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Analysis of forest management plans for environmental sustainability

Análisis de los planes de gestión forestal para la sostenibilidad ambiental

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ABSTRACT

Today, environmental care, conservation, and improvement are three key factors in humankind's survival, including sustainable forest management as a crucial tool for maintaining environmental balance in terms of biodiversity, climate, and human well-being. This study was conducted aiming to explore the theoretical and methodological frameworks of forest harvesting, natural resource management plans, and environmental improvement plans across different regions worldwide. The PRISMA methodology was used, which allowed for the analysis of relevant information from various recognized scientific databases. Understanding and evaluating the effectiveness of forest harvesting and environmental improvement plans is essential, particularly for promoting forest sustainability and environmental conservation. The variables focused on different geographical contexts: Europe, Asia, Africa, North and Central America, South America, Colombia, and the department of Santander. The studies analyzed identified research processes focused on environmental improvement and conservation as the main trend. These processes reflect a growing concern and commitment among organizations, governments, environmental leaders, and the general community, who seek to work on the conservation of forest resources and their benefits for ecosystems and people's communities. In addition, there is a strengthening of environmental awareness and an increasing focus on progress related to sustainable development indicators.

Keywords: biodiversity; forest ecosystem; forest resources; habitats; resource conservation; sustainable development

RESUMEN

En la actualidad, el cuidado, la conservación y la mejora del medio ambiente son necesidades, fundamentales para la supervivencia de la humanidad, incluyendo al aprovechamiento forestal sostenible como herramienta crucial para mantener el equilibrio del medio ambiente, en cuanto a su biodiversidad, clima y bienestar del ser humano. El objetivo de este estudio es explorar el contexto teórico y metodológico de los planes de aprovechamiento forestal y de recursos naturales y la mejora ambiental en distintas regiones a nivel global. Se empleó la metodología PRISMA, que permitió analizar información relevante a partir de diversas bases de datos científicas reconocidas. La relevancia de este artículo radica en la necesidad de comprender y evaluar la efectividad de los planes de aprovechamiento forestal y mejora ambiental, especialmente en lo que respecta a la promoción de la sostenibilidad forestal y la conservación del medio ambiente. Las variables se enfocaron en diferentes contextos geográficos: Europa, Asia, África, América del Norte y América Central, América del Sur, Colombia y el departamento de Santander. Los estudios analizados identificaron como tendencia principal los procesos de investigación enfocados en la mejora y conservación ambiental. Estos procesos reflejan una creciente preocupación y compromiso de organizaciones, gobiernos, líderes ambientales y la comunidad en general, que buscan trabajar en la conservación de los recursos forestales y sus beneficios para los ecosistemas y las comunidades humanas asociadas. Además, se observa un fortalecimiento de la conciencia ambiental y un enfoque creciente en los avances relacionados con los indicadores de desarrollo sostenible.

Palabras clave: biodiversidad; conservación de recursos; desarrollo sostenible; ecosistema forestal; hábitats; recursos forestales

INTRODUCTION

As ecological awareness and sustainability have become global priorities, both public and private organizations play a significant role in promoting adaptive management and the conservation of natural resources. Sustainable forest management is a fundamental principle for ensuring the continued provision of tangible and intangible resources and functions by forest ecosystems while preserving their intrinsic values. Numerous public and private organizations are currently leading processes aimed at increasing ecological awareness and moving towards sustainability. The conservation community has focused on the monitoring and evaluation of management practices, as well as ecological and social governance, as part of a global movement in order to achieve adaptive management and conservation (Bennett, 2016). In this context, sustainable forest management is increasingly seen as an essential principle for ensuring both the conservation of ecosystems and the production of the multiple goods and services they provide.

Recently, forest management plans have become essential tools for promoting the sustainable use of natural and forest resources, minimizing environmental impacts and promoting environmental improvement. However, their formulation and implementation vary considerably between regions and countries due to differences in conceptual frameworks, methodological approaches, socio-ecological contexts, and environmental policies. According to Romero *et al*. (2023), it is necessary to consider the management and conservation of forests, as well as the current policies that regulate the use of resources. Despite the growing interest in sustainable forest management, there is a dispersion of theoretical and methodological approaches, making it difficult to identify good practices, compare international experiences, and consolidate forest and natural planning models that adequately integrate environmental conservation, sustainable use, and local development. In this context, there is a need to analyze and systematize the theoretical and methodological foundations present in forest use and environmental improvement plans at the global level, in order to recognize their main trends, approaches, and contributions to sustainable ecosystem management.

MATERIALS AND METHODS

To attain the central objective of this study, a procedure based on the PRISMA methodology was used, which, according to Page *et al.* (2021), is widely employed to carry out systematic reviews and meta-analyses in scientific research. The systematic review procedure consisted of several steps: study selection, quality and pedagogical relevance assessment, data extraction and analysis, presentation of results, and final evaluation of the quality of the evidence. This methodology enabled the selection and analysis of 50 research articles published over the last 10 years, which address environmental improvement plans organized into five categories classified according to geographical context.

The geographical categories include, first, Europe, Asia, and Africa, providing a global view of approaches and experiences in environmental improvement plans. Second, North, Central, and South America, allowing for an analysis of the specific challenges and particularities of these areas. In addition, a category dedicated to Colombia was incorporated to explore environmental improvement plans at a national level. Finally, the Department of Santander (Colombia) was examined in depth as a specific case, allowing for a detailed analysis of the plans implemented in this area.

In this regard, Aguirre-Calderón (2015) points out that sustainable forest management in the 21st century is a principle that ensures the production of various goods and services from forest ecosystems in a perpetual and optimal manner, always preserving the values of these ecosystems. Thus, the main purpose of this article is to identify the plans and projects which have been carried out globally in relation to environmental improvement and utilization, highlighting their importance for the social, economic, and environmental sustainability of humanity.

