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Multifunctional Forest Restoration in Brazil: A Critical Analysis of the Trends and Knowledge Gaps in the Scientific Literature

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Abstract: The global demand for forest products will increase in the coming decades due to population growth and increasing environmental awareness. Therefore, the production of forest products through multifunctional forest restoration could be a meaningful opportunity for large-scale restoration while promoting sustainability and vegetation recovery. We conducted a comprehensive literature review to explore how forest restoration in Brazil can meet the growing global demand for forest products, thereby promoting the widespread adoption of restoration practices. The number of forest restoration publications addressing forest product supply has increased, but remains limited. Notably, only studies on payments for environmental services have increased significantly over the years, while studies on non-timber forest products and timber have not increased significantly. Similar patterns and trends were found in earlier studies. Many studies do not provide insights into the socioeconomic outcomes of multifunctional forest restoration, which is consistent with other research findings. The studies cited 108 native species of commercial value. According to the literature, these species can provide multiple forest products, making their management economically attractive. Multifunctional restoration in Brazil has the potential for meeting global demand for forest products and supporting large-scale restoration. However, advancing scientific and technological knowledge in this area is needed to make this feasible.

Keywords: bioeconomy; bibliometric analysis; forest resources management; restoration ecology; tropical forest

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1. Introduction

Forest restoration has garnered unprecedented global attention as a critical strategy for addressing social and environmental problems resulting from human degradation [1], leading to an increase in restoration efforts across the planet [2]. Due to the importance of forest restoration to society, many initiatives led by several groups, such as government, entrepreneurs, and NGOs, have proliferated worldwide [3]. For example, the Bonn Challenge aims to restore >200 million hectares of forest by 2030. More recently, the United Nations (UN) has declared the Decade on Ecosystem Restoration (2021–2030), broadening visibility and increasing the engagement of many sectors in restoration initiatives around the world [4].

These initiatives have the main goal of restoring landscapes on a large scale while providing multiple benefits, such as climate mitigation, biodiversity conservation, water regulation, and food security [2]. Based on this, restoration practice and science have developed a portfolio of methods to recover multiple environmental benefits [5], such as forest structure and biodiversity [6], neglecting important socioeconomic aspects, such as job creation, income generation, and the commercialization of forest products [1]. Although most of the forest restoration evidence-based practice has focused on environmental targets, key stakeholders like governments, entrepreneurs, and landowners are much more interested in the socioeconomic outcomes arising from forest restoration [1,7].

In addition to the fast job creation triggered by forest restoration programs [1], recent studies have shown that restored areas can provide several forest products and services [8,9]. In this way, the payment for ecosystem services (PES) and for the harvesting of forest products, such as timber and non-timber forest products (NTFPs), from restoration plantations can create sustainable and diverse income sources for a variety of stakeholders [1,9], driving the uptake of large-scale restoration and, still, helping achieve ambitious restoration goals [10]. Furthermore, the diversity of forest products that can be exploited in restoration plantations drives economic security and adaptability during periods of hardship, such as economic crises, market price fluctuations, and natural disasters [9]. Therefore, this context has created a crucial opportunity for forest restoration to emerge as a forest-based bioeconomy [11].

The replacement of degraded lands with multifunctional restoration plantations may catalyze ecosystem recovery while promoting socioeconomic development through the commercialization of NTFPs, timber, and the monetization of ecosystem services [9]. Therefore, besides being ecologically justifiable, the multifunctional restoration of degraded ecosystems may also be socioeconomically viable, synergistically generating ecological and socioeconomic benefits [1,9,12].

The future global demand for forest products is estimated to increase gradually over the next few decades due to a rampant population growth [13]. Thus, the production of forest products through forest restoration plantations could also represent a meaningful opening for forest restoration to be practiced on large scales [1]; but, the current knowledge on this topic is limited, the trends unclear, and the potentials are not yet fully understood [1]. Therefore, it is crucial to review and synthesize the scientific literature on the potential of forest restoration for forest product supply. In this study, we have conducted a comprehensive literature review to explore how forest restoration can effectively meet the growing global demand for forest products and, in turn, facilitate the promotion of large-scale restoration practices. Our goal is to provide a holistic perspective on two key aspects, as follows: (I) identify existing research gaps and emerging trends within the scientific literature on this topic, and (II) highlight the critical areas that future research should emphasize to advance ambitious restoration goals and further expand our scientific understanding in this area.

2. Materials and Methods

2.1. Geographic Focus

The geographic focus of this literature review comprises the entire Brazilian territory and its six biomes according to the IBGE—the Brazilian Institute of Geography and Statistics [14]—as follows: Amazon Forest, Atlantic Forest, Cerrado, Caatinga, Pampa, and Pantanal (Figure S1, in Supplementary File S1). Brazil is a global priority area for ecosystem restoration, where restoration initiatives are expected to be able to achieve multiple benefits [2,10]. Moreover, the Brazilian Atlantic Forest and the Cerrado are considered to be biodiversity hotspots and priority areas for restoration due to their extensive degradation history and the high biological diversity of their native vegetation [10,15].

In Brazil, unsustainable land use has converted native forests, resulting in about 50 million hectares of degraded areas [10]. These areas comprise a large portion of what is needed to meet the growing global demand for forest products by 2050 [16], in addition to comprising almost 25% of the total area set to be restored with the Bonn Challenge. Hence, Brazil can contribute to global demands for forest products and to the upscaling of forest restoration efforts. Therefore, the country may be able to develop multifunctional restoration models that generate ecological (e.g., biodiversity conservation, climate mitigation, and water security) and socioeconomic benefits (e.g., income, jobs, and forest products) [10]. In addition, the Brazilian flora harbors about 14.5% of all tree species identified worldwide [17]. At least a hundred of these species are known for their high-quality timber production and for their provisioning of many forest products, such as oils, medicines, resins, and fibers [18,19]. Given the considerable number of native species with a high economic potential, Brazil naturally has a great potential to leverage a bioeconomy based on forest restoration products while upscaling its restoration efforts.

