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REVIEWS

Protection measures for the Araucaria Forest and their efficiency in the conservation of *Araucaria angustifolia* in southern Brazil

Medidas de protección del Bosque de Araucaria y su eficiencia en la conservación de *Araucaria angustifolia* en el sur de Brasil

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ABSTRACT

Forests require sustainable management because of the long cycle of the species, the balance of the ecosystem, the structure or processes on which the species depend, and socioeconomic development. This study shows the effect of adopting protection measures (non-management and conservation) and their results on the forest structure of a Mixed Ombrophylous Forest, specifically for *Araucaria angustifolia* available in official publications and scientific articles. Bibliometric analysis was used to obtain and evaluate scientific publications based on their statistical methods, forest inventory techniques, modeling and, which contributed valuable information and scientific impact on the development of the topic. We argue that there are uncertainties about the threat of extinction and that lack of management may increase the disregard for forest resources. The losses of ecosystem services, economic structure, diversity, reproduction, and production of the forest due to non-use of resources are larger than the benefits.The results indicate the need for sustainable forest management as a public policy for the conservation of the species and the Mixed Ombrophilous Forest in southern Brazil.

Keywords: mixed ombrophilous forest, araucaria, multiple use, forest stability, species dynamics.

RESUMEN

Los bosques requieren un manejo sostenible debido al largo ciclo de las especies, por el equilibrio del ecosistema, por la estructura o procesos de los que dependen las especies y por el desarrollo socioeconómico. Este estudio muestra el efecto de la adopción de medidas de protección (no manejado, conservación) y sus resultados para la estructura del Bosque Ombrófilo Mixto, específicamente para *Araucaria angustifolia* disponibles en publicaciones oficiales y artículos científicos. La metodología utilizada fue el análisis bibliométrico, para obtener y evaluar publicaciones científicas con base en sus métodos estadísticos, técnicas de inventario forestal, modelación y que aportaron información valiosa, impacto científico en el desarrollo del tema. Sostenemos que existen incertidumbres sobre la amenaza de extinción y que la falta de gestión puede aumentar la falta de interés en los recursos forestales. La explotación excesiva de semillas comestibles puede desestabilizar la dinámica y regeneración de la especie *A. angustifolia*. Las pérdidas ecosistémicas, económicas, de estructura, diversidad, reproducción y producción de las masas forestales por la no utilización de los recursos son mayores que los beneficios. Los resultados indicaron la necesidad del manejo forestal sostenible como política pública para la conservación de la especie y del Bosque Mixto Ombrófilo en el sur de Brasil.

Palabras clave: bosque ombrófilo mixto, araucaria, uso múltiple, estabilidad forestal, dinámica de especies.

INTRODUCTION

Notwithstanding the Brazilian Forest Code, issued in 1934, and other temporary regulations, forest management techniques have never been applied to the use of Mixed Ombrophilous Forest (MOF) resources, and irrational exploitation has been permitted (without scientific basis for growth [diameter, cm year^{-1}, basal area, m² ha year^{-1}, volume, m³ ha year^{-1}], age, cutting cycle, technical rotation, etc.) for economic, agricultural, and urban expansion purposes. Historically, the MOF has been used in response to society's needs, exploring the economic potential of *Araucaria angustifolia* (Bertol.) Kuntze, a target of intense exploitation due to the erroneous mentality

regarding its large abundance in the forests of southern Brazil (Ribeiro *et al*. 2009).

In the 1990s, the Brundtland report (Our Common Future), conferences such as the Eco92, world panels, seminars, and agreements on sustainable development recognized natural resources as exhaustible (Hess 2011), bringing about social and economic changes in forest management practices and policies (Curtis *et al.* 1998). Brazil chose the restrictive and exhaustive bureaucracy of laws (Eisfeld *et al.* 2019), disallowing the use of forest resources or the use of licensing without scientific basis and, ineffective for sustainability.

Such changes in mentality and training in the approach to forest resources are the object of our study, since according to Curtis *et al.* (1998), differences in background and experience often result in communication difficulties, misconceptions, and misunderstandings that are not always recognized. Studies on mixed forest management suggest that systematic analysis should be conducted with as many different tree species mixtures as possible. Recent research has revealed that mixed species stands may be more stable amidst biotic or abiotic disturbances (Jactel and Brocherhoff 2007, Bauhus *et al*. 2017, del Río *et al.* 2017); more resilient after damage (Pretzsch *et al.* 2013a, Pretzsch *et al*. 2013b, Metz *et al.* 2016); more productive due to reduced or facilitated competition (Liang *et al.* 2016, Jactel *et al.* 2018); and may provide a broader supply of ecological and socioeconomic services (Gamfeldt *et al.* 2013, Griess *et al.* 2013, Biber *et al*. 2015, Felton *et al*. 2016, Heinrichs *et al*. 2019).

