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Impact of plastic waste on agricultural soils

Impacto de los residuos plásticos en suelos agrícolas

Impacto dos resíduos plásticos nos solos agrícolas

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ABSTRACT

Introduction: Plastic waste has become a global problem due to its persistence in the environment and accumulation in agricultural soils. Therefore, this article reviews the current status of this issue and addresses the effects of microplastics and macroplastics, which are solid waste in agricultural soils. Materials and methods: The research is non-experimental because it is conducted without deliberately manipulating variables. Data are collected through direct observation and surveys conducted in recent research are reviewed. Literature on this topic from the last five years was reviewed in indexed databases such as Scielo and others available on Google Scholar. Discussion: In Latin America, in general, there is a problem in the implementation of waste control, caused by the lack of control and spaces for waste disposal, the maintenance of landfills in poor condition, and the low value given to the informal sector. Results: Therefore, as a result of the research, biochar filters, regulatory restrictions as biodegradable alternatives, and global treaties are proposed. The latter to reduce plastic production, in the face of opposition from oil-producing countries. Discussion: Future challenges on this topic focus on conducting more in-depth studies to avoid the silent crisis with documented impacts on soil fertility, food security, and human health. Conclusions: The transition to circular agriculture, free of synthetic plastics, is essential to preserve the soils of Latin America and, above all, those of Ecuador.

Keywords: agriculture, pollution, sustainability, agricultural soils.

RESUMEN

Introducción: Los residuos plásticos se han convertido en un problema global debido a su persistencia en el ambiente y la acumulación en suelos agrícolas. Por ello, este artículo revisa la actualidad de esta temática y aborda los efectos de los microplásticos y macroplásticos, que son residuos sólidos en los suelos agrícolas. Materiales y métodos: La investigación es un diseño no experimental debido a que se realiza sin manipular deliberadamente variables. Se recolectan los datos mediante la observación directa y se observan las encuestas aplicadas en investigaciones recientes. Se revisó la bibliografía sobre esta temática en los últimos cinco años en bases de datos indexadas como Scielo y otras que estaban presentes en el Google Scholar. Discusión: En la región de América Latina, de manera general, existe una problemática en la ejecución del control de residuos donde las causas son la ausencia de control y espacios para aplicar el proceso de eliminación de desechos, la manutención de vertederos en mal estado y la ínfima valoración hacia sector informal. Resultados: Por ello, como resultados de la investigación se propone los filtros de biocarbón, las restricciones regulatorias como alternativas biodegradables y los tratados globales. Estos últimos para reducir la producción de plástico, frente a la oposición de los países petroleros. Discusión: Los desafíos futuros sobre el tema se encaminan a realizar estudios

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más profundos para evitar la crisis silenciosa con impactos documentados en fertilidad del suelo, seguridad alimentaria y salud humana. Conclusiones: La transición hacia una agricultura circular, libre de plásticos sintéticos, es esencial para preservar los suelos de América Latina y, sobre todo, los del Ecuador.
Palabras clave: agricultura, contaminación, sostenibilidad, suelos agrícolas.

RESUMO

Introdução: Os resíduos plásticos tornaram-se um problema global devido à sua persistência no ambiente e acumulação em solos agrícolas. Portanto, este artigo revisa o estado atual desta questão e aborda os efeitos dos microplásticos e macroplásticos, que são resíduos sólidos em solos agrícolas. Materiais e métodos: A pesquisa não é experimental porque é conduzida sem manipulação deliberada de variáveis. Os dados são coletados por meio de observação direta e pesquisas realizadas em pesquisas recentes são revisadas. A literatura sobre este tema dos últimos cinco anos foi revisada em bases de dados indexadas como Scielo e outras disponíveis no Google Acadêmico. Discussão: Na América Latina, em geral, há um problema na implementação do controle de resíduos, causado pela falta de controle e espaços para descarte de resíduos, a manutenção de aterros sanitários em mau estado e a baixa valorização do setor informal. Resultados: Portanto, como resultado da pesquisa, filtros de biochar, restrições regulatórias como alternativas biodegradáveis e tratados globais são propostos. Este último para reduzir a produção de plástico, diante da oposição dos países produtores de petróleo. Discussão: Os desafios futuros neste tema concentram-se na realização de estudos mais aprofundados para evitar a crise silenciosa, com impactos documentados na fertilidade do solo, na segurança alimentar e na saúde humana. Conclusões: A transição para uma agricultura circular, livre de plásticos sintéticos, é essencial para preservar os solos da América Latina e, sobretudo, os do Equador.
Palavras-chave: agricultura, poluição, sustentabilidade, solos agrícolas.