2.2. Literature Search

We performed a literature review incorporating some principles of systematic reviews and maps [20]. It is possible to conduct highly reliable literature reviews in a timelier manner through this approach. We conducted a bibliographic search of the peer-reviewed literature on the Web of Science platform (main collection: SCI-E, SSCI, and ESCI) and on the Scopus, CAB Direct, and SciELO databases. The bibliographic search was not restricted by year of publication or language. We designed the search string by consulting researchers and specialists in this field to improve its accuracy and comprehensiveness as much as possible, in order to find the literature most relevant to our goals. We used the following search terms: '(restor* OR regenerat*) AND ("native timber" OR "native wood" OR timber OR wood OR "timber product*" OR "wood product*" OR "forest product" OR "commercial natives species" OR "payment for environmental services" OR " payment for ecosystem services" OR "non-wood forest product*" OR "non-timber forest product*" OR silviculture OR forestry OR cost–benefit OR financ* OR economic*) AND (forest) AND (Brazil* OR Brasil*)'. The search was performed from August to September 2022 and updated in December of the same year.

2.3. Eligibility Criteria and Data Extraction

After we performed the search, we screened the studies according to the eligibility criteria. Only primary studies that met the following eligibility criteria were considered in this review: (I) studies estimating the potential of forest restoration for the supply of forest products; and (II) studies carried out in Brazilian biomes or terrestrial forest ecosystems, based on the IBGE [14]. After the screening process, we extracted data from the studies through full-text reading. Table 1 and Figure S2, in Supplementary File S1 provide more details about the data extracted from the publications and the screening process.

Table 1. Description of the data extracted from the publications after full-text reading.

Variable	Example
Direct or indirect study	Direct—studies conducted in areas undergoing a restoration process, whether active (e.g., native tree plantations, mixed plantations intercropped with commercial native species) or passive (e.g., forest regrowth after land abandonment, assisted natural regeneration); and indirect—studies conducted outside areas undergoing a restoration process, but which make a proxy by applying their results in restoration areas (i.e., in vitro studies with native species used in restoration)
Publication year	Year of publication of a study
Brazilian biome/Ecosystem [1]	Cerrado Caatinga Atlantic Forest Amazon Forest Pampa Pantanal

Table 1. *Cont.*

Variable	Example
Forest product category [2,3]	Timber Non-timber forest products Payment for ecosystem services
Type of nature's contributions to people [4]	Biodiversity conservation Soil conservation Security, quality, and water regulation Climate mitigation Medicinal Cosmetic Food Wood Rubber Resin Wax Fiber Energy Fuel
Socioeconomic outcomes	Presence or absence of socioeconomic outputs (e.g., job creation, revenue-generating, cost–benefit analysis, income generation, and market prices)
Native species studied	Name(s) of the native commercial species reported in a study
Species' potential use	Potential commercial use of the native species reported in a study (e.g., plywood, sawn wood, firewood, production of resins, oils, and waxes)

Notes: According to [1] IBGE [14], [2] Shackleton et al. [21], [3] Food and Agriculture Organization [13], and [4] Díaz et al. [22].

2.4. Data Analysis

We used Pearson's chi-squared test with Monte Carlo randomizations to verify differences in the proportion of studies between (I) types of forest products, (II) biomes, and (III) studies with a presence or absence of socioeconomic outputs. The geolocations of each study were extracted and mapped in the QGis version 3.26.1 program. Some studies did not report their geographic locations. Therefore, these studies had to be excluded from the analysis. We checked whether the proportion of published studies depended on their geographic region through a chi-squared test of independence [23]. We also analyzed the data through descriptive statistics. All the statistical analyses were performed in the R software program version 4.3.1 [24].

3. Results and Discussion

3.1. Publications' Outputs

Our searches resulted in 2583 peer-reviewed studies. After removing duplicates, 1796 studies remained. We selected 115 publications that met our eligibility criteria for a full-text analysis. After a full-text reading of the 115 records, a total of 51 studies were included in the final analysis. More than 65% of the studies retrieved with the search were excluded because they did not investigate any forest products, such as timber, NTFPs, or PES. Another 20% of the studies were excluded because they were not studies on forest restoration. Details about the reasons for the exclusion of studies after the full-text analysis are shown in Supplementary File S2. About 20% of the studies focused on more than one forest product and/or biome; thus, each forest product or biome studied in a publication was considered an observation. Therefore, the final database consisted of 70 observations from a total of 51 publications. About half of the observations (52.8%) were taken from indirect studies.

3.2. Knowledge Gaps and General Trends over Time

Based on the results, the first study on the potential of forest restoration for the supply of forest products in Brazil was published in 2006. There was an irregular, increasing trend in the number of publications on this subject, with abrupt declines in the publication rates in some years (Figure 1). The number of publications only began to increase more regularly after 2016. Specifically, only publications on PES and timber have shown a subtle increase in recent years, more precisely from 2016 onward (Figure 1). However, no increasing trend can be observed in the number of publications for NTFPs due to the low number of studies per year, often with only one publication (Figure 1).