Systematic choices such as the path of legislation and the inclusion of *A. angustifolia* on the list of critically endangered species (without conducting a study, as proposed by the International Union for Conservation of Nature (IUCN)), not approval of management plans, restricting actions for their conservation, preservation, and use of new technologies, mainly due to the lack of interest in Araucaria Forest. Three decades of such decisions have led to greater damage to ecosystems than benefits. According to Bergseng *et al.* (2018), increased protection of forest biodiversity implies reduced income from timber production for both society and forest owners, and consistent analysis of the relationships between biodiversity benefits and corresponding costs is important for both forest managers and policymakers.

Given this scenario, this study investigates whether 1) forestry legislation was efficient for conserving the MOF and *A. angustifolia*; 2) there were benefits or damages to the dynamics of the forest and society; and 3) what risks this rigidity in the legislation posed to the remaining MOF. The objective of this study was to evaluate the scientific and legal framework for the management of conservation of the Araucaria Forest ecosystem, specifically for *A. angustifolia* using information and results available in online publications from official websites and scientific papers, pointing out inconsistencies in the legislation and whether there were benefits or damages to the structure, diversity, and stability of Araucaria Forest and *A. angustifolia* in southern Brazil.

METHODS

- ***Technique of the study and forest cover*.** This is an applied, qualitative, quantitative, diagnostic, inductive, and exploratory study. The research hypotheses were verified by analyzing the forest cover, of the legislation related to forest management and scientific papers on conservation, benefits, or losses in how MOF resources are managed in Santa Catarina State, Brazil. The study may seem to be concentrated in one state and the review is specific to a species; however, its greater occurrence is in three states in southern Brazil, thus justifying the importance, consequences, and magnitude of the study. It also occurs in São Paulo and Minas Gerais but to a lesser extent.

Forest cover data from Santa Catarina (Southern Brazil) were collected from Collection 05 of the Annual Mapping of Land Cover and Land Use Project in Brazil, MapBiomas (figure 1). MapBiomas provides information on land cover and use from 1985 to the present day, with all maps produced using Landsat satellite imagery (Souza *et al.* 2020). This platform provides information on land cover and use from 1985 to 2019, and all maps were produced using Landsat® satellite imagery (MapBiomas 2019).

Data from the National Forest Inventory – Santa Catarina (NFI), published in 2018 by the Brazilian Forest Service (SFB), and the Santa Catarina Forest Inventory (cycles 2007 – 2011) were also used. These databases were used to obtain variables related to dendrometry measurements of the species *A. angustifolia* in the Araucaria Forest, as well as the degree of forest cover in the state, to determine whether or not the legislation has benefited the MOF and araucaria species, and to calculate the density of trees for the total coverage area in the state of Santa Catarina.

- ***Legislation and scientific papers on forest management and the araucaria species*.** The literature review on forestry legislation and management comprised publications obtained from the Scopus©, Elsevier© Scientific Electronic Library Online SciELO®, Brazil, Researchgate®, periodic CAPES, Google Scholar, and National Council for Research and Graduate Studies in Law (CONPEDI) databases, and legislation, such as organic laws, decrees, regulations, federal, state, or municipal normative instructions, and the Federal Constitution. VosViewer© software was used to build and visualize bibliometric networks, inclu-