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Introduction

Solid waste pollution such as plastics in agricultural soils has increased significantly due to the intensive use of this and other materials in agriculture. Unlike aquatic ecosystems, soils receive less attention, despite their crucial role in the food industry and in the sustainable development of countries' economies. Agriculture's goal is to produce food without losses. This article summarizes and scientifically demonstrates the need to protect soils from material waste, some of which is present in the use of agricultural and agrochemical plastics. The latter, at the end of their useful life, become hazardous waste, which, with poor management, has a negative environmental impact.

The modernization of industrial processes generates the creation of products that meet human needs, and it is precisely for this reason that plastic has surpassed any other human-produced material. According to da Silva Fernandes et al. (2023), 52 kg of plastics are discarded per person worldwide; At the national level in Ecuador, it is estimated that plastics generate more than 500 tons of waste each year (Riofrio et al., 2022). These figures are worrying, and if consumption habits and waste management do not change, approximately 12 billion tons of plastic waste will have been generated by 2050 (Zambrano-Monserrate & Alejandra Ruano, 2020).

For this reason, hazardous waste management poses a significant challenge, due to population growth in urban areas and, with it, the high demand for food. Therefore, there is a crucial need to increase the number of agricultural products that have led to the technological advancement of outdoor agriculture and replaced them with greenhouses, tunnels, and the widespread use of fertilizers and chemicals for pest control (Guamushig and Rivera, 2024). Agrochemicals, which are considered a collection of inputs applied in the field and which can include fertilizers and pesticides, prevent losses due to plant diseases, insects, and weeds. Among the advantages and disadvantages are:

Table 1. Advantages and disadvantages of pesticides

Advantages	Disadvantages
They are easy to apply	Soil and water pollution
Their effect is rapid	Loss of biodiversity
They increase productivity	Pests tend to develop resistance to agrochemicals.
They are affordable and available	Human health is affected along with soils.
They meet the need for nutrients in the soil	Their high levels can cause burns in plants.

Source: Own elaboration

Environmental pollution is known as the presence of harmful elements in any of its components, but especially in the soil, which is the area of the present research. Agriculture gives rise to two problems: one is agricultural plastics, where mulch is the most difficult plastic to recycle, generating 32% of waste, and greenhouse plastic is much more recyclable, with waste accounting for 59% (López, 2020). Furthermore, agrochemicals cause harm to the environment, animals, and food.

Municipal solid waste is characterized by organic matter, which is distinguished as biodegradable waste; this name is given due to the composition of food scraps that can be found in kitchens, restaurants, and markets (Espinoza et al. 2021). Organic waste management is necessary due to the emission of toxic gases that cause diseases directly and indirectly and are transmitted by various vectors (insects and stray animals). These diseases can range from typhoid fever to dengue and chikungunya, a crucial consideration for Latin American nations (Ferronato et al., 2021).

In addition to preventing the spread of diseases, solid waste management is essential to ensuring effective protection of the atmosphere, since large amounts of decomposing garbage produce methane, which harms soil and water, a common occurrence in Latin America (Kumar et al., 2023).

Materials and Methods

To conduct this review, a detailed analysis of the available scientific literature was conducted, focusing on the production of bioplastics from renewable sources and their environmental impact relative to conventional plastics. The objective was to collect and evaluate relevant information to understand the current status of these materials and their potential as a sustainable alternative. The methodological process was structured in three stages: source selection, definition of selection criteria, and analysis of the collected information. This research was based on descriptions through field observations and induction of information collected from affected soils in Ecuador.

The data obtained were tabulated to summarize the information on environmental impacts, concluding with a proposal for minimizing and managing solid waste in agricultural soils. This research was able to find updated information from the last five years in previously conducted studies on this topic. The research is a non-experimental design because it is conducted without deliberate manipulation of variables. Data were collected through direct observation and surveys conducted in recent research.

In the first phase of the research, and with the aim of ensuring the quality and reliability of the reviewed studies, the information search was conducted in widely recognized scientific databases such as Scopus, ScienceDirect, SpringerLink, and Google Scholar. Priority was given to articles published in indexed journals and peer-reviewed works that addressed key topics such as the production, characterization, and biodegradability of bioplastics. Using this bibliographic material, it was observed and discovered that the types of chemicals are a form of polluting solid waste. The most common types of agrochemical containers used in crops, and types of greenhouse plastic or mulch, were recorded. The collected information was organized and analyzed through a comparative approach that integrated both a narrative review and a systematic analysis.