The procedure used was based on the PRISMA methodology (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) (Page *et al*., 2021). Using this methodology, a systematic review was conducted to identify and analyse bibliographic references. This was a systematic, well-defined, and replicable process, guided by explicit criteria that clarified how the data were obtained and interpreted (Torres-Fonseca & López-Hernández, 2014).

The review was conducted in the following phases: the first stage consisted of stating the problem, objective, or research question. In the second phase, relevant research is located and selected according to the criteria established in the previous stage. Subsequently, the relevance of the selected studies was evaluated, the data were extracted, the results were presented and finally, an analysis and interpretation of the results was performed (Ceniceros Maya *et al.*, 2019).

Eligibility Criteria

To select the studies required to address the central objective of the study, inclusion and exclusion criteria were established. These criteria focused solely on research articles published in indexed electronic journals, excluding printed publications due to access difficulties.

Another criterion established was to include recent research carried out in different countries. In terms of language, priority was given to publications in Spanish, since this is the first language of the researchers, although research in English was also included, given that it is the predominant language in most of the specialized journals (Table 1).

Table 1. *Inclusion and exclusion criteria for article selection in the systematic review*

Characteristic	Criteria	Inclusion	Exclusion
Publication	Articles from journals indexed in databases	x	
	Thesis		x
	Books		x
Article format	Electronic	x	
	Printed		x
Language	English	x	
	Spanish	x	
	other		x
Date of Publication	Years 2013-2023	x	
	Years before 2013		x
Keywords	Environment	x	
	Environmental conservation	x	
	Forest ecosystem	x	
	Forest resources	x	

Sources of Information

Sources for the systematic review were retrieved from reliable databases such as *Scopus* and *Web of Science* using relevant keywords. For the analysis of this study, the multidisciplinary database *Social Sciences Citation Index* (SSCI) was used. This is available online through Web of Science (WoS), which is part of the *ISI Web of Knowledge* (Wok) service. The logical operators (AND, OR) and parentheses were used for the formulation of the search equation to optimize results. In addition, basic filters were applied in the corresponding search engines to improve the accuracy of the search process, facilitating the collection and information analysis. The search equation used was as follows:

Environment AND environmental conservation OR forest ecosystem OR forest resources.

This equation made it possible to obtain a classification of the different research areas according to the number of publications, with a total of 431 studies, as shown in Figure 1.

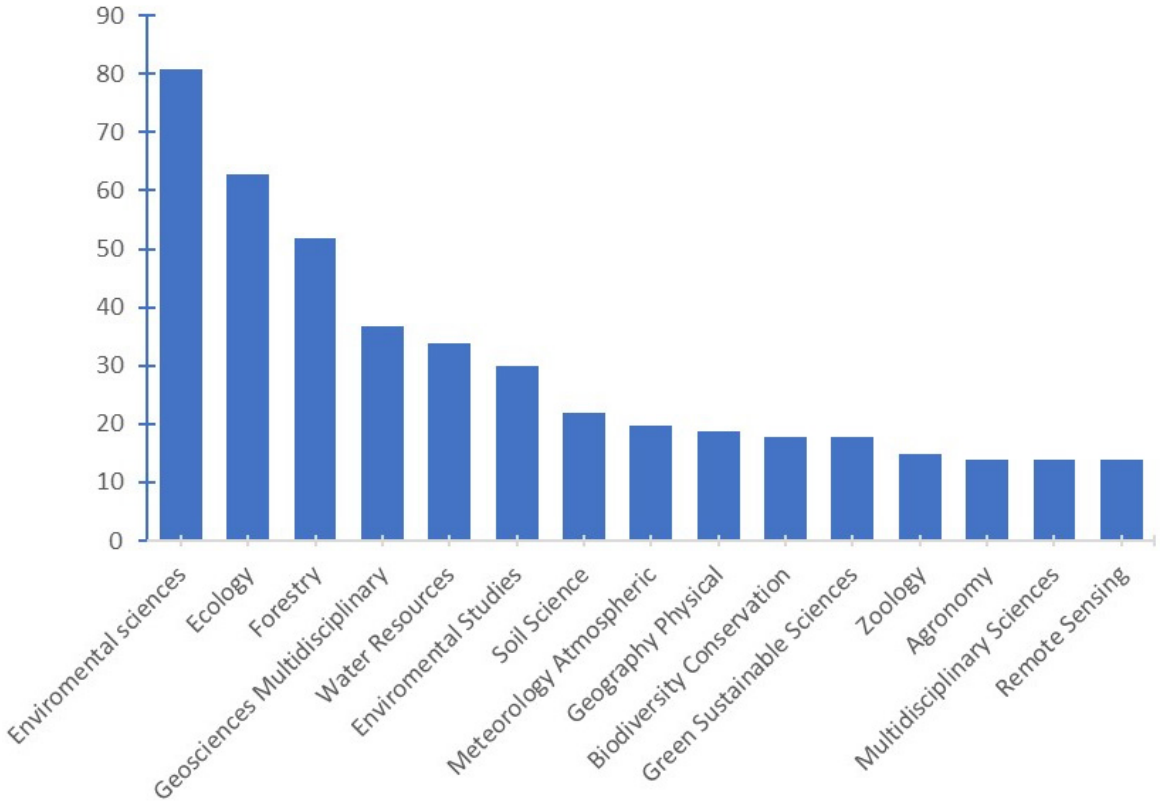

Figure 1. *Classification of the research by area of study*

These search engines were selected for their reliability and simplicity, which helped in organizing and analysing the information reviewed. The search period was determined between January and July 2023.