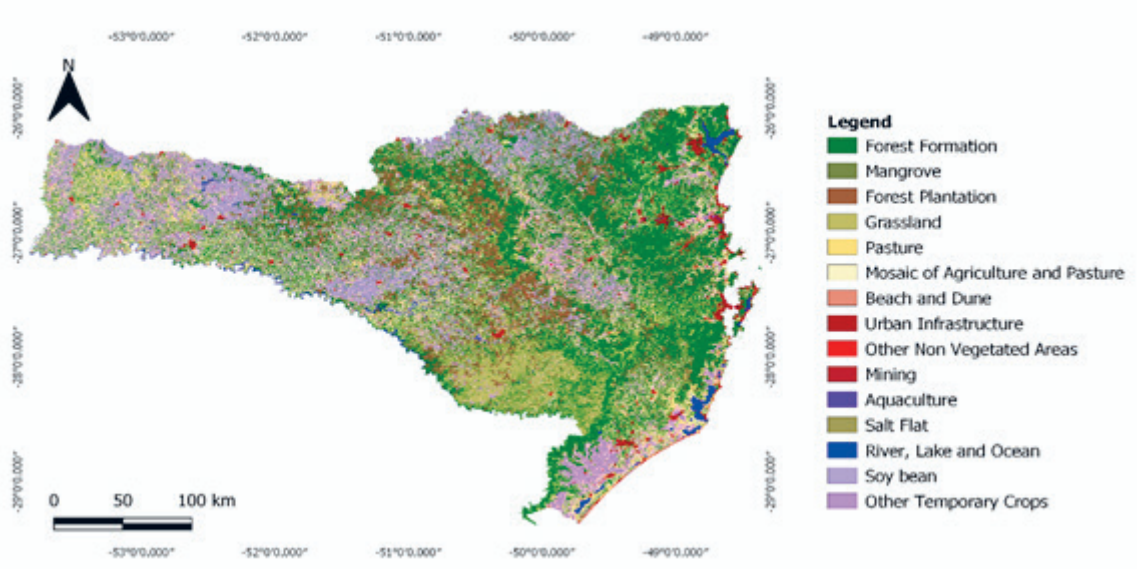

Figure 1. Forest and other land use cover in Santa Catarina state (2019). Source: Vibrans *et al.* 2021.

Cobertura forestal y de otros usos del suelo en el estado de Santa Catarina (2019). Fuente: Vibrans *et al.* 2021.

ding publications and individual researchers on the topic of study in citation relationships, bibliographic coupling, co-citation, or co-authorship.

The search strategy included the following keywords: *Araucaria angustifolia*; Araucaria Forest, mixed rainforest, sustainable exploration, sustainable management, forest management, Atlantic Forest, IUCN red list, IUCN criteria, preservation, conservation and sustainable management, araucaria extinction, environmental legislation, forest legislation, forest legislation evolution, forest code, and Mixed Ombrophilous Forest.

Economic, sociocultural, environmental, dynamic, forest structure, and forest ecosystem criteria were used to evaluate the literature, as well as their relationship to araucaria management. The statistical criteria included descriptive statistics, regression, and multivariate analyses.

RESULTS

- **What about of the forest cover?** Located in southern Brazil, Santa Catarina has an area of 95,738 km². Its forests cover approximately 38 % of the territory (Vibrans *et al.* 2021). MOF is the predominant typology in areas classified as forest, representing approximately 33,91 % of the forest area in the state (1,89 million hectares) (MapBiomas 2019).

To illustrate one of our research topics, according to the Santa Catarina Forest Inventory, coverage with MOF remnants at the top of the mountain (municipality of Lages) have a forest cover of 32 %, comprising native and planted forests. Thus, native forest represents a total of 327,000 ha. An average of 300 araucaria trees per ha (with some sites having more than 500 trees ha^{-1}) (Hess *et al.* 2010b, Silveira *et al.* 2018, Costa *et al.* 2018c, Costa *et al.* 2020a, Souza *et al.* 2020), this represents a total of 98 million araucaria trees over 10 cm in diameter, which does not meet the IUCN criteria for listing as an endangered species. Conversely, the MOF cover in Santa Catarina totals 1.89 million hectares, which is equivalent to a total of 567 million trees; that is, with this number of trees, it can be considered a threatened species based on the IUCN criteria?

- **Legislation on MOF management.** As for environmental protection, according to Roriz and Fearnside (2012), when the 1988 Constitution of the Federative Republic of Brazil was enacted, "the environment received specific protection as a result of the evolution of environmental awareness." According to the Constitution, everyone has the right to an ecologically balanced environment, as a common good, imposing the duty to defend and preserve Public Power and society for present and future generations (Jordace 2016).

Ordinance no. 443 of December 17, 2014, from the Ministry of Environment (MMA) listed the endangered species of Brazilian flora (Official National List of Endangered Flora Species), published in Annex I of the document. Article 2 names fully protected species classified as Extinct in Nature, Critically Endangered, Endangered, and Vulnerable; that is, those prohibited from being collected,

cut, transported, stored, handled, processed, and commercialized (Brasil 2008).

According to Eisfeldt *et al.* (2019), the list of endangered species is elaborated with based in technical-scientific reports and studies, promoting activities to conserve these species in situ. This attribution was passed to the Rio de Janeiro Botanical Garden by means of Article 7 of Decree no. 43 of the Ministry of Environment on January 31, 2014 (CONSEMA 2014). However, this assessment is currently carried out by the National Flora Center (CNCFlora), which assesses the conservation status of the species and supports the periodic update of the Official National List of Endangered Brazilian Flora Species (Brazil 2014a), adopting the methodology of the IUCN. First, there are no technical or scientific reports that list the species, but IUCN methodology was adopted. Second, a team of experts outside the board is handed over, in this case, to CNCFlora, a fact not foreseen by law, to subsidize the list of endangered species (Eisfeldt *et al.* 2019).