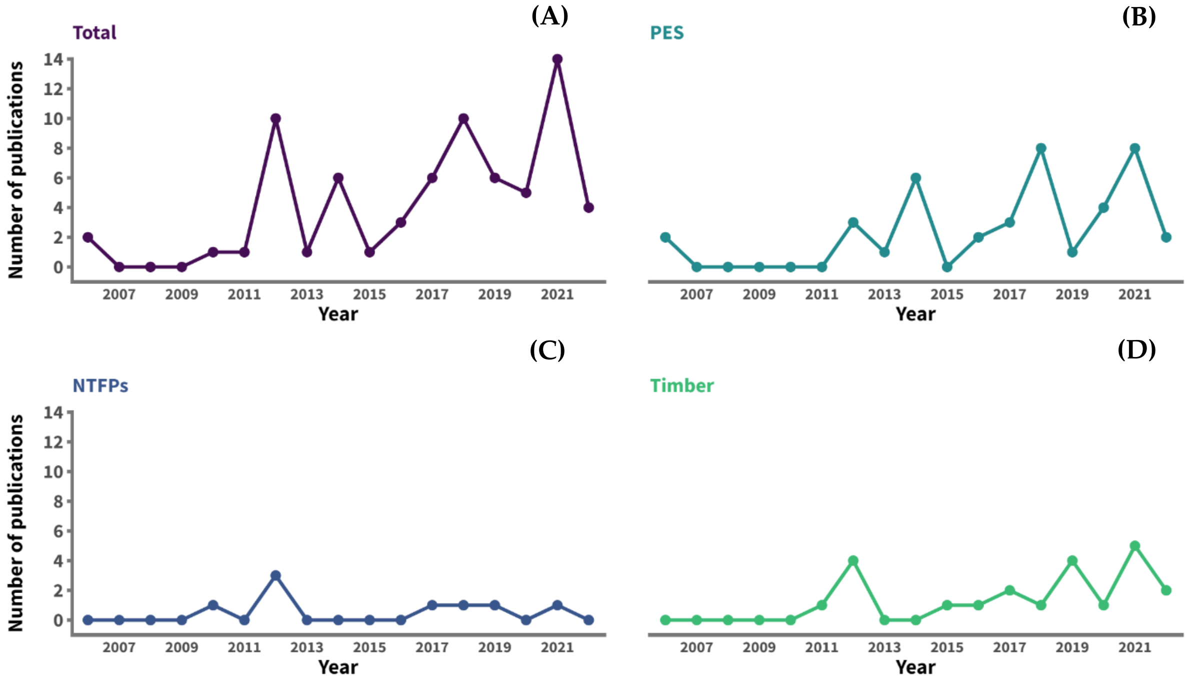

Figure 1. Number of (**A**) total, (**B**) payments for environmental services—PES, (**C**) non-timber forest products—NTFPs, and (**D**) timber studies from 2006 to 2022.

It was observed that most studies clustered along the southern (24.2%) and southeastern regions (54.8%) (Figure 2). Thus, these two regions together hold about 79% of the observations. The third region with the largest number of studies was the northern region (11.3%). Other regions (to the northeast and mid-west) represented only 4.8% of the total observations. Our analysis showed that the observation proportions strongly depended on their geographic region ($X^2 = 54.7$; $p < 0.01$).

Our review showed that studies regarding the potential of forest restoration for the supply of forest products in Brazil have not increased over time. Other studies have reported similar patterns [25,26]. For NTFPs, Debrot et al. [25] found that the number of publications on the exploitation of NTFPs in restoration areas did not increase significantly over time. In addition, Salzman et al. [27] also pointed out that publications on PES have increased rapidly worldwide, mainly driven by private initiatives such as the Latin American Water Funds Partnership. Approximately 250 studies regarding ecological restoration were published in Brazil in 2018 [28]. However, according to our results, only six of these publications (2.4%) address the exploitation of forest products in forest restoration areas. Notably, the creation of a legal framework in Brazil that supports the legal exploitation of forest products in natural forests played a crucial role in shaping the observed publication rates. Historically, Brazilian legislation for native vegetation protection was focused on restricting the advance of the agricultural frontier over sensitive areas of native vegetation [29,30]. It was only in the last two decades that governments started incentivizing the sustainable use of native forests, primarily driven by socioenvironmental and economic pressures resulting from the growing global demand for natural resources [31].

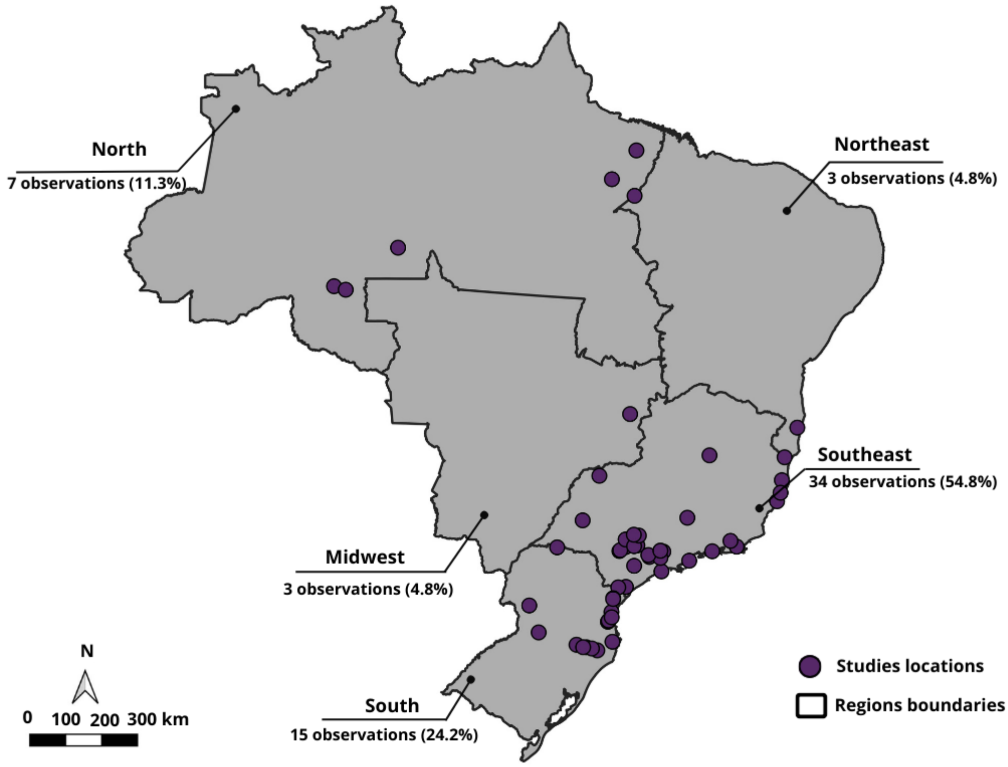

Figure 2. Geographic distribution of the observations (N = 58) across Brazilian geographic regions.

It was only in 2012, with the enactment of the new Brazilian Forest Code (Law No. 12.651/2012), that the sustainable economic exploitation of native vegetation on private properties was allowed [32]. In 2006, another legal instrument was created, the Public Forest Management Law (Law No. 11.284/2006), enabling the exploitation of public forests and establishing criteria for the concession of these areas for the sustainable harvesting of native timber and NTFPs [33]. All these legal changes likely had a significant impact on the number of studies on this subject, particularly since 2012, as illustrated in Figure 1.

The strong spatial bias in the number of observations is partly due to the southern and southeastern regions being embedded within one of the most studied biomes in Brazil in terms of ecological restoration, the Brazilian Atlantic Forest (BAF) [28,34]. In addition to covering almost the entire southeastern and southern regions, the BAF has historically been one of the most degraded biomes worldwide, and, after social pressures and the enactment of a conservationist legal framework, several restoration initiatives have been conducted in the region [28]. These two geographic regions also encompass some of the main Brazilian research institutions, as well as one of the richest state research funding agencies in Brazil, the São Paulo Research Foundation [35]. Moreover, the state of São Paulo in the southeastern region is an international reference point for forest restoration, a place where pioneering state legislations were created, enabling the emergence of many restoration initiatives and boosting the development of scientific studies [1,28].