Results

Regarding solid waste in Latin America, a variety of criteria must be taken into account. In the case of Bogotá and Mexico City, Rodríguez-Díaz et al. (2022) point out that a new waste management system ("zero waste") is being efficiently implemented; its objective is recycling through a company that handles the disposal of stored waste. They point out that for both cities, the obstacles are inadequate waste transportation operations and the costs incurred, which lead to poor organization.

Regarding the shortcomings of a government's management, Vargas et al. (2022) affirm that the absence of a legislative factor impairs the various actions that comprise the process. They state that, in different Brazilian cities, the legislation includes an article that presents an organic law specifically to address environmental issues; however, no sanctions are evident.

Carmen-Niño et al. (2019) mention that Article 115 of the legislation of the United Mexican States grants municipalities the power and responsibility to manage waste, in conjunction with localities and organizations. From this, it is clear that in the province of Xaltianguis, by not having adequate municipal regulations, it does not

meet the minimum conditions for proper management. For Gutiérrez and Stevanato (2021), political innovations in waste management indicate that the budget is not a relevant condition for improving the process, since it depends on various factors. These factors are represented by the intervention of the private sector in the process.

In the Colombian context, Ortega-Ramírez et al. (2021) point out that the policy that promotes environmental education has changed the population's perspective and has had a positive impact. The implementation of this policy occurs through the joint work of public and private institutions such as UTCH, CODECHOCÓ, among others. This improvement is evident in contrast to the 1990s, when the recycling rate reached only 0.32%; a far cry from current trends. Thus, it is essential to efficiently organize the distribution of expenses, materials, and machinery for efficient management.

Evaluation of the procedure and infrastructure

Regarding the waste disposal process, Mathias (2021) points out that the process varies across different establishments in southern Brazil. He highlights that internal transportation causes problems in 60% of supply locations, as only 20% adequately separate materials for selective collection. This suggests that waste management in Brazil suffers from an imbalance in the effectiveness of each part of the process individually. Thus, the legal regulation is insufficient to channel successful procedures and lacks the tendency to produce performance reports to evaluate future improvements.

In the case of Argentina, López et al. (2021) highlight the position of the Autonomous City of Buenos Aires, where the city government entered into a lease agreement with six companies for the collection and cleaning of public spaces. On the contrary, the results of applying this process reveal inefficient operation, since in 2019, 1% of 388.6 kt was recovered as recyclable material. Regarding the final disposal of waste, there are no landfills in the city of Buenos Aires, and none are recorded within the city limits; however, these landfills are located outside the city limits. Regarding recycling possibilities, García et al. (2019), in their research on the Puerto Bolívar Municipal Market in Ecuador, point out that the Municipal Company (EMAM) concluded that there is no waste control where municipalities apply the various state regulations. In addition, the amount of organic and inorganic waste represents a recycling potential that is not being properly utilized.

In Latin America, in general, there is a problem with the implementation of waste management. According to Rodríguez and Baca (2022), the causes are the lack of control and spaces for implementing waste disposal processes, the maintenance of landfills in poor condition, and the low value placed on the informal sector. For this reason, according to Batista et al. (2021), the development of programs in Latin American countries (Argentina, Chile, Colombia, Ecuador, and Brazil) would not be sufficient to achieve significant change, given the existence of structural barriers and deficiencies. Thus, the current infrastructure processes, government implementation, and the availability of spaces and technology are ineffective. The problem of waste management lies both in the intervention of informal actors, which tends to result in ineffective service delivery, generating a negative image among the population, and in the insufficient maintenance of the infrastructure.

Based on these results, specific figures were obtained regarding studies conducted in Latin America and those that presented the current reality of the territory. In this case, it is notable that in Brazil (23.3%) and Mexico (16.6%), studies on urban waste management are the most prevalent; followed by Colombia (13.3%) and Peru (10%) that present studies that analyze process shortcomings, which allows us to identify areas for improvement in this region of the continent. The fewest studies are provided by Ecuador (7%), Bolivia (3.3%), and Chile (3.3%). Finally, those studies where the region is not specified (13.3%) are those that provide information on technological and procedural innovations, which are mentioned in general in Latin America (Figure 1).