According to Eisfeldt *et al.* (2019), after more than two decades of suspended management plans and the use of MOF resources, the situation remains worrisome, with a reduced natural and planted area, lack of natural regeneration, divorce between the producer and the species, elimination of regeneration by landowners, and economic disinterest in the species.

- **What about scientific literature and the MOF structure?** Research results show that scientists are interested in the sustainable management of araucaria (figure 2), whereas other topics appear in a smaller amount of research. Figure 2 clearly indicates three large groups of keywords that determine the main research linked to the area of knowledge for the Araucaria species. The largest group (red) deals with forest management, araucaria, endangered species, mapping, and so on. This was followed by the blue and purple groups and themes such as biomass, southern Brazil, other genera of the species, climate, and forest soils. As it is a specific species from southern Brazil, there are a greater number of national authors, at the same time, the main reference is forest management (figure 2), and the sustainable use and conservation of Araucaria Forest is of social, economic and scientific interest.

Figure 3 shows the main authors and their connectivity in terms of scientific publications referring to research carried out in sustainable forest management, araucaria, and related areas. The size of the circle reflects the number of articles published, while the line between the circles shows the relationships between the authors, the distan-

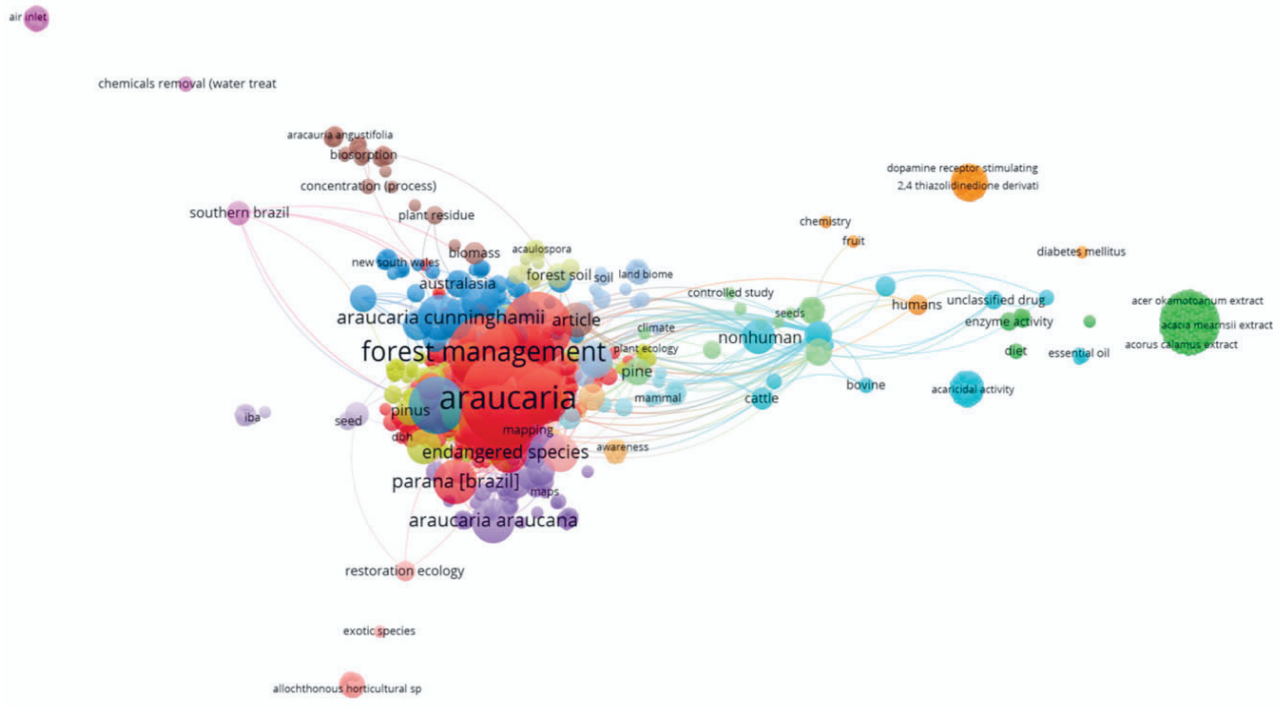

Figure 2. The main themes of research conducted on the management of the species *Araucaria angustifolia* and its connection with other areas and research focuses.

Los principales temas de investigación realizados sobre el manejo de la especie *Araucaria angustifolia* y su vinculación con otras áreas y focos de investigación.