Although there are significant knowledge gaps regarding the exploitation of forest resources within restoration areas in Brazil [19], in recent years, a variety of initiatives have been launched in Brazil by both public and private stakeholders to fill these gaps. In this context, Batista et al. [8] documented about 12 business cases with a primary focus on commercially oriented restoration for the provision of various forest products, such as food and timber. One of these business cases is Symbiosis, a forestry company founded in 2011 in Porto Seguro, Bahia [8]. Symbiosis specializes in the transformation of degraded areas into forest production stands with native species. Another notable business case is Amata, a company specializing in the supply and sale of certified wood, including both sawn wood and roundwood from mixed native species plantations [8]. In addition, several successful

PES programs have been consolidated in Brazil, including the Water Producer Program and the Oasis Project, which may explain the patterns identified in this study [36,37].

3.3. Trends and Gaps by Biome and Forest Product Category

Most observations were performed in the Brazilian Atlantic Forest (68.5%), Amazon Forest (15.7%), and Cerrado (11.4%) (Figure 3). The other Brazilian biomes (Caatinga, Pampa, and Pantanal) represented only 1.4% of the observations. According to the chi-squared test, the proportion of studies among biomes was statistically different (X^2 = 143.6; $p < 0.01$). The PES was the most investigated forest product (57.1%), followed by timber (31.4%) and NTFPs (11.4%) (Figure 4). We found strong statistical differences in the proportion of publications among each forest product category (X^2 = 22.05; $p < 0.01$).

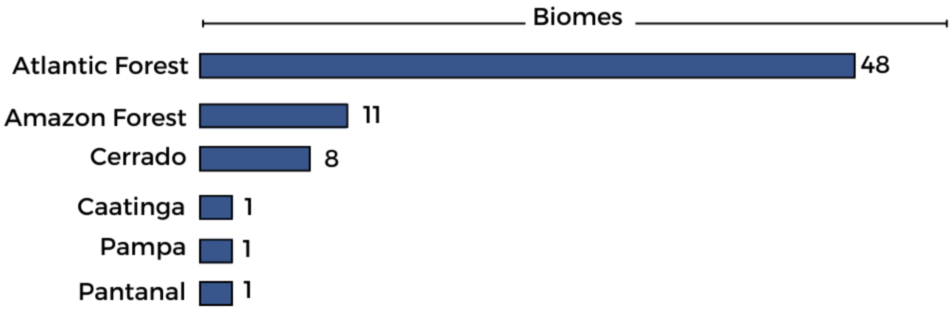

Figure 3. Total number of observations (N = 70) by biome.

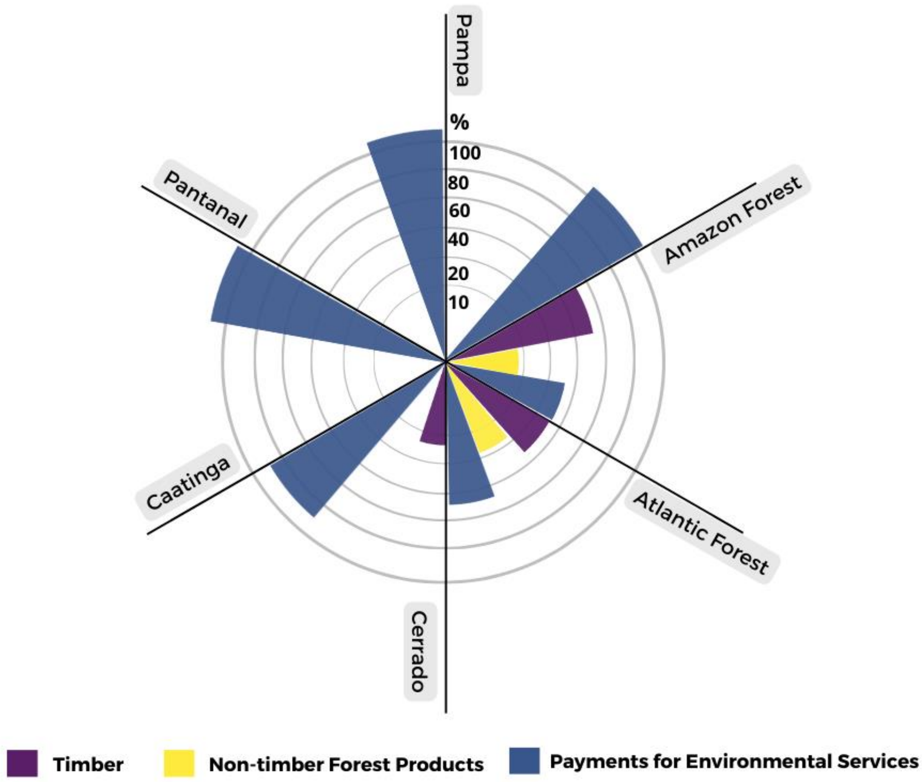

Figure 4. Proportion of observations (N = 70) on payments for environmental services (PES), timber, and non-timber forest products (NTFPs) among the Brazilian biomes.

The proportion of observations that addressed timber, NTFPs, and PES among biomes was also quite discrepant (Figure 4). In the Atlantic Forest domain, 64.1% of the publications investigated PES, 31.2% timber, and 14.5% NTFPs. For the Amazon Forest, about 54.5% of publications focused on timber, 36.4% on PES, and 9.1% on NTFPs (Figure 4). The Caatinga biome presented 87.5% of publications on PES and 12.5% on timber. Only publications on PES were found in the other biomes (Cerrado, Pampa, and Pantanal) (Figure 4).

There are strong biases and knowledge gaps related to the type of biomes studied. The Caatinga, Cerrado, Pampa, and Pantanal biomes have been understudied. As expected, our results demonstrated that the BAF has continually been one of the main focuses of ecological restoration studies in Brazil [28]. The BAF is considered a restoration hotspot where restoration initiatives may achieve greater socioecological benefits [10]. This exerts an evident effect on the study and scientific production focused on this biome [38]. The Amazon Forest was the second most studied biome (15.7%). This biome has attracted a lot of attention mainly due to its important role in mitigating climate change [39] and providing other ecosystem services, such as water regulation [40]. This, combined with a surge in its secondary forests' area after deforestation and land abandonment, has led to a significant number of studies being conducted in the Amazon Forest in recent years [39,41]. Cerrado is the second largest Brazilian biome and threatened biodiversity hotspot, but the low number of observations diverges from its large territorial dimension [42,43]. This may reflect its relatively smaller area of forest ecosystems, given that it is primarily a savanna biome, while our study focused on forests [14,44]. The huge gap in studies of the Caatinga (tropical dry forest) (1.4%), Pampa (grasslands) (1.4%), and Pantanal (flooded grasslands) (1.4%) biomes may also be a consequence of the lower proportion of forested areas within their territory [44]. The low number of studies located in the Caatinga, Pampa, and Pantanal biomes can also be a consequence of their low territorial coverage, which, combined, only covers about 14% of the entire Brazilian territory [14,44].

