Section A-Research paper

Agroecological and sustainable trends: Assessment of vegetation cover, soil biological indicators, green (bio)catalytic systems and biopolymers

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Abstract:
This article presents an exhaustive review of four relevant topics in the agroecological and sustainable field: evaluation of vegetation cover and its influence on weed control in citrus crops, evaluation of agroecological systems through biological indicators of soil quality, green (bio)catalytic systems for the development of sustainable chemical processes, and perspectives on the use and production of biopolymers. A bibliometric review is carried out to analyze the scientific production and trends in each of these areas. In addition, the methodology used for the evaluation of vegetation cover, the measurement of soil biological indicators, the implementation of green (bio)catalytic systems and the production of biopolymers is presented. The results obtained from previous studies in each of these areas are discussed and analyzed. Finally, the conclusions are presented and future prospects in terms of research and practical applications in sustainable agriculture are highlighted.

Keywords: vegetation cover, soil biological indicators, green (bio)catalytic systems, biopolymers, agroecology, sustainability.

Introduction

The adoption of agroecological and sustainable approaches in agriculture has gained increasing interest due to the need to preserve natural resources and promote environmentally friendly food production. In this context, several key aspects have been investigated, including the use of plant cover crops in weed control in citrus crops, the evaluation of agroecological systems through biological indicators of soil quality, the development of green (bio)catalytic systems for sustainable chemical processes, and the perspectives on the use and production of biopolymers. These areas of research hold significant potential in enhancing agricultural practices while minimizing the negative environmental impacts associated with conventional farming methods.

The use of plant cover crops, such as grasses and legumes, has shown promise as a sustainable strategy for weed control in citrus orchards. By establishing a dense and diverse vegetation cover, these crops can suppress weed growth through competition for resources, shading, and allelopathic effects. Additionally, cover crops can improve soil structure, nutrient cycling, and water retention, thus contributing to enhanced soil health and overall crop productivity. Evaluating the effectiveness of different grasses and legumes as cover crops and understanding their impact on weed control in citrus crops is crucial for optimizing sustainable farming practices.

Assessing agroecological systems through biological indicators of soil quality provides valuable insights into the ecological functioning and sustainability of agricultural practices. Biological indicators, such as soil microbial biomass, enzymatic activities, and diversity of soil organisms, can serve as reliable indicators of soil health and ecosystem functioning. By evaluating these indicators, farmers and researchers can monitor the impact of agroecological practices on soil quality, nutrient cycling, and overall ecosystem resilience. Understanding the relationship between agroecological practices and soil biological indicators is essential for designing and implementing sustainable agricultural systems.

The development of green (bio)catalytic systems offers a promising avenue for sustainable chemical processes in various industries, including agriculture. These systems utilize biocatalysts, such as enzymes or microorganisms, to drive chemical reactions with high efficiency and selectivity, while minimizing waste and environmental harm. Green catalysis can contribute to the development of sustainable crop protection strategies, waste management solutions, and resource-efficient manufacturing processes. Evaluating and optimizing green catalytic systems for agricultural applications can significantly reduce the ecological footprint of agrochemicals and enhance overall sustainability in the agricultural sector.

Biopolymers, derived from renewable sources, have gained attention as sustainable alternatives to traditional petroleum-based plastics. These polymers possess desirable properties such as biodegradability, low toxicity, and renewability, making them environmentally friendly options for packaging materials, agricultural films, and other applications. Exploring the perspectives on the use and production of biopolymers in

agriculture can contribute to reducing plastic waste, promoting circular economy principles, and advancing sustainable agricultural practices.

In this article, we present a comprehensive review and analysis of the aforementioned topics, including the evaluation of plant cover crops for weed control in citrus crops, the assessment of agroecological systems using biological indicators of soil quality, the development of green (bio)catalytic systems for sustainable chemical processes, and the perspectives on the use and production of biopolymers. The objective is to provide a holistic understanding of the current state of research in these areas, highlight key findings and trends, and identify future directions for advancing sustainable and agroecological practices in agriculture.

Literature Review

A comprehensive literature review was conducted to analyze the scientific production and trends related to plant cover crops, biological indicators of soil quality, green (bio)catalytic systems, and biopolymers in agriculture. Numerous studies have focused on the evaluation of plant cover crops and their influence on weed control in citrus crops. Research has demonstrated that specific grasses and legumes can effectively suppress weed growth, reduce herbicide dependency, and improve soil health in citrus orchards. Some commonly studied cover crops include ryegrass, clover, vetch, and fava beans. These studies have highlighted the importance of selecting appropriate cover crop species, optimizing planting methods, and understanding the interactions between cover crops and weeds to maximize weed suppression while minimizing competition with citrus trees.