Figure 2 shows the number of studies published and cited during this period, which was used for the systematic analysis.

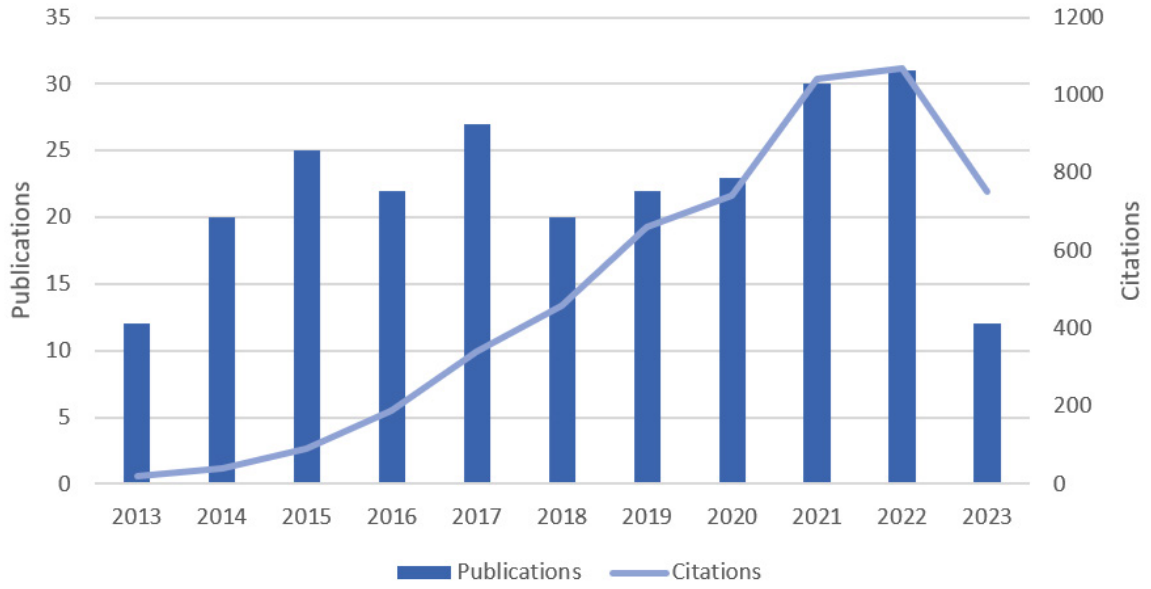

Figure 2. *Studies published and cited in the period established for the systematic analysis*

Search Strategy

The literature review which consolidated the systematic review process covered the period from 2013 to 2023 (Figure 3). It was observed that approximately 100% of the literature cited corresponds to research published in the last 10 years.

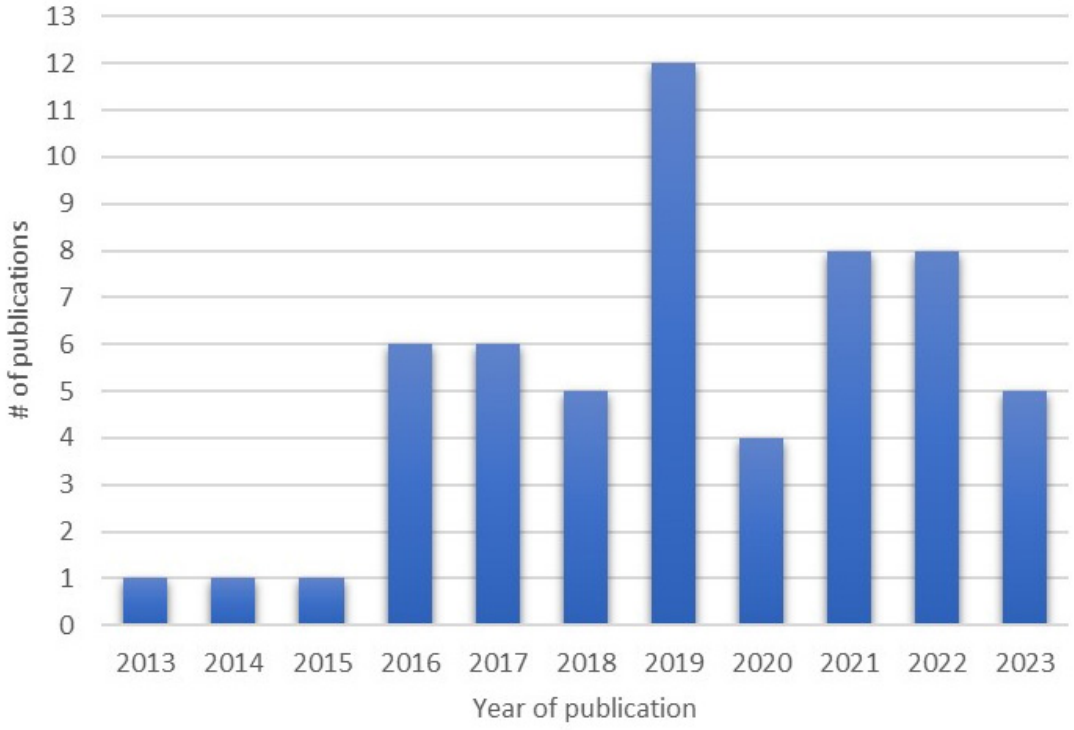

Figure 3. *Studies collected and analyzed in the systematic review by year and number*

To carry out the strategy, keywords related to the topics of interest were used. VOSviewer software, a bibliometric network visualization tool developed at the Centre for Science and Technology Studies (CWTS), was used to process quantitative data. This approach allowed the optimization of the terminology used during the search, facilitating the collection and accurate analysis of a large amount of information (Figure 4).