The number of publications addressing NTFPs in this study is significantly lower than that of studies conducted worldwide [45,46]. Nevertheless, several studies have highlighted the potential of forest restoration for proving NTFPs, such as food, medicines, and latex [47–51]. In a recent study, Gasparinetti et al. [52] presented case studies conducted in three different countries, including Peru, Cambodia, and Indonesia, which successfully implemented restoration models specifically designed for NTFPs extraction. On the other hand, an earlier study conducted in 28 countries showed that the value of NTFPs is also often overlooked in Europe, mainly due to data deficiencies [53].

NTFPs (11.4%) tend to be neglected when compared to other categories, such as timber (31.4%). Despite NTFPs being traditionally exploited by local communities in the Brazilian Amazon, in most cases, they came from old-growth forests [54]. Additionally, the present market prioritizes timber products, such as plywood and sawn wood [55,56], also because there is a knowledge gap in the use, management, and market for NTFPs [18]. Another issue arising from NTFPs' exploitation is that no specific legislation supports the management, extraction, and commercialization of these products in planted forests in Brazil [57]. There are some paragraphs on the exploitation of new forest products from managed forests in the Public Forest Management Law (Law No. 11.284/2006) and in the New Forest Code (Law No. 12.651/2012) [32,33], but these regulations are insufficient both for areas under protection by law (legal reserves) and for alternative land-use areas, such as forest plantations with native species. The lack of specific legislation dealing with the exploitation of non-timber forest products is currently one of the central barriers that make the exploitation of these products from planted forests economically unattractive. Therefore, NTFPs in Brazil urgently need the creation of specific legislation which supports a legal market for these products.

Many studies have already demonstrated the significant potential of forest restoration for timber production [58,59]. A previous global study has mapped and recognized that well-managed forest restoration plantations, located in appropriate regions, are well suited for both conserving biodiversity and meeting human needs, such as timber [60]. Despite this, there is a limited number of publications on timber production in Brazilian restoration areas, mainly because the use of native species with commercial timber value is still minimal in Brazil [61]. This limitation constrains the development of new studies, such as species growth, productivity modeling, wood technology, and species management [19,61]. One of the reasons commercial timber species are rarely planted is due to the limited knowledge available regarding various silvicultural aspects related to these species, including stem shape, growth rates, and nutritional and edaphic requirements [62]. Another barrier is the negative implications that Brazilian legislation has on the native species' silviculture and their timber products. The production and commercialization of native timber in Brazil is an economic activity subordinated to several controversial regulations and laws that discourage entrepreneurs due to the enormous number of certifications, licenses, bureaucracy, and exorbitant fees [29]. Many of these regulations involve obtaining licenses and permits for wood harvesting and transportation, along with government fees and taxes like the Circulation of Goods and Services Tax (ICMS) and the Industrialized Product Tax (IPI), which increase operating costs excessively [29,63].

In recent years, many countries have explored ways to implement and integrate PES programs with forest restoration projects [64–66]. Several studies have already demonstrated the feasibility of generating profits from PES programs related to carbon sequestration, biodiversity conservation, and water-related services [27,67]. Other evidence-based reviews have also highlighted the rapid increase in PES publications in recent years [68,69]. The main driver behind this surge in interest is the program's ability to generate new funding opportunities [70]. Additionally, government initiatives to implement payment schemes have played an important role in boosting this popularity [71,72]. Successful cases of PES programs have been consolidated in Brazil, such as the Water Supply Program of Extrema in Minas Gerais [73]. In 2019, Brazil instituted the National Policy for Payments for Environmental Services (Law No. 14.119), regulating this activity and increasing its economic attractiveness [74], which certainly made PES the target of many studies [73]. Another reason for the observed amount of studies on PES, specifically in the Atlantic Forest, is a biome's legal framework which surpasses other national legislation, often forbidding the exploitation of old-growth forest products such as timber and NFTPs [29,32].

The patterns and trends observed in forest product categories are likely strongly related to the predominantly investigated biomes, since the most well-studied biomes, the Amazon and the Atlantic Forest, primarily consist of forested ecosystems [14,44]. Consequently, it is more feasible to find studies on timber and NTFPs in these biomes. Conversely, the Caatinga, Cerrado, Pampa, and Pantanal are characterized by open phytophysiognomies with a predominance of ground vegetation and a smaller number of trees [44,75]. As a result, research in these biomes predominantly focuses on payments for environmental services, with less frequent studies on NTFPs and timber [26,76,77].

Despite the challenges and barriers associated with the exploitation of forest products in restoration plantations, some recent studies in Brazil have already highlighted promising business cases where multifunctional restoration models have been successfully implemented to exploit a variety of forest products [8,52,57,78,79]. Previous studies conducted in the Amazon have shown that restoration models designed to provide NTFPs can be economically viable [52]. Furthermore, Batista et al. [8] showed that restoration models designed to provide forest products in Brazil have the potential to generate higher profits compared to commercial eucalyptus plantations.

3.4. Socioeconomic Outcomes Reported in the Studies

In total, 37.1% of the observations presented socioeconomic outcomes, while 62.8% of them did not (Figure 5). There were differences between the proportion of studies with a presence and absence of socioeconomic outcomes ($X^2 = 4.6$; $p < 0.05$). Specifically, about 40% of the PES studies, 50% of the NTFPs studies, and 27% of the timber studies did not present any socioeconomic outputs (e.g., job creation, income generation, and market prices of products).