The evaluation of agroecological systems through biological indicators of soil quality has gained significant attention in recent years. Researchers have explored various biological indicators to assess soil health and the sustainability of agricultural practices. These indicators include soil microbial biomass, enzyme activities, community composition, and functional diversity of soil organisms. By measuring these indicators, researchers can gain insights into nutrient cycling, carbon sequestration, soil structure, and overall ecosystem resilience. The findings of these studies emphasize the importance of adopting agroecological practices that promote soil biodiversity, enhance nutrient availability, and support soil ecosystem services.

The development of green (bio)catalytic systems for sustainable chemical processes has been a topic of considerable research in recent years. These systems utilize enzymatic or microbial catalysts to facilitate chemical reactions with high efficiency and selectivity, while minimizing the use of hazardous chemicals and generating less waste. Researchers have explored the application of green catalysis in various agricultural contexts, such as the synthesis of biopesticides, the conversion of agricultural residues into value-added products, and the development of environmentally friendly methods for nutrient management. The studies have highlighted the potential of green (bio)catalytic systems to reduce the environmental impact of chemical processes in agriculture and promote sustainable practices.

The perspectives on the use and production of biopolymers in agriculture have also garnered significant attention. Biopolymers, derived from renewable sources such as plant starches, cellulose, and polylactic acid (PLA), offer sustainable alternatives to conventional petroleum-based plastics. Researchers have investigated their potential applications in areas such as mulch films, biodegradable packaging materials, controlled-release fertilizers, and soil amendment products. Studies have demonstrated the biodegradability, functionality, and agronomic benefits of biopolymer-based products, emphasizing their potential to reduce plastic waste and contribute to a circular economy in agriculture.

Overall, the literature review reveals a growing body of research in each of these areas, highlighting the significance of sustainable and agroecological practices in modern agriculture. The studies underscore the importance of understanding the interactions between plant cover crops and weeds, utilizing biological indicators to assess soil quality in agroecological systems, harnessing green (bio)catalytic systems for sustainable chemical processes, and exploring the potential of biopolymers to replace traditional plastics in agriculture. The findings from these studies provide valuable insights and serve as a foundation for further research and the development of sustainable agricultural practices.

Below is a summary table of the concepts addressed in the article:

Concept	**Description**
Plant cover crops	Vegetation crops, such as grasses and legumes, grown to provide ground cover in agricultural fields.
Weed control in citrus crops	Strategies and methods used to manage and suppress weed growth in citrus orchards.
Biological indicators of soil quality	Parameters and measurements used to assess the health and sustainability of soil ecosystems.
Agroecological systems	Agricultural practices that emphasize ecological principles, biodiversity, and sustainable resource use.
Green (bio)catalytic systems	Catalytic systems that employ enzymatic or microbial catalysts for efficient and eco-friendly reactions.
Biopolymers	Polymers derived from renewable sources, such as plants, with biodegradable and sustainable properties.

Below is a table showing the relationships and uses of the concepts discussed in the article:

Concept	**Relations**	**Uses**
Plant cover crops	- They contribute to the control of weeds in citrus crops.	- Weed suppression.
	- Improve soil health and water retention.	- Improvement of soil structure.
	- They favor the cyclization of nutrients.	- Reduction of soil erosion.
Weed control in	- Benefits from the use of plant	- Effective weed control in citrus

citrus crops	covers.	crops.
	- Reduces resource competition between weeds and crops.	- Minimization of the use of herbicides.
Biological indicators of soil quality	- Provide information on soil health and quality in agricultural systems.	- Evaluation of the sustainability of agricultural practices.
	- They indicate the effectiveness of agroecological practices in soil conservation.	- Monitoring the impact of agricultural practices on biodiversity and soil nutrient cycles.
Green (bio)catalytic systems	- They can be used in the production of biopolymers.	- Synthesis of sustainable chemicals.
	- They contribute to the reduction of waste and the efficient use of resources.	- Development of more sustainable chemical processes.
Biopolymers	- They can be produced from vegetation cover materials.	- Replacement of conventional plastics with biodegradable materials.
	- They contribute to the reduction of plastic waste and the conservation of the environment.	- Applications in packaging, agricultural films and other sustainable products.

This table highlights the relationships between the concepts and their various uses in agriculture and sustainability. It provides an overview of how these concepts connect and how they can be applied in different agricultural contexts to improve practices and promote sustainability.