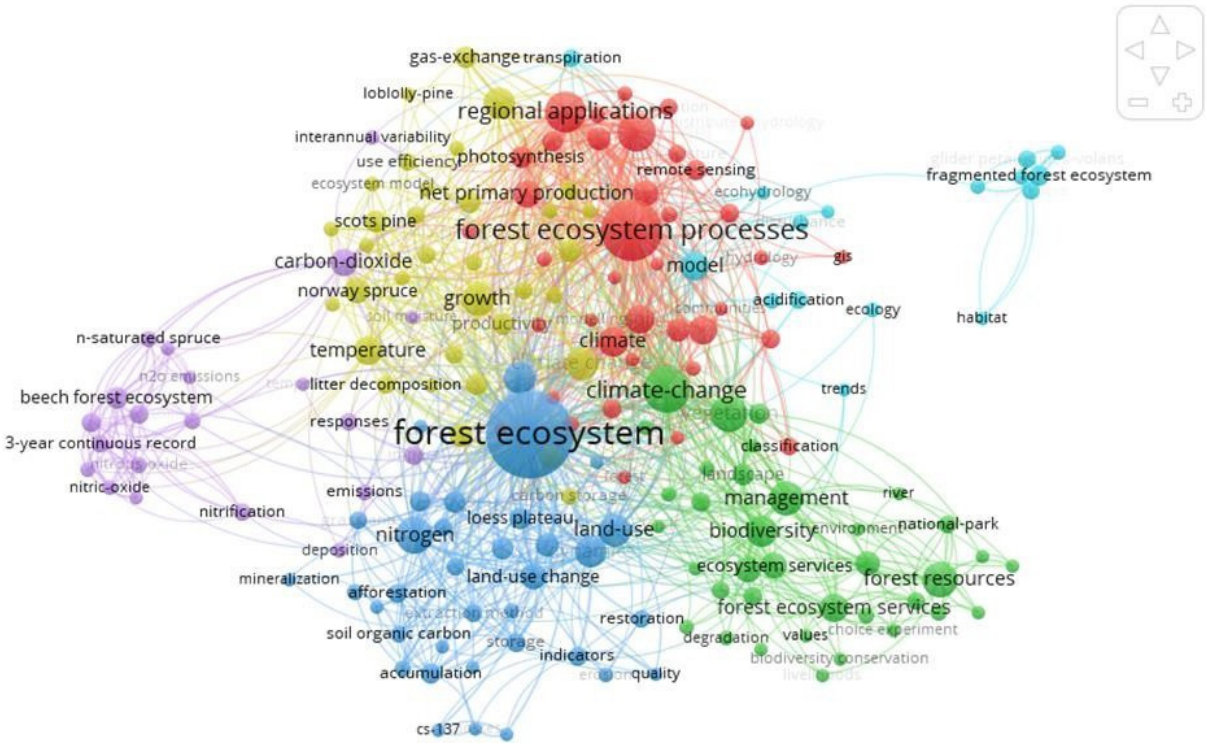

Figure 4. *Labeled bibliometric map with graphical visualization of KW+ using labeled nodes and thematic groupings*

Furthermore, specific filters were applied to account for the geographical context of the literature used as theoretical reference. This made it possible to obtain a more relevant perspective adapted to the reality of the different countries worldwide, with special attention to Latin America.

Selection Process

The selection process of the studies was carried out following the established inclusion criteria, which required the articles to be published in journals indexed in databases, in electronic format and in English or Spanish. The search covered the period from 2013 to 2023 and was based on previously defined keywords, which were fundamental for the identification of relevant studies according to the established criteria.

Data Collection Process

To extract, compile, and systematize the data, *Excel* was used to organize and classify the publications in a clear and orderly manner. The most relevant data from each study such as the year of publication, the author's name, the objective of the study, the study population, the methodology used, and the results obtained were summarized.

Synthesis Method

The research papers were analyzed according to their geographic classification: at the international, national, and regional levels. This enabled the researchers to define five contextual categories: 1) Europe, Asia, and Africa; 2) North and Central America; 3) South America; 4) Colombia; and 5) Santander (Colombia), in a local context. Figure 5 below shows a summary of the contextual categories and the number of studies included in the systematic review.