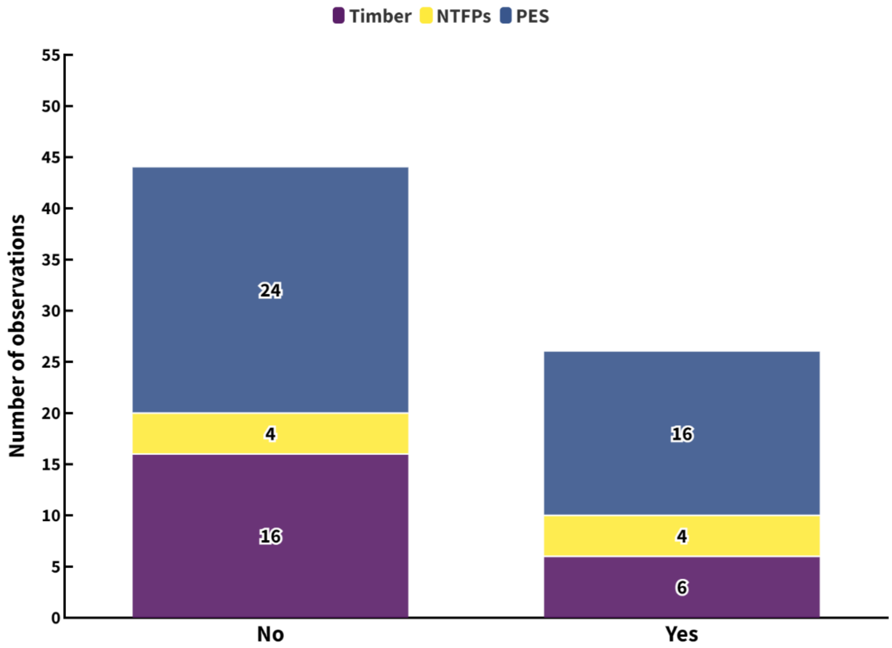

Figure 5. Proportion of the observations (N = 70) that presented (yes) or did not present (no) socioeconomic outcomes.

So far, most studies have offered poor insights into the potential socioeconomic outcomes that can be attained through exploiting timber, NTFPs, and PES in forest restoration plantations. Most of the socioeconomic information reported in the studies concerns the cost of implementing restoration projects and not necessarily the whole cost structure, like their maintenance and harvesting, or the benefits, like timber and NTFP prices, job creation, revenues, and cashflows. Without this information, it is impossible to assess the economic viability of these restoration programs and attract private investors and landowners [52]. The absence of socioeconomic data in a substantial portion of studies underscores the necessity for a more holistic approach to assessing the socioeconomic consequences of restoration projects [80,81]. It is important to better understand how restoration plantings designed for economic purposes affect the forest market, the regional economy, and local communities [82]. Unfortunately, socioeconomic analyses for restoration projects are scarce [82]. Previous studies have also shown that practitioners and researchers often fail to report the socioeconomic outcomes of restoration programs [78,82]. Other global literature reviews have also indicated that the socioeconomic measures of restoration programs are often not reported and that the benefits to society are often not examined in detail [82–85].

Only recently has forest restoration been studied from a socioeconomic perspective around the world [8,52,86–88]. In California, Elias et al. [89] showed that the exploitation of several, highly profitable products from forest restoration is not only possible but can provide financial support for the restoration efforts. In addition, Montagni and Piotto [90] found that revenues from timber harvesting can exceed the costs of establishing and managing mixed plantations of native species. In Brazil, the VERENA (Economic Valuation of Reforestation with Native Species) project found that multifunctional restoration plantations were more profitable than eucalyptus monocultures [8,91]. Additionally, unlike many benefits that typically materialize in the long term, promoting forest restoration in Brazil has been shown to have the potential to create approximately 2.5 million jobs [1].

It is necessary to determine the socioeconomic impacts of forest restoration designed for sustainable production in order for investors to feel safe in financing such activities [29]. Likewise, it is crucial to promote participatory restoration approaches by integrating multiple stakeholders, such as landowners, farmers, governments, and entrepreneurs [92]. Therefore, researchers and professionals in this field must acknowledge the importance of effectively communicating the socioeconomic outcomes of their activities, since it can be crucial for supporting decision-making and promoting sustainable practices [93]. Thus, future research must consider socioeconomic aspects demonstrating the potential of forest restoration's financial returns and socioeconomic benefits in order to break this paradigm.

3.5. Nature's Contributions to People (NCP) Reported

A total of 41 reports on NCP were observed in the NTFPs' category, primarily for medicines (61%), resins/oils (19.5%), and food (14.6%) (Figure 6). The timber category (127 reports) showed a low variety of NCP reported, in which wood (95%) was the most representative NCP class (Figure 6). Water security (39.1%) and climate mitigation (36.9%) were most reported for the PES category (Figure 6).

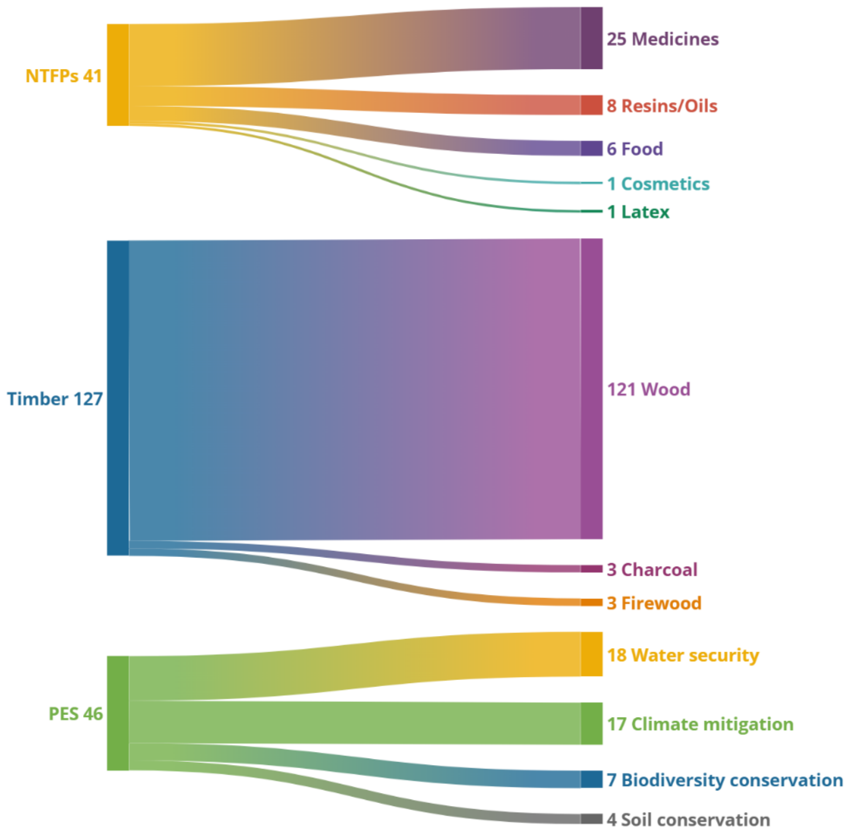

Figure 6. Sankey diagram showing the number of nature's contributions to people (**right**) identified through the three forest product categories (**left**).