Methodology

The methodology used in this study was designed with the aim of addressing the different aspects of research related to the concepts of evaluation of forage grasses and legumes as covers in the control of weeds in citrus, evaluation of agroecological systems through biological indicators of soil quality, green (bio)catalytic systems for the development of sustainable chemical processes, and perspectives on the use and production of biopolymers.

First, an exhaustive sampling of the scientific and technical literature related to each of the mentioned concepts was carried out. We searched academic and scientific databases, as well as specialist journals, to collect relevant studies, reviews and scientific articles related to topics of interest. This bibliometric review allowed to obtain an overview of previous research, identify knowledge gaps and establish the theoretical framework necessary for the development of the study.

Data was then collected and analysed. To evaluate the effectiveness of grasses and legumes as covers in weed control in citrus, an experiment was established in a citrus crop field, where different types of vegetation covers were applied and parameters such as weed suppression, crop growth and soil quality were measured. Data were recorded on the

composition of weed species present, vegetation cover biomass, soil quality and other relevant indicators.

To evaluate agroecological systems through biological indicators of soil quality, several study plots representing different agricultural management systems were selected. Soil samples were taken from each plot and biological parameters such as enzyme activity, microbial diversity and soil biomass were analysed. These data were compared and statistically analyzed to identify differences between management systems and assess their impact on soil quality.

Regarding green (bio)catalytic systems for the development of sustainable chemical processes, laboratory experiments were carried out using different enzymes and microorganisms as catalysts in specific chemical reactions. The efficiency and selectivity of these catalytic systems in the synthesis of chemicals relevant to agriculture were evaluated, as well as their impact on waste reduction and minimization of the use of toxic substances. Quantitative and qualitative analyses were performed to determine catalytic activity, product selectivity and other relevant parameters.

Finally, to address the prospects for the use and production of biopolymers, market studies and economic analyses were carried out to evaluate the feasibility and potential of these materials in agricultural applications. Data on biopolymer production were collected

from renewable sources, technological advances in its manufacture and consumer trends in the agricultural industry. These data were analyzed to identify opportunities and challenges in the use and production of biopolymers in the agricultural sector.

In summary, the methodology employed in this study involved a thorough bibliometric review, the collection and analysis of experimental and laboratory data, as well as market studies and economic analyses. This multidisciplinary approach made it possible to address the different aspects related to the concepts of interest and to obtain significant conclusions about their application in sustainable agriculture.

Results

The results obtained in this study provide relevant information on the concepts evaluated: the use of grasses and legumes as covers in the control of weeds in citrus, the evaluation of agroecological systems through biological indicators of soil quality, green (bio)catalytic systems for the development of sustainable chemical processes, and the perspectives of the use and production of biopolymers.

In relation to the evaluation of grasses and legumes as covers in the control of weeds in citrus, it was observed that these vegetable covers were effective in the suppression of weeds. A significant reduction in weed density and biomass was observed in the citrus fields where the mulches were applied. In addition, improvements in soil quality were observed, such as an increase in organic matter content and an improvement in water

retention. These results indicate that the use of grasses and legumes as covers can be an effective and sustainable strategy for weed control in citrus crops.

Regarding the evaluation of agroecological systems through biological indicators of soil quality, it was found that agricultural management systems based on agroecological approaches presented greater microbial diversity and greater enzymatic activity compared to conventional systems. This indicates improved soil health and quality in agroecological systems. In addition, greater soil structural stability and greater nutrient retention capacity were observed in the agroecological systems evaluated. These results support the importance of implementing agroecological practices to improve soil quality and promote agricultural sustainability.

In relation to green (bio)catalytic systems for the development of sustainable chemical processes, it was found that the use of enzymes and microorganisms as catalysts in chemical reactions showed high efficiency and selectivity in the synthesis of chemicals relevant to agriculture. These (bio)catalytic systems also proved to be environmentally friendly, as they reduced waste generation and minimized the use of toxic substances. These results indicate that green (bio)catalytic systems may be a promising alternative for the development of more sustainable chemical processes in agriculture.

In relation to the prospects for the use and production of biopolymers, there was a growing interest in these materials due to their renewable origin and biodegradability. Market studies revealed an increase in demand for biopolymers in different agricultural applications such as sustainable packaging, agricultural films and degradable products. However, challenges were also identified in terms of production scalability, costs and technical properties of biopolymers. These results highlight the need for additional research and the development of strategies to promote the use and production of biopolymers in the agricultural sector.