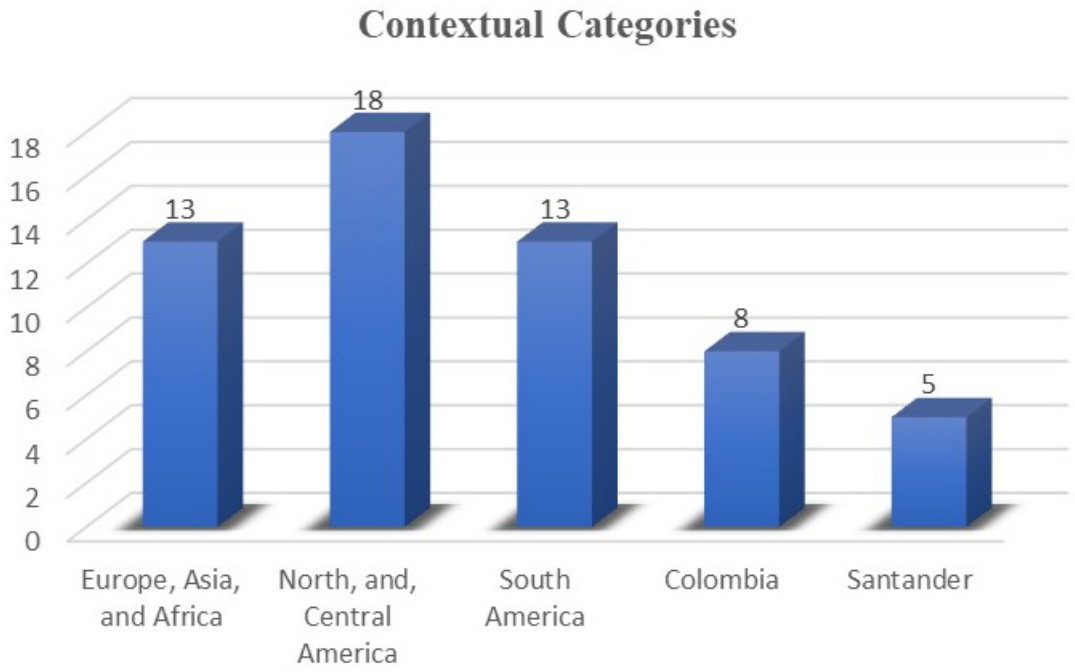

Figure 5. *Contextual synthesis of the research consulted for the systematic review*

RESULTS

Forest Environmental Improvement and Harvesting in Europe, Asia, and Africa

In the European context, Kimengsi *et al*. (2023), published a review article highlighting the work of government agencies in Europe. However, they point out the lack of comparative reviews at the global level that would improve understanding of how forest management institutions (FMIs) are conceptualized and the parameters used to assess their impact and compliance. Additionally, they mention the fragmentation of existing knowledge on methodological approaches that should be prioritized in the new MFI research agenda. In Finland, the choice experiment method was applied to investigate the potential participation of forest owners in an incentive scheme. Participants were invited to practice both timber and nature conservation-oriented management strategies. The results showed that most owners were willing to participate in a contract-based payment scheme, especially those supporting biodiversity and non-market ecosystem services (Juutinen *et al*., 2021).

In Italy, Agnoletti *et al*. (2022) emphasize a growing worldwide interest in the role of forests to tackle global warming and preserve biodiversity, suggesting the need to expand forest areas and improve their ecological integrity. However, their study on cultural values and forest dynamics in Italy over the last 150 years shows that, due to

rural abandonment, Italian forest areas have doubled since 1861. Therefore, there is no danger of deforestation, but rather an uncontrolled increase in forests, which implies that it is not necessary to promote more reforestation. Instead, the focus should aim at improving the management of existing forests. In central Sweden, Ekholm *et al*. (2022) evaluated the short-term impact of biomass production and biodiversity (vascular plants, bryophytes, wood-dwelling fungi) in individual trees, finding that unharvested stands have higher biodiversity than logged stands. They conclude that individual tree selection could become a useful tool for improving biodiversity in managed forests.

In Spain, Corral-Verdugo *et al*. (2019) presented research about the psychology around environmental conservation, exploring pro-environmental behavior. Similarly, Maki and Rothman (2017) analyzed people's pro-environmental intentions and behavior, highlighting that sustainable behavior (SC) refers to the set of actions aimed at ensuring the relationship between the present and future physical and social resources of the planet. In the Asian continent, Chen *et al.* (2019) developed a project on the evaluation and improvement of wetland environmental protection plans to achieve sustainable development. They proposed a comprehensive model for sustainable wetland protection, stressing that these plans are affected by various interrelated factors. Therefore, they propose a decision-making model to enhance the development of sustainable plans that consider people's comfort and safety, improving living standards and achieving human welfare expectations. In China, Jing *et al*. (2022) evaluated the spatial distribution patterns and temporal variations of ecosystem services and climatic factors in the Loess Plateau over a 20-year period. Their study enabled the generation of theoretical bases for effective planning of ecological restoration in the region and provided recommendations for its sustainable development. Yeo *et al.* (2016) identified one of the main problems faced by companies in driving environmental sustainability: lack of focus. To overcome this, they proposed a methodology based on eco-efficiency improvement (EEI), which helps companies to plan improvements in environmental sustainability.

In Bangladesh, Miah *et al*. (2023) document the multiple environmental problems that are not being addressed by government policies, resulting in increasing degradation year after year. They suggest converting unprotected forests into protected green forests to improve environmental conservation. In Angola, Gonzáles Días *et al.* (2016) recommend developing strategies to reduce waste generation in a galvanizing plant and minimize environmental impact. This would improve product quality and boost customer reliability, meeting the ISO 14000 requirements and leading to cleaner production. Nketia *et al.* (2022) in Ghana state that deforestation is one of the major environmental problems facing southern countries. In response, policy makers have launched various reforestation programs. A study of this program in Ghana assessed the prospects and challenges of reforestation involving 60 young people, showing great potential for restoring degraded forests, although these efforts face financial, logistical, and political challenges. Finally, Lwasa *et al.* (2014) in their study on temperature reduction and regulation in urban terrestrial microclimates state that many sustainable development initiatives seek to ensure a balance between man and nature, contributing significantly to global sustainability.

Environmental Improvement Plans and Strategies in North and Central America

Forest improvement and harvesting projects in Canada proposed by Bouchard *et al.* (2017) suggest a long-term integrated planning model that anticipates impacts on economic and logistical activities within the forest value chain. In the short term, an optimization approach was identified that includes acceleration strategies to solve

practical cases of integrated planning efficiently and at a large scale. Meanwhile, in Cuba, Leyva Fontes *et al.* (2016) present the "Green Map" as a proposal for environmental education and improvement at the local scale, facilitating communities to become drivers of sustainable development and promoting care and protection of the environment in their respective contexts.