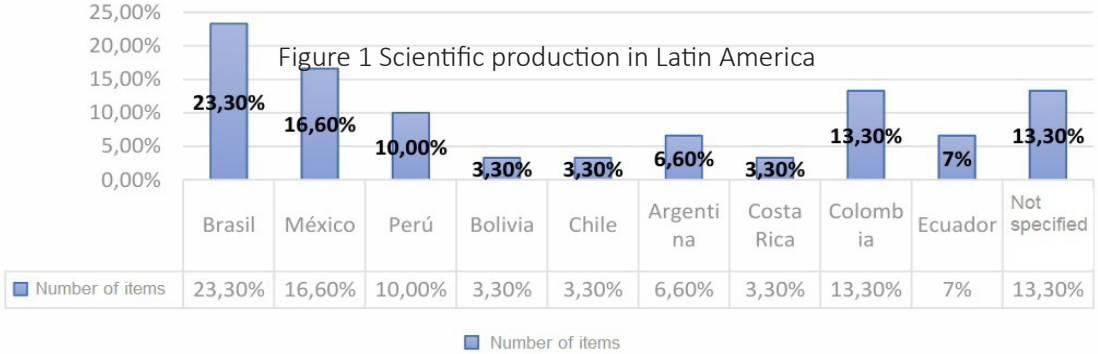

Figure 1 Scientific production in Latin America

Discussion

Organic waste production ranges between 50% and 60% of all waste collected (Mora-Cervetto & Molina-Moreira, 2017). According to the Ecuadorian Tariff Framework, the Organic Code of Territorial Organization, Autonomy, and Decentralization, these services are charged based on electricity, taking the kWh/month consumed by users as a reference (Arrieta, 2018).

As part of the Sustainable Development Goals, strategic goals are promoted that may be related to mitigating the polluting effects of plastic waste in agricultural soils. Therefore, some of the 17 goals of the 2030 Agenda are related in some way to the responsibility for the impact of productive activities on the environment and specific goals are set.

Especially considering that, in agriculture, plastic films represent more than 90% of the total plastic used, which is evident in crops. And the need to strengthen markets for recycling this plastic, innovate in new materials, and ensure proper waste management is highlighted. (Pratelli et al. 2022)

The effects caused by this plastic waste on soils used for cultivation speak of physical and biological alterations related to porosity and water retention. Microplastics reduce water retention capacity and alter soil structure, affecting aeration. The population of earthworms, mites, and larvae, crucial for soil fertility, also decreases. Enzyme reduction disrupts nutrient cycles.

Therefore, the research suggests biochar filters, regulatory restrictions as biodegradable alternatives, and global treaties. The latter aim to reduce plastic production, despite opposition from oil-producing countries. Future challenges on the topic focus on conducting more in-depth studies to prevent the silent crisis with documented impacts on soil fertility, food security, and human health. The transition to circular agriculture, free of synthetic plastics, is essential to preserve the soils of Latin America and, especially, those of Ecuador.

A comparative study of bioplastics and conventional plastics shows that biopolymers have the potential to be a viable alternative to reduce the pollution generated by the excessive use of synthetic plastics. Materials such as polylactic acid (PLA), starch, and cellulose offer significant environmental benefits, as they are biodegradable and do not rely heavily on fossil fuels. However, their production faces limitations, such as high costs, lower mechanical strength, and specific processing requirements.

On the other hand, conventional plastics remain the most widely used due to their low cost, widespread availability, and versatility in various industrial applications. Despite these advantages, their slow degradation and accumulation in the environment exacerbate the plastic pollution crisis, generating serious ecological and social problems.

Although bioplastics represent a more sustainable option, they still require improvements in their strength and production costs. Furthermore, it is essential to promote public policies and regulations that encourage their use and foster an effective transition to biodegradable materials, in order to mitigate the environmental impact generated by traditional plastics.

Conclusions

Solid waste generation in agricultural soils has a moderate impact due to the use of agrochemicals, and the proposal for minimizing this hazardous waste focuses on fundamental pillars. The first is education and training, in addition to proper waste management and the promotion of sustainable alternatives. It is suggested that training programs be implemented for farmers and farm workers on solid waste management and the safe use of chemicals.

Secondly, a system for the collection and treatment of this hazardous waste should be established in collaboration with local authorities to ensure proper disposal and prevent contamination of agricultural soils and water. These integrated actions not only help reduce the generation of solid hazardous waste in these soils, but will also contribute to the environmental health and agricultural sustainability of Ecuador. Finally, periodic monitoring is suggested to evaluate the effectiveness of the measures implemented and ensure the health of the environment and the community.

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Conflict of interest

The authors declare that they have no conflicts of interest.

Declaration of responsibility of authorship

We, the authors of the aforementioned manuscript, DECLARE that we have directly contributed to its intellectual content, as well as to the genesis and analysis of its data; therefore, we are able to take public responsibility for it and accept that their names appear on the list of authors in the order indicated. Furthermore, we have complied with the ethical requirements of the aforementioned publication, having consulted the Declaration of Ethics and Publication Malpractice.

Nancy de las Mercedes Barreno Silva, María Elena Morocho Cuenca, Susy Natalia Gómez Zurita y Maritza Tatiana Chaglla Cango: Literature review and article writing process.