The large number of NCP found in our study shows that it is possible to obtain a wide variety of both material (e.g., wood, medicines, and food) and non-material (e.g., biodiversity conservation and soil conservation) goods for human use from forest restoration plantations [22]. However, most studies on timber showed limited information about native wood use. Hence, the wood NCP class reported in the studies can have a variety of applications, such as domestic use, firewood, plywood, or sawn wood. This is likely a direct result of the limited availability of studies on wood technology and wood properties for native species, which are essential for characterizing the potential uses and applications of wood [19]. Our results highlight a significant diversity within the NTFPs category. This diversity can play a pivotal role in income diversification, contributing to the resilience and sustainability of restoration businesses during periods of financial crises or market fluctuations [9,94], as well as contributing to the resilience and sustainability of restoration plantations [9]. The great diversity of NCP reported in the studies, especially for timber and NTFPs, also indicates great opportunities for future innovative research [50]. This may encompass the exploration of novel non-timber products, forest biotechnology, industrial applications, and genetic improvement and the development of new sustainable forest management practices [50,95].

Recent global modeling of nature's contributions to people has shown great potential and opportunity for ecosystem restoration to increase nature's contribution to people, such as water-related services and crop pollination [96]. Another study assessing the evidence base for nature's contributions to people through forest restoration in the tropics found that different restoration models provide different nature's contributions to people [97].

3.6. Native Species Reported and Their Potential Use

A total of 108 native species were cited in the studies (Table S1, in Supplementary File S1). Despite the high number of species cited among the studies, most of them (65%) were cited only once. Figure 7 shows that the most cited native species was *Schizolobium parahyba* (Vell.) Blake, followed by *Schinus terebinthifolia* Raddi, and *Hymenaea courbaril* L., *Euterpe edulis* Mart., *Cedrela fissilis* Vell., *Araucaria angustifolia* (Bertol.) Kuntze, and *Anadenanthera colubrina* (Vell.) Brenan. The top 10 most-cited species were cited in 34% of the studies.

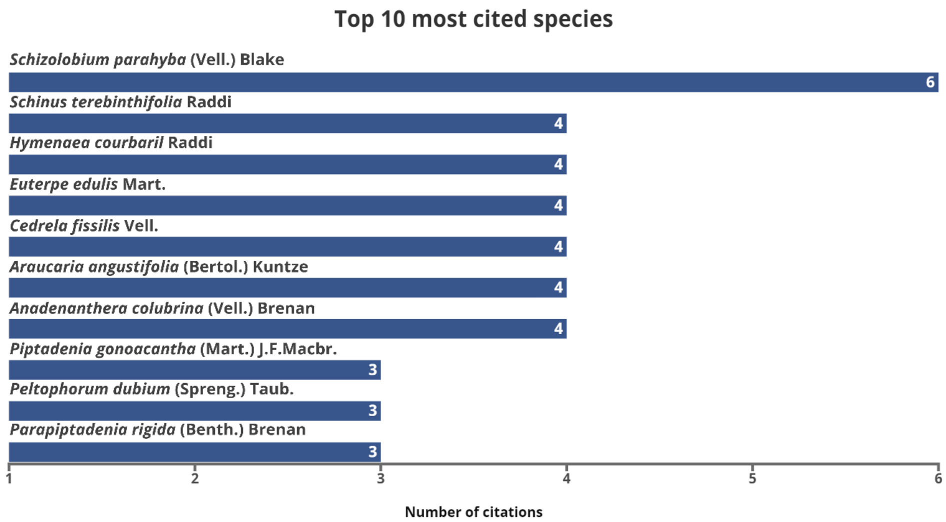

Figure 7. Top 10 most-cited species among the studies.

Several studies have shown that native species can provide better silvicultural performance, such as a higher productivity and good stem quality, compared to pure plantations of exotic species [58,90]. In contrast to previous studies conducted across the Americas and Asia [98–101], the number of commercial native species identified in this review is significantly higher. Another study conducted in the Brazilian Atlantic Forest produced a comprehensive list of 92 commercially valuable native species, each with the potential to provide a variety of valuable products [102]. This confirms Brazil's natural potential for providing forest products and promoting the development of multifunctional restoration models.

Most of the ten most-cited species can provide more than one type of forest product, making their use economically attractive. For example, *A. angustifolia* (conifer tree) can provide several forest products such as food, timber, resins, oils, and medicines [57,103,104]. *H. courbaril* is another native species with a long history of use. Its fruits are sources of essential oils, and the bark has antimicrobial properties [105]. This species is also used as a source of wood and provides high-quality stems for sawn wood products [61]. In addition, many native species—*Schizolobium parahyba* (Vell.) Blake, *Peltophorum dubium* (Spreng.) Taub., *Anadenanthera colubrina* (Vell.) Brenan, and *Parapiptadenia rigida* (Benth.) Brenan—are recognized for their good silvicultural characteristics, high growth rates, and wood quality [61,103]. In Table 2, we have summarized the products that can be obtained from each of the ten most-cited species.

Table 2. Summary of forest products supplied by the ten most-cited species. 1—yes; 0—no.

Native Species	Wood	Food	Medicines	Resins	Oils
Anadenanthera colubrina (Vell.) Brenan	1	0	1	1	0
Araucaria angustifolia (Bertol.) Kuntze	1	1	1	1	1
Cedrela fissilis Vell.	1	0	1	0	0
Euterpe edulis Mart.	0	1	1	0	0
Hymenaea courbaril L.	1	1	1	0	1
Parapiptadenia rigida (Benth.) Brenan)	1	0	1	1	0
Peltophorum dubium (Spreng.) Taub.	1	0	1	0	0
Piptadenia gonoachantha (Mart.) J.F.Macbr.	1	0	0	0	0
Schinus terebinthifolius Raddi	0	1	1	0	1
Schizolobium parahyba (Vell.) Blake	1	0	1	0	0

Notes: The categories of wood, oil, and resin can have various uses and applications, such as firewood, construction, furniture, sawmill, plywood, cosmetics, and medicine.