Moreover, Chibás-Creag and Gómez-Martínez (2019) suggest redefining Botany education in Cuba from the perspective of environmental sustainability. The objective is for students to use their knowledge and skills to understand the challenges of unsustainability during their training and make decisions that respond to the needs of their communities, transforming them into multipliers of the need for sustainability. Regarding the conservation of white bark pine (*Pinus albicaulis* Engelm.), Tomback *et al.* (2022) analyze joint actions between Canada and the United States for its restoration, highlighting a set of measures such as genetic conservation, natural resistance enhancement, plant material collection, cultivation, and planting of seedlings or direct sowing of seeds, as well as seed protection. In addition, other silvicultural management activities in plantations, monitoring through stand health surveys, and monitoring of restoration impacts to implement adaptive management are also included.

In the United States, Haber *et al.* (2023) showed the potential of remotely sensed features, such as the normalized difference reflectance difference vegetation index (reNDVI), to be used as early indicators of forest functional change following disturbances. This constitutes a promising approach as spectral and hyperspectral data collection platforms become more accessible. The authors recommend that future studies concentrate on thoroughly characterizing the temporal dynamic mechanisms underpinning forest production resilience. In this context, Rodriguez Franco and Conje (2023) highlight the United States as a world leader in sustainable forest management, as it has managed to maintain a stable forest area despite population growth, and remains one of the leading producers of timber globally. These achievements are the result of the country's legislation, which preserves both public and private ownership, and a series of government programs that provide incentives, technical assistance, financial support, and tax relief to landowners who proactively implement responsible forestry practices.

In Mexico, several studies regarding the use of forest resources have been identified, understanding this activity as the management of resources to ensure biological diversity, regeneration capacity, productivity, and vitality, fulfilling ecological, social, and economic functions in an orderly manner. In this sense, Cervantes Salas (2018) exposes the historical mechanisms of production in the field of community forest conservation, characterized by the good management of local forests. On the other hand, Moctezuma López and Galicia Luis (2018) indicate that Mexico's forest areas are inhabited by approximately 12 million people, most of whom live in conditions of extreme poverty. These communities lack the necessary support to rationally use their resources, as training to develop skilled foresters is not adequately promoted, limiting their ability to improve their quality of life. Furthermore, limited knowledge and connection to forest resources underlies many forest management issues in the country. In this context, Santiago-García *et al.* (2020) note that the use and generation of models in Mexico has advanced significantly in recent years, resulting in the constant creation of biometric tools for the design, planning, implementation, and execution of forest management and harvesting programs.

In line with this, Martínez Gallegos (2021) emphasizes that sustainable development should be understood as a process built on three fundamental pillars: man, nature,

and the economy. Similarly, Tadeo-Noble *et al.* (2019) argue that timber harvesting can alter the ecological and dasonomic attributes of arboreal vegetation, affecting both biodiversity and ecosystem productivity. However, little is known about the effects these practices may have on tropical forests in Mexico. On the other hand, Sánchez-Vidaña *et al.* (2018) found that the ejido has made significant progress in the development of human capital competencies, especially in the management of scientific innovations. Regarding silviculture, Mendoza-Briseño *et al.* (2021) note that the peninsular silvicultural method (MSP) is designed to achieve greater capitalization of property value compared to conventional forest management methods used in Mexico. Ramírez *et al.* (2019) suggest that silvicultural practices tend to simplify forest structure and composition. In this sense, they propose a study to evaluate changes in tree structure, diversity, and dynamics in intervened mixed stands using the group selection (GS) and parent trees (PA) method. Similarly, Hernández-Moreno *et al.* (2020) state that forest management and silviculture, whose main objective is timber production, should also promote the conservation of forest ecosystems to ensure the sustainable production of goods and services for humanity.

In American, Benson *et al.* (2022) present a study on forest dynamics applied to the conservation, restoration, and management of small forests, mainly those of less than 50 hectares. They analyze 54 models to determine the degree of effectiveness and efficiency in meeting conservation objectives. They highlight that the SORTIE and FORMIND models obtained the best results and consider that these can be replicated in other contexts. Likewise, Valencia-Trejo *et al.* (2020) propose strategies for productive reconversion by changing from traditional ornamental production systems to more sustainable systems in Xaltepuxtla, Puebla. These strategies are based on producers' interests and the potential of the land units, and are aligned with the needs identified by the government of Puebla and its federal agencies.

In Costa Rica, Salas-Garita and Quesada-Monge (2022) evaluated natural forest management using a hierarchical scheme of Principles, Criteria, and Indicators of Sustainability (PCI). They quantified and validated a set of indicators to be used in retrospective sustainability assessment. The first step was the quantification of 30 sustainability indicators, selected from previous studies as suitable for this type of assessment. Out of these, a total of 25 indicators were validated, covering the ecosystemic, social, institutional, and economic dimensions on which sustainability is based.

Environmental Improvement Plans and Strategies in South America

In Uruguay, Traversa-Tejero & Alejano-Monge (2013) analyzed the tree composition, distribution and silvicultural management of forests in the Rivera region. This study was conducted due to the forests of northern Uruguay are undergoing processes of land transformation and degradation. In addition, there is little information on the composition and floristic structure of tree communities, which makes it difficult to study and understand their dynamics. The study reveals that all forests are vulnerable due to livestock practices, as there is no integrated forest management that considers the multifunctionality of uses such as livestock and forestry. In addition, forests near cities are more degraded due to the presence of exotic species.

Bannister *et al.* (2016) promote silvicultural practices as tools for temperate forest restoration in Chile. They indicate that, in the context of forest restoration, the main objective of silviculture is to increase biodiversity and the level of structural complexity in degraded adult forests, secondary forests, burned forests, and plantations, to improve

their ecological functionality. On the other hand, Carter Gamberini *et al.* (2019) highlight the contributions and challenges of the Environmental Impact Assessment System (SEIA) in biodiversity conservation in Chile. They point out that SEIAs are preventive environmental management instruments whose main purpose is to incorporate environmental considerations into the activities and processes that accompany the country's economic growth. In this sense, their application in biodiversity conservation is essential, as they make it possible to identify and evaluate the possible environmental impacts of these activities to define actions toward remediation, compensation or mitigation.