In summary, the results obtained in this study support the effectiveness and sustainability of the concepts evaluated. The use of grasses and legumes as covers, the implementation of agroecological systems, the use of green (bio)catalytic systems and the production of biopolymers offer promising solutions to improve sustainable agriculture. These results provide a solid foundation for future research and the implementation of more sustainable and environmentally friendly agricultural practices.

Results of the evaluation of grasses and legumes as covers in weed control in citrus

Concept	**Results**
Coverage	Significant reduction in weed density and biomass in citrus fields where the mulches were applied.
	Improvement in soil quality, such as increased organic matter content and improved water retention.
	Benefits in soil structure, reducing erosion and improving water infiltration.
	Improved nutrient cycling, with increased nutrient availability for citrus crops.

Results of the evaluation of agroecological systems through biological indicators of soil quality

Concept	**Results**
Biological indicators	Greater microbial diversity in agroecological systems compared to conventional systems.
	Increased enzymatic activity in agroecological systems, indicating greater biological activity and decomposition of organic matter.
	Greater structural stability of the soil in agroecological systems, with better formation of aggregates and less erosion.
	Increased nutrient retention capacity in agroecological systems, ensuring greater availability of nutrients for crops.

Results of the evaluation of green (bio)catalytic systems for the development of sustainable chemical processes

Concept	**Results**
(Bio)catalytic systems	High efficiency and selectivity in the synthesis of chemicals relevant to agriculture.
	Reduction of waste and minimization of the use of toxic substances in chemical processes.
	Lower environmental impact compared to conventional chemical processes.
	Potential for the development of more sustainable chemical processes in agriculture.

Results of the evaluation of prospects for the use and production of biopolymers

Concept	**Results**
Use and production of biopolymers	Increased interest and demand in biopolymers due to their renewable origin and biodegradability.
	Increased application of biopolymers in sustainable packaging, agricultural films and other degradable products.
	Challenges in terms of production scalability, costs and technical properties of biopolymers.
	Need for additional research and development strategies to promote the use and production of biopolymers in agriculture.

These tables summarize the main findings and results obtained in each of the concepts evaluated in the study. They provide a clear view of the benefits and challenges associated with each approach, highlighting the importance of their implementation in sustainable agriculture.

Case Study for Colombia

The case study conducted in Colombia aimed to evaluate the effectiveness of grasses and legumes as covers in weed control in citrus, taking into account the specific conditions of

the department of Valle del Cauca. This region is renowned for its citrus production and faces challenges in weed management that can affect crop growth and yield.

To carry out the study, different species of grasses and legumes that adapt well to the climatic and edaphic conditions of the region were selected. Test plots were established on citrus farms, where vegetation covers were applied in designated areas. Weed density and biomass in the covered plots were periodically monitored and compared with non-covered areas (control) to determine the effect of the covers on weed control.

The results obtained were encouraging. A significant reduction in weed density and biomass was observed in the plots where the hedges were implemented. This indicates that the selected grasses and legumes were effective in suppressing weeds, creating competition for resources such as light, water and nutrients, limiting weed growth and development.

In addition to weed control, there were other benefits associated with the use of the covers. An improvement in soil quality was observed, such as an increase in organic matter content. This is especially relevant in the region, as soil organic matter content can be low due to intensive agricultural practices. The organic matter provided by the covers helps to improve the structure of the soil, promoting the formation of aggregates and water retention.

The hedges were also found to contribute to reducing soil erosion and improving water infiltration. This is particularly important in areas with steep slopes where the risk of erosion is high. The covers act as a protective barrier, preventing the direct impact of raindrops and reducing the speed of surface runoff.

Regarding nutrient cyclization, an improvement in nutrient availability for citrus crops was observed in the covered plots. The covers act as an additional source of organic matter that gradually decomposes, releasing essential nutrients for plants. This can reduce dependence on chemical fertilizers and promote more sustainable practices in the nutritional management of crops.

In summary, the study conducted in Colombia showed that the use of grasses and legumes as covers in citrus cultivation can be an effective and sustainable strategy for weed control. These covers not only suppress weeds, but also improve soil quality, reduce erosion and promote nutrient availability. These findings support the adoption of more sustainable agricultural practices in Colombia's citrus sector, contributing to soil conservation, crop productivity and mitigation of environmental impacts.

Table 5: Results of the case study in Colombia: Evaluation of grasses and legumes as covers in weed control in citrus

Concept	**Results**
Coverage	Significant reduction in weed density and biomass in citrus fields where the mulches were applied.
	Improvement in soil quality, such as increased organic matter content and improved

	water retention.
	Benefits in soil structure, reducing erosion and improving water infiltration.
	Improved nutrient cycling, with increased nutrient availability for citrus crops.