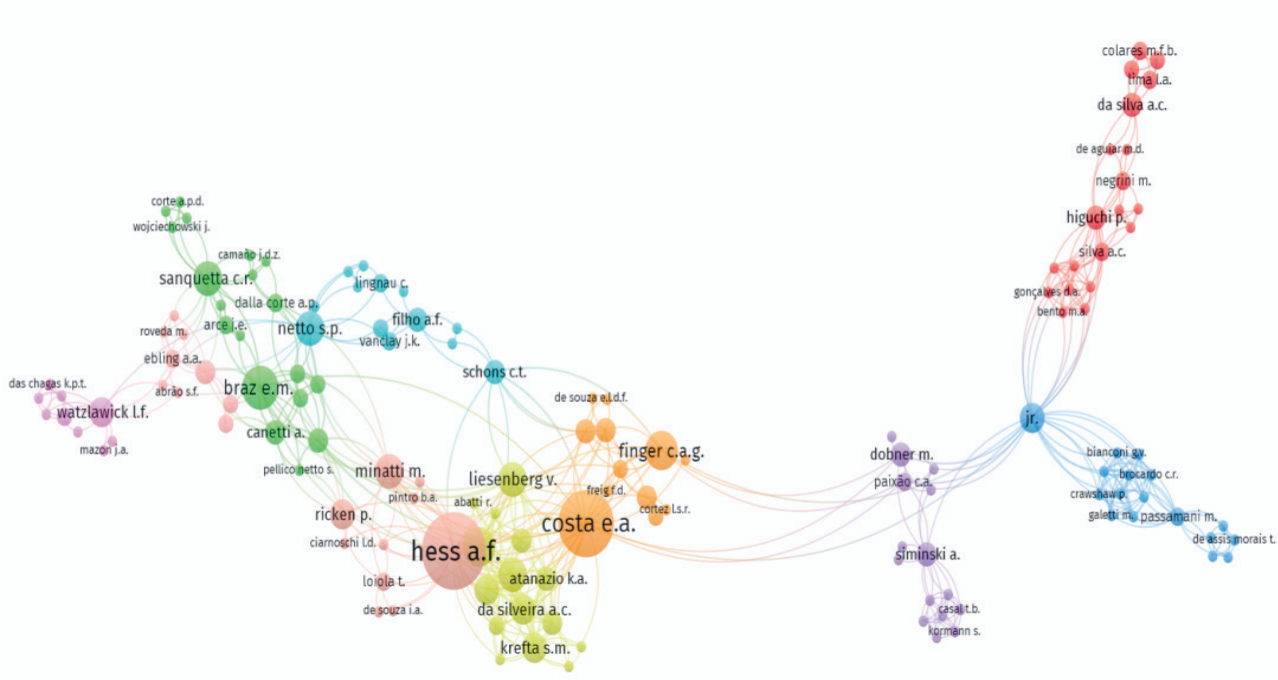

Figure 3. Connectivity between the main authors and researchers with the aim of managing and conserving the species *Araucaria angustifolia* and forest with araucaria.

Conectividad entre los principales autores e investigadores con el objetivo del manejo y conservación de la especie *Araucaria angustifolia* y bosque con araucaria.

ce between them, and the frequency of their interactions. The results indicated 10 groups of authors, three of which showed a higher frequency of cooperation in publications.

As such, many papers point out the importance of MOF management in southern Brazil, such as, Borsoi 2004 (application of management regimes), Hess *et al.* 2009, Hess *et al.* 2010ab, Mattos *et al.* 2010, Hess 2012 (increment, growth and management regimes), Sevegnani et al. 2013 (management), Beckert *et al.* 2014 (growth, natural regeneration, structure), Curto *et al.* 2014 (growth, competition, management), Canetti *et al.* 2014 (growth, competition), Hess et al. 2014, Costa et al. 2015ab, Canetti *et al.* 2016, Costa et al. 2016abc, Hess *et al.* 2016, Minatti *et al.* 2016, Costa *et al*. 2017ab, Klein *et al.* 2017 (increment, growth, competition, modeling, morphometry, management), Orellana *et al.* 2017 (management), Costa 2018abc, Hess *et al.* 2018abcde, Longhi *et al.* 2018, Orellana *et al.* 2018 (density management diagrams, management regimes, taper function, competition, crown efficiency, morphometry, modeling), Ricken *et al.* 2018(increment), Roik *et al.* 2018 (increment), Silveira *et al*. 2018 (management regimes), Hess *et al.* 2019 (crown efficiency, pine cones), Lambrecth *et al.* 2019 (competition), Costa *et al.* 2020ab (modeling, production, management), Hess *et al.* 2020 (modeling, morphometry, management), Ricken *et al.* 2020 (morphometry), Curto *et al*. 2021 (growth), Hess *et al.* 2021 (forest structure pattern), Silveira *et al.* 2021 (morphometry, density, crown, space availability), Stepka *et al.* 2021(increment, growth), Atanazio *et al.* 2022 (pine cones, morphometry), Costa *et al.* 2022ab, Demétrio *et al.* 2022 (male strobili, morphometry, crown effiiency), Mattos *et al.* 2022 (management, increment), Finger *et al.* 2023 (management, basal area, morphometry). Highlights of published studies can be presented for ecosystem processes and commitments to the future conservation of the species and the Araucaria Forest (table 1).