In Argentina, Loto and Bravo (2020) analyzed the species composition, structure, and functional traits of plants in two forests of the semi-arid Argentinean Chaco, both with different land uses in the last three decades: a protected area and an experimental area with land management practices. The results showed that the average diameter and height of plants decreased in the experimental area compared to the protected area. In the protected area, species with shrubby growth, leathery leaves, absence of thorns and low shoots predominated, while in the experimental area, subshrubs, thorns, and high shoots predominated. On the other hand, Deon (2021) studied collective narratives in socio-environmental struggles in Argentina related to ecological disasters that have displaced approximately 95,000 people between 2010 and 2020. He demonstrates how the developmentalist complex, in its advanced colonialist form, continues with deforestation, fumigation, and displacement affecting social minorities. The study concludes that forest and forest life defense, driven by socio- environmental assemblies, undermines agribusiness, metalliferous mega-mining, quarrying and real estate development in Argentina. Politi and Rivera (2019) point out that it is necessary to establish economic compensation to improve the profitability of the forest, by promoting harvesting practices towards sustainable forest management, where the various ecosystem services offered by the southern Yungas are recognized and paid for.

In Brazil, Pashkevich *et al.* (2022) conducted a review on the ecological restoration of tropical agroecosystems through the application of nine strategies, maximizing the benefits of these actions for ecosystem conservation. Successful case studies from around the world support these strategies. Hernández (2015) mentions that the binary integer programming-based approach considers different scenarios modeled from real cases. This model considers several factors, such as: resource constraints, forest plantation characteristics, and market demands, among others. Regarding this, Molina Pereira (2019) proposes reforestation as an environmental strategy for the conservation of streams and rivers, arguing that, given the effects of climate change, it is essential to maintain natural resources such as water, air, and soil, in good condition. Through several reforestation days, 250 bamboo (*Guadua angustifolia* Kunth) plants were planted, applying strategies for biodiversity conservation and promoting responsibility and social commitment for the environmental balance of present and future generations. Similarly, Mendoza (2017) implemented a reforestation proposal with *Mijao* to strengthen biodiversity in the San Pedro ravine sector in Barinas, noting that reforestation is only one of the multiple practices oriented towards conservation and responsible land use, being even more important to ensure the protection and management of existing forests and groves. Boccolini *et al.* (2019) states that cover crops (CC) represent a potential practice to reduce herbicide use and its environmental impact. Additionally, by increasing crop yields and controlling weeds, CCs increase microbial biomass and improve soil activity through the addition of organic residues.

In Peru, Avalos Ortecho (2018) outlines a model to improve copper production

more cleanly, considering that the mining sector has caused significant environmental impact since the 1980s affecting water, air, and large areas of flora and fauna due to a lack of environmental regulation. The Avalos model promotes the adoption of clean technologies, proper waste management, constant environmental monitoring, participation of local communities and strengthening of environmental regulation. These actions will allow to move towards a more responsible and environmentally friendly mining sector.

Finally, in Chile, Tricallotis (2023) compares "old" and "new" policies for sustainable forest management (SFM), highlighting that both are important, as they complement each other. The classic policies are marked by the predominance of state actors, while the new ones are grouped under the concepts of corporate social responsibility (CSR) and industrial self- regulation (ISR), which are community-oriented and easy to apply.

Environmental Improvement Plans and Strategies in Colombia

Palomeque and Hinestroza (2016) analyze agreements between third parties and Afro-Colombian communities for forest use and harvesting in Chocó (Colombia), highlighting that these agreements are legal and covered by Law 70 of 1993. Nevertheless, these territories are affected by an irrational use of forest resources and the lack of training. Moreover, the implementation of specific programs in this area forces communities to form partnerships with third parties. This is due to the scarcity of resources, machinery, and trained personnel to develop forest management plans, which further aggravates inequality and poverty in the region. Córdoba-Moreno *et al.* (2017) point out that forest harvesting not only impacts the territories of Afro-Colombian communities but also indigenous reserves. In addition, they emphasize that forests in Colombia are underutilized and, at the same time, irrationally exploited.

In another area, Carmona-García *et al.* (2017) present a study on environmental management, sustainability and mining competitiveness, based on the premise that mining is an economically beneficial activity, carried out in a large part of the Colombian territory, with a total area of 4,485,910 (ha) granted for the exploration and exploitation of mining resources. The mining industry has proposed incorporating elements of "sustainability" in its operations, seeing them as contributions to sustainable development. It is mentioned that environmental management, understood as a factor leading to competitiveness, has been implemented especially in those mining processes where its use generates an added value to the final product.

On the other hand, Arroyave-Puerta and Marulanda-Valencia (2019) explore the relationship between the creation of sustainable businesses, environmental care and the generation of social and economic value through the evaluation of the "Entrepreneurship for Life" program, which promotes green businesses in the Aburrá Valley, Colombia. In line with this approach, Cañola *et al.* (2021) consider that the construction sector is a fundamental pillar for the country's economy and development. However, this sector, which has experienced accelerated growth in recent years, also generates a large amount of solid waste, which is deposited in open or improperly managed landfills, representing a serious environmental problem for the surrounding community.

Similarly, Chacón Páez *et al.* (2016) conducted a study aimed at exploring the use of carbon footprinting (CoC) as a tool for brand building in companies in Colombia. Their research concludes that branding and green marketing represent an opportunity to position companies with CoC practices. In addition, Rodríguez Robayo *et al.* (2021) identify the absence of a comprehensive analysis of the relationship between nature,

society and socioecological conflicts in the territory, pointing out disputes related to fish farming, tourism and onion production as livelihoods in the region. They also emphasize the influence of water resources as an essential pillar for the local economy. This highlights the need to incorporate an integrated approach in institutional dynamics to reorient natural resource management strategies, seeking to balance conservation and production objectives in the watershed.