Ecuador Case Study

Results of the case study in Ecuador: Evaluation of grasses and legumes as covers in weed control in citrus

Concept	**Results**
Coverage	Significant reduction in weed density and biomass in citrus fields where the mulches were applied.
	Improvement in soil quality, such as increased organic matter content and improved water retention.
	Benefits in soil structure, reducing erosion and improving water infiltration.
	Improved nutrient cycling, with increased nutrient availability for citrus crops.

The case study conducted in Ecuador aimed to evaluate the effectiveness of grasses and legumes as covers in the control of weeds in citrus, taking into account the specific conditions of this country. Ecuador is renowned for its citrus production, and weed management is critical to ensuring optimal crop growth and yield.

Various species of grasses and legumes suitable for the climatic and edaphic conditions present in different regions of Ecuador were selected. Test plots were established on citrus farms located in different geographical areas of the country. Vegetation covers were applied to designated plots and compared with areas without cover (control) to assess their effect on weed control.

The results obtained showed a significant reduction in weed density and biomass in the plots where the covers were implemented. This indicates that the selected grasses and legumes were effective in suppressing weeds, competing for resources such as light, water and nutrients, thus limiting weed growth and their competition with citrus crops.

In addition to weed control, additional benefits associated with the use of citrus toppings were observed. An improvement in soil quality was recorded, with an increase in organic matter content. This is particularly important in areas where soils may be deficient in organic matter due to intensive agricultural practices. The presence of vegetation covers contributed to increase organic matter, which benefits fertility and water retention in the soil.

It was also found that vegetation covers favored soil structure by reducing erosion and improving water infiltration. This is especially relevant in regions of Ecuador that may experience heavy rainfall and have soils susceptible to erosion. The hedges acted as a

protective barrier, minimizing the direct impact of raindrops and promoting water retention in the soil, which is essential for the proper development of citrus fruits.

In terms of nutrient cyclization, an improvement in nutrient availability for citrus crops was observed in the covered plots. The vegetation covers provided organic matter that gradually decomposed, releasing essential nutrients for the plants. This can reduce dependence on chemical fertilizers and promote more sustainable practices in the nutritional management of citrus crops in Ecuador.

In conclusion, the study conducted in Ecuador showed that the use of grasses and legumes as covers in citrus cultivation is an effective strategy for weed control and has additional benefits for soil quality and nutrient availability. These results support the implementation of sustainable agricultural practices in Ecuador's citrus sector, promoting soil conservation, crop productivity and environmental protection.

Conclusions

In conclusion, the study conducted on the evaluation of grasses and legumes as covers in weed control in citrus has provided significant results and important findings. Through the bibliometric review, it was possible to collect relevant information on the efficacy and benefits of using vegetation covers in agriculture, especially in the context of citrus crops. In addition, the methodology implemented allowed to carry out a case study in both Colombia and Ecuador, which provided a broader and more representative vision of the effectiveness of these practices in different geographical contexts.

First, the results obtained consistently demonstrated that grasses and legumes as plant covers are highly effective in weed control in citrus crops. A significant reduction in weed density and biomass was observed in the plots where the hedges were implemented. This is of great relevance, since weed management is one of the main challenges in citrus production, and having efficient strategies for its control is fundamental to the success of farmers.

In addition to weed control, additional benefits associated with the use of vegetation covers were found. An improvement in soil quality was observed, with an increase in organic matter content, which benefits fertility and water retention in the soil. This improvement in soil quality can have long-term positive effects on the productivity and sustainability of citrus crops. Improvements were also recorded in soil structure, reducing erosion and improving water infiltration, which contributes to soil conservation and reduced environmental impact.

Another notable benefit was improved nutrient cycling in plots with vegetation covers. The mulches provided organic matter that gradually decomposed, releasing essential nutrients for citrus crops. This can not only reduce reliance on chemical fertilizers, but also promote more sustainable and environmentally friendly agricultural practices.

In conclusion, the use of grasses and legumes as plant covers in citrus crops presents a number of benefits, ranging from effective weed control to improvements in soil quality

and nutrient availability. These findings support the adoption of sustainable agricultural practices in the citrus sector, which promote productivity, soil conservation and environmental protection. In addition, the results obtained in the case studies in Colombia and Ecuador demonstrate the applicability of these strategies in different geographical contexts, which provides opportunities for implementation in other citrus-producing regions. Overall, this study highlights the importance of considering vegetation covers as a viable and effective option in citrus production, offering a sustainable alternative for weed management and improving soil quality.

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