These studies investigated dendrometric and morphometric variables, crown efficiency, increment, growth, age, competition indices, application of management regimes, production of reproductive structures, and adjusted functions related to these variables. The studies recommended the need for management for future conservation of the species and the importance of changing the conservation status for the implementation of a landscape management proposal based on economic and ecological goals. The contributions of each author were related to the application of a management regime with a reduction in basal area, studies of increment/growth/productivity, competition of the Araucaria species and relationship with dendrometry and morphometric variables, morphometry and silvicultural intervention, quantification of cones and male strobili and its relationship with morphometric variables, tapering function, application of management re-

Table 1. Information on processes/factors and commitments to the conservation of the species *Araucaria angustifolia* in Mixed Ombrophylous Forest under an unmanaged regime.

Información sobre procesos/factores y compromisos para la conservación de la especie *Araucaria angustifolia* en Bosque Mixto Ombrófilo bajo régimen no manejado.

Process	Description	Commitment
Growth	Lower rate of increment in trees of the largest and smallest diameter classes and competition	Formation of a continuous horizontal and vertical structure
	A large number of trees have reached biological rotation, or technical rotation	Growth stagnation - competition - changes in the distribution pattern of diameter classes - unbalanced forest
	The average increment in diameter over the last ten years shows a loss of growth capacity of between 40 and 70 % (according to given diameter class)	Competition, loss of productive capacity, socioeconomic and environmental damage to the diversity and structure of the forest
	Reduction in basal area by 20 % there was an increase in the rate of increase for species	Without intervention compromises diversity, growth rate, structure and productivity
Productivity	The mean annual increment in diameter shows variability - values between 0.15 year^{-1} to 0.9 year^{-1}	Loss of productive capacity, lack of incentives for forestry of the species, lack of use of the resource with a rapid cutting cycle, socioeconomic damage
	The dynamics of the diametric structure in an Araucaria Forest during 4 years of evaluation decreased by 18.82 % in the number of trees in the smallest diameter classes (12.5 cm), while the 22.5 to 67.5 cm classes kept the number of trees stable	
Dynamics	Non-intervention regime produces a regular forest, a form of normal distribution in several sites in southern Brazil.	Commitment to the natural regeneration of the species and maintenance of the only source of income for rural owners (edible seeds), food maintenance for fauna
	The physiological and reproductive structure of the species, female strobili male strobili is extremely dependent on the development of the crown, density, age and silvicultural intervention	
Diversity	For a period of 18 years without intervention there was a loss of eight species of use value in the structure of the forest	Reduced diversity, compromised biodiversity, risk of extinction, economic and cultural loss

gime based on the De Lioucort quotient, and operational research. Studies involving the science of forest management.

All studies indicate a commitment to the development of forest structures (figure 4) with larger diameter trees in the future, even after a silvicultural intervention. The left side of figure 4 shows the current conditions of Araucaria species in the MOF, competition, unbalanced structure, dominance, concentration of trees in the 30-60 cm diameter classes, small regeneration, and reduced growth. The results of forest measurement once modeled indicate, as in the figure 4, that this information generates the necessary knowledge for managing the species and guarantees the future structure of the forest, natural regeneration and increase in growth rate (right side of the figure 4).

Finger *et al.* (2023) accentuated the significant implications of the lack of forest management initiatives in rural properties, potentially resulting in irreversible deterioration. The exact consequences of this deterioration remain unclear, emphasizing the need for further studies to better understand its effects on the growth of trees of different diameters, sizes, ages, and crown conditions after their release through the application of sustainable forest management.