Finally, Escobar *et al.* (2021) present an investigation on ecological restoration in plantations of pino *(Pinus patula* Schltdl & Cham), based on four restorative actions. They conclude that the elimination of post-harvest residues of *P. patula* is key to the natural regeneration of moorlands affected by exotic forest plantations.

Plans and Strategies for Environmental Improvement in Santander - Colombia

Numerous projects have been carried out in recent years in Santander that reflect the interest in implementing environmental improvement plans and a more sustainable utilization of resources in different sectors and levels of the region. This is exemplified in the work undertaken by Ordoñez-Díaz and Rueda-Quiñónez (2017), who evaluated the socio- environmental impacts of panela (low-grade brown sugar) production in Santander. Although the transformation of sugarcane juice into panela is mainly carried out in an artisanal manner in sugar mills, constituting an important source of employment for peasant families, this activity also generates significant environmental impacts, such as contamination of water resources, alterations in atmospheric composition, and modifications of the microclimate. Similarly, Duarte Hernández and Avella Muñoz (2019) analyzed a restoration project led by the environmental authorities of Santander, focusing on the integration of fundamental socioecological aspects. The authors stress the importance of identifying both positive aspects and areas for improvement, concluding that proper planning in the propagation phase of vegetative material is essential, as well as the selection of species relevant to local communities.

On the other hand, Rojas-Molina *et al.* (2021) conducted a study on the decomposition and release of nutrients in cocoa (*Theobroma cacao L*.) pruning biomass in Rionegro, Santander. Their research revealed that the biomass generated by cocoa pruning acts as an important nutrient sink, with leaves and branches providing short-term nutrients, while primary and secondary branches have a slower release process, favoring long-term nutrient storage in the system. From a conservation perspective, Castillo-Figueroa *et al.* (2019) conducted a study focused on environmental education and rural communities' knowledge of the Andean Condor in the Almorzadero moorland (Santander). This study highlights the importance of developing educational activities and training for all community members, evaluating the effectiveness of environmental education strategies and linking local knowledge to promote the conservation of this emblematic species.

Finally, Camargo-Espitia *et al.* (2019) undertook a study on the composition and structure of a sub-Andean forest fragment in the municipality of Bolívar, affected by agricultural expansion, deforestation, and habitat loss. This study revealed the importance of high Andean, Andean, and sub-Andean forests, which have particular water dynamics due to fog and wind-borne rain, contributing to the water balance of the system. Consequently, the study raises awareness of the urgent need to conserve these ecosystems, which play a crucial role in the region's water regulation.

DISCUSSION

In the international context, in regions such as Europe, Asia, and Africa, several projects have been developed that show a high interest in improving environmental processes. In Asia and Africa, there are initiatives focused on the evaluation and improvement of environmental protection plans, seeking to improve standards of comfort, safety, and human wellbeing. Meanwhile, in Central America, countries such as Cuba and Mexico have promoted studies related to the responsible use of forest resources, promoting their management to guarantee biodiversity and fulfill their ecological, economic, and social functions. In South America, Uruguay, Chile, Argentina, Venezuela, Peru, and Colombia also have a community of leaders committed to environmental protection, working actively in various areas to promote sustainable socio-environmental processes.

In Colombia, numerous studies document the underutilization and irrational exploitation of forests, despite the country's abundant natural wealth. However, at the local level, especially in Santander, there is evidence of projects and initiatives that show a solid commitment to the implementation of environmental improvement plans and sustainable practices, aiming at a positive transformation in the different sectors and levels of the region.

In essence, the research findings suggest that, although there is a wide variety of methodologies and theoretical approaches in forest management plans, there is evidence of a gradual convergence toward sustainable management models that integrate various dimensions, such as ecological, social, and economic, without overlooking the challenges related to the standardization of processes and the evaluation of results, which may be available to researchers and environmental policy planners for the use of natural resources at the global level.

CONCLUSIONS

Based on this analysis, it is estimated that deforestation and the expansion of agricultural frontiers are some of the main causes of environmental and productive impacts in several countries. Similarly, poor planning in the forestry sector, marked by the practice of illegal logging, led to the development of strategies for responsible harvesting.

On the other hand, key factors for environmental protection include: carbon dioxide sequestration, watershed protection, erosion prevention, slope stabilization and the incorporation of forest by-products into conservation processes. These aspects are essential for forest management that not only cares for the environment but also promotes economic sustainability.

Thus, the objective of environmental planning in forest harvesting is to ensure environmentally safe product extraction in the areas where these projects are implemented. The development of adequate management plans in the various stages of natural resource extraction or industrial activities contributes to improving both the environment and production methods, always complying with the regulations applicable to this sector, which makes planning indispensable in any type of harvesting.

AUTHOR CONTRIBUTIONS

Conceptualization, J.P.D.M. and D.H.G.; Methodology, J.P.D.M. and D.H.G; Software, J.P.D.M.; Validation J.P.D.M. and D.H.G.; Formal Analysis, J.P.D.M. and D.H.G.; Investigation, J.P.D.M.; Resources, J.P.D.M. and D.H.G; Data Curation, J.P.D.M.; Writing—Original Draft Preparation, J.P.D.M. and D.H.G.; Writing—Review & Editing, J.P.D.M. and D.H.G.; Visualization, J.P.D.M.; Supervision, J.P.D.M.; Project Administration, J.P.D.M.; Funding Acquisition, J.P.D.M.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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