calderón Cisneros; validation, Mariana Esperanza Guadalupe Vargas., Imelda Arias-Montero and Juan Tarquino Calderón Cisneros.; formal analysis, Juan Tarquino Calderón Cisneros; investigation, Imelda Arias-Montero; resources, Mariana Esperanza Guadalupe Vargas.; data curation, Mauricio Alfredo Guillen Godoy.; writing—original draft preparation, Mauricio Alfredo Guillen Godoy and Juan Tarquino Calderón Cisneros.; writing—review and editing, Mariana Esperanza Guadalupe Vargas and Imelda Arias-Montero.; visualization, Imelda Arias-Montero.; supervision, Mauricio Alfredo Guillen Godoy; project administration, Mauricio Alfredo Guillen Godoy.; funding acquisition, Mauricio Alfredo Guillen Godoy. All authors have read and agreed to the published version of the manuscript.” Please turn to the CRediT taxonomy for the term explanation. Authorship must be limited to those who have contributed substantially to the work reported.

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