The application of operational research (Souza *et al.* 2019) demonstrated that Liocourt's q' value of 1.3 and a cutting cycle of 25 years maximized the objective function in US$ 41,700 (currently economic loss) and presented socioeconomic and forest structure and dynamics performance. Another study indicated an economic loss for a rural owner with 84 ha of forest, and total of 330 trees ha^{-1}, with attributing the cut based on the De Liocourt quotient (removing 10 % of the number of trees would represent a total of 63 m³ ha^{-1}, which represents 5,292 m³. Considering the gross m³ value (standing tree) of US$ 71.87, it represents an economic loss of US$ 380,328.5, dividing this value in a 20-year cycle, represents US$ 19,016.4 year^{-1} (Silveira *et al.* 2018). Studies on MOF have shown that polycyclic models with a reduction of up to 20 % of the basal area favor the growth of remaining species and increase in diversity, natural regeneration, stability, and productivity of the forest (Longhi *et al.* 2018).

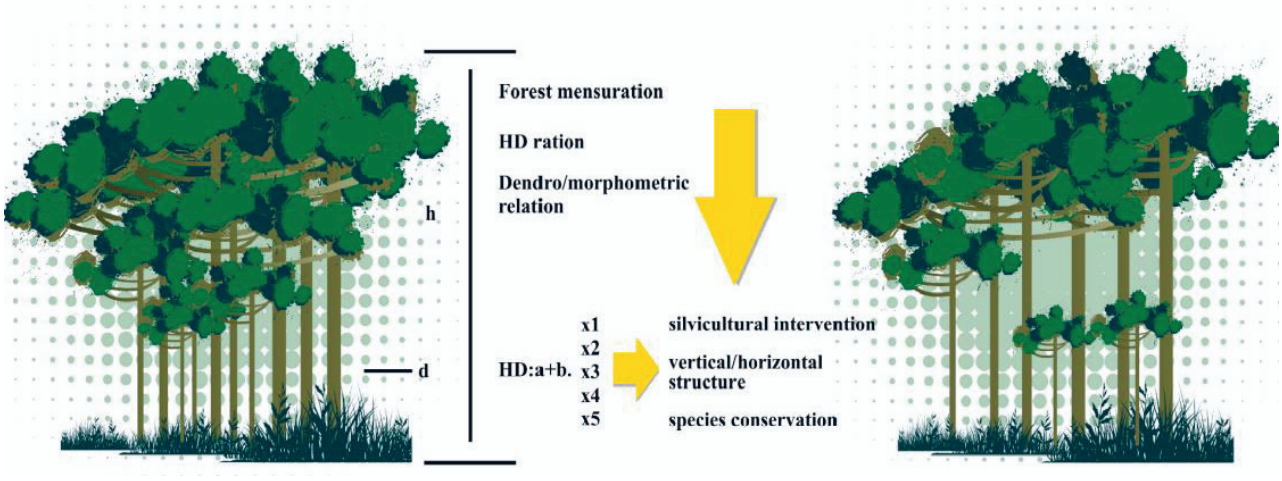

Figure 4. Illustrative representation of a simulation of a management regime with silvicultural intervention for the conservation of the structure, species and araucaria forest.

Representación ilustrativa de una simulación de un régimen de gestión con intervención silvícola para la conservación de la estructura, las especies y el bosque de araucarias.

DISCUSSION

The benefits or services provided to people by forest ecosystems are often divided into social, ecological, and economic categories or social, environmental, and economic aspects (Western *et al*. 2017). Sustainable forest management means that forestry should be sustainable in all these aspects. Cultural sustainability is sometimes mentioned as the fourth aspect, or social and cultural aspects are combined in the sociocultural dimension of forest management. Cultural sustainability requires forest management to, for example, correspond to people's perceptions of the correct way to manage forests (Shindler and Brunson 2004).

Economic sustainability refers to timber production and the income obtained from timber sales. It requires that the current use of forests does not diminish future harvest levels and that the forest's ability to generate economic returns is maintained. "Environmental sustainability" implies a non-decreasing flow of environmental, regulatory, and protective benefits. "Ecological sustainability" means that forestry should not compromise the viability of tree species populations. "Social sustainability" has many definitions (Magee *et al.* 2013), but in the forestry context, it often means respecting the traditional uses of forests (Pukkala 2021).

The types of sustainability cited by the author refer to different types of components of the MOF habitat, such as maintenance of macro and micro fauna, species diversity, fragmentation of forests to maintain flora and fauna, traditional populations, formation of reproductive structures, diversity, avoiding rural exodus, favoring sociocultural development, forestry of the araucaria species, and local overexploitation by tourism. Habitats and niches are neglected because nature regulates itself. However, the process of forest return due to the abandonment of small properties occurs at a faster pace than deforestation itself. The modification of the landscape, for example, more forested, may be true; on the other hand, it is more abandoned and decaying in its structures (Andrae *et al.* 2018).

Thus, forests provide various benefits for both forest owners and society (Pukkala 2021). This could be true if provided by law, but it is not a reality for MOF owners. It is important to highlight that the social benefits of mixed forests are greater than those of homogeneous forests. Unfortunately, MOF owners are excluded from the social, economic, and cultural benefits that forests can provide, thereby generating social exodus, lack of interest in maintaining ownership, and loss of cultural identity. Unmanaged forests do not produce sustainable economic and environmental benefits and even less social and cultural. It promotes the abandonment of resources, loss of species diversity, problems in forest structure and dynamics, productive stagnation, mortality, impoverishment, and neglect of extremely important social and ecosystem resources.

Bergseng *et al.* (2012) used a complex dynamic forest optimization model to analyze the impacts of forest management restrictions implemented to protect biodiversity on the economy and biodiversity. A reference scenario is compared to two preservation regimes based on 1) the current Norwegian forest certification system and 2) an expert judgement designed to put strong emphasis on biodiversity protection in boreal forests. They concluded that different restrictions resulted in a 10–45 % decrease in the economic value of the forest compared to no restrictions. The most costly measures were found to be a 50 % increase in rotation and maintaining old-growth proportions higher than 20 %.

The bias adopted in not managing MOF forest resources can be part of the distorted rationality. The results of legislation based on preservation by non-use were unexpected. Neither the goals nor proposals to expand the conservation contained in the law were met. It is noticeable that the abandonment of the traditional populations, deprivation of the use of resources, and even knowing the elements for the elaboration of sustainable management plans. Unfortunately, not even the most complex Brazilian legislation has managed to fulfill these precepts. However, management plans are supported and authorized in the Amazon Forest. In southern Brazil, legislation allows it, but government agencies do not authorize its execution.

Preservation of biodiversity is an important aspect of forest management. Conservation of biodiversity in many countries is often mandated by law. This implies that restricted timber management practices are a common policy to promote biodiversity preservation in forests. The literature is rich in analyses of topics related to biodiversity and forest management. However, the literature in these fields mainly looks for optimal regimes for biodiversity preservation only, and does not generally consider the costs of such biodiversity preservation measures, actions, or regimes (Berseng *et al.* 2012).

In this sense, changes in forest legislation are not intended to boost the efficient use of natural resources, much less so they contribute to mitigating diversity loss. Recognizing the value of an ecosystem's forest and environmental resources is not synonymous with the non-use of resources, or conversely, with irrational exploitation, decimation, and resource depletion. The policies established should be applied to the rational management of forests and the economic, social, and environmental activities of natural resources.

Sustainability is not solely synonymous with protecting nature, but mainly with production, since the former cannot exist without the latter. Thus, sustainable use can be the greatest guarantee of the continuity of a system as opposed to the exclusive protection of nature. The biggest obstacle is not knowledge of management techniques, but overcoming administrative obstacles and paradigms (Andrae *et al.* 2018). According to the same authors, "multiple use does not apply to the production of raw materials, but to forest functions, with each forested area having to fulfill four functions simultaneously: production, protection, ecological benefits and leisure. This makes it obvious that each forest plot can be managed as long as its social functions are fulfilled".

In this study, characterizations of future consequences on the structure and dynamics of Araucaria Forest are shown (table 1), which indicate the need for management plans in conjunction with conservation, as conservation alone does not guarantee the supply of goods and services to the forest ecosystem. Management should maximize the landscape. Therefore, the conservation of one species can compromise all forest diversity. Thus, management for conservation represents the construction of a feasible capacity model, which is much better than the creation of an increasing amount of legislation. Mazziota *et al.* (2017) concluded that this challenge can be solved by building capacity between land managers and landowners.

CONCLUSIONS

Despite the strictness of the forestry legislation in southern Brazil, there is no prohibition on sustainable forest management. Only if it is not authorized by government regulatory institutions. Investigation 1 of the study can be answered negatively; that is, legislation only for conservation is not efficient for Araucaria and MOF.

Aspect 2 also indicates that there was more damage to the dynamics of the forest and society, as the non-use of forest resources, self-regulation of the structure, growth, regeneration, etc., compromises the maintenance of the species. The abandonment of resources and lack of interest on the part of owners increased the risks of past exploration more than the risks.

Third, the study indicates that management plans with multiple objectives favor benefits for society and the forest ecosystem and avoid irreversible losses in economic production, as proven by rigid legislation.

AUTHOR CONTRIBUTIONS

AFH, ARZ, and VL designed and performed this study. GAB and TFS contributed to the writing of the study, and ANS, EAC, and LD revised the manuscript.

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