Our results also showed that most of the studies only focused on a few species. Therefore, there is limited information within restoration studies about most of the species cited [106,107]. Even with the high number of cited species (108 species) in the publications, it is seen that several native species recognized for their high economic value are not considered in most studies, being studied little (e.g., *Cariana legalis* (Mart.) Kuntze (Jequitibá-rosa), *Aspidosperma polyneuron* Müll.Arg. (Peroba-rosa), *Zeyheria tuberculosa* (Vell.) Bureau ex Verl. (Ipê-felpudo), *Cordia trichotoma* (Louro-pardo), *Paubrasilia echinata* (Lam.) Gagnon, H.C.Lima & G.P.Lewis (pau-brasil), and *Handroanthus serratifolius* (Vahl) S.Grose (Ipê-amarelo)). Because of their silvicultural characteristics (e.g., timber quality, high growth rate, etc.), the species cited above are within the 30 Priority Native Tree Species for Silviculture in various Brazilian biomes [19] but have not been investigated in scientific literature.

Although at least one hundred of commercially available native species are known, little silvicultural information is currently available in the scientific literature [19]. Only recently have studies begun to focus on describing the potential uses and applications of native species in restoration plantations [19]. In this context, Krainovic et al. [18] investigated the potential biotechnological applications, such as medicines, cosmetics, food, and other market segments, for more than one hundred native species growing naturally in natural regeneration or passive restoration areas in Brazil.

3.7. The Potentialities, Advances, and Limitations of Multifunctional Forest Restoration in Brazil

Brazil has a high potential for developing a green economy based on the sustainable production of timber and NTFPs and on the establishment of PES programs from forest restoration [108,109]. Furthermore, restoration projects designed for these purposes may be able to accelerate and scale-up forest restoration in addition to generating socioeconomic benefits [78,87]. However, a new bioeconomy based on native forestry in restoration plantations mainly depends on a robust set of information that can support the development of public policies and the strengthening of an appropriate forestry market [29].

Our results showed that knowledge related to the production of forest products from restoration plantations is still very incipient and premature. For example, it requires more species-specific studies to increase the scientific and technological knowledge about the species growth, productivity, market prices, timber uses, and applications [19]. Another problem is that most of the information provided in the scientific literature on this subject comes from indirect observations (52.8%). In other words, this means that the scientific and technological knowledge produced so far is not necessarily derived from empirical experiments in restoration or silvicultural plantings. Consequently, it becomes almost impossible to extrapolate results and propose practical technical recommendations because the knowledge related to species behavior in forest planting trials is limited [19]. Thus, based on our results and the main research gaps observed, we recommend three thematic groups of research priorities, which urgently need more investigation to fill the information gaps evidenced in this review (Table 3). These thematic research groups were adapted from Rolim et al. [19], a study in which different researchers and specialists in native forest species from several Brazilian institutions created eight research priority groups for the silviculture of native species in Brazil.

Table 3. Thematic groups of research priorities and the main research and development (R&D) gaps.

Thematic Group	Main R&D Knowledge Gaps
Native forestry	Wood technology (workability, physical and mechanical properties, and use indications), species-specific allometric equations, productivity models, and species management.
Economy and market	Production chain, market prices, cost–benefit analysis, socioeconomic outputs, financial analysis, income, and job generation.
Forestry policy and legislation	Review of Brazilian forest legislation, administrative and bureaucratic procedures, fees, and charges.

Incentives to implement restoration programs designed for the sustainable exploitation of forest products are needed to achieve ambitious restoration goals [78]. Some incentive schemes could include tax exemptions and increased public and private funding, which would increase the value of this commodity, as well as the consolidation of a market [29,57]. Brazil has a great potential and presents a favorable position for developing forest restoration models planned for economic exploitation. On the other hand, great efforts are still required to create new forests with economic value. Engaging various stakeholders and key decision makers (e.g., specialists, government, public research centers, farmers, and industry) is crucial to overcoming the barriers and gaps identified in this review [92,110].

Finally, it is essential to rethink and reformulate forestry legislation to promote a bioeconomy based on the production of forest products from forest restoration. The current Brazilian Forest Legislation has strong contradictions and inconsistencies in norms and procedures that generate juridical insecurity and unnecessary economic costs for investors [29]. These contradictions arise mainly due to disagreements between federal and state legislation. Since Brazilian states have autonomy and specific competence in controlling and issuing permits and licenses, among other documents [29,111], the process for obtaining licenses and permits can vary significantly from state to state, requiring investors to adapt their processes to meet different regulations in different locations. In addition, there are numerous bureaucratic administrative processes, fees, and charges that make such forestry enterprises unfeasible. Such costs may also vary depending on the species to be exploited and the exploitation's purpose (firewood or sawn wood) [29]. All of the above materialize as risks for investors and hinder the development of a new forest economy supported by the restoration of native forests [29].

3.8. Practical Implications and Future Research Directions

An evidence review is an important tool that can help decision-making [112]. Evidence review studies follow rigorous, objective, and transparent standards that increase their reliability; thus, they can be used to underpin policies and practices [112]. This study is particularly important in the field of environmental science and forest management, so that decisions are not only made based on experience but also evidence. Our synthesis study shows the main barriers and which aspects future research needs to prioritize to achieve ambitious restoration goals and advance scientific—technological knowledge on the potential of forest restoration for the supply of forest products. Our results can help guide future research which reconciles multi-stakeholder interests by promoting the market for forest products from restoration in Brazil.

We have synthesized information from various studies to provide a comprehensive overview of how forest restoration in Brazil can meet the global demand for forest products, thereby facilitating the widespread adoption of large-scale restoration efforts. Our study not only identifies current trends and gaps but also outlines important research priorities and policy implications. This information can serve as a guide, a resource for researchers, policymakers, and key stakeholders who are interested in promoting sustainable forest production through forest restoration in Brazil. Our study has identified the main research bottlenecks in this area. This information is essential for understanding the differences across biomes and forest product classes and for identifying where future research efforts should be focused.

This study provides a comprehensive list of native species along with insights into their potential applications, providing valuable information on the economic potential of these species. This list can serve as a starting point for future research to explore the silvicultural potential of these species. Finally, the most important finding of this study is the demonstration that forest restoration can effectively serve as a pathway for the sustainable production of a wide range of forest products. Therefore, it becomes clear that multifunctional restoration models in Brazil could emerge as one of the main strategies for meeting the global demand for forest products, scaling-up restoration efforts, and supporting the achievement of ambitious restoration goals.

Despite its clear potential, Brazil still needs to make significant advances in its technical and scientific knowledge to establish itself as a leader in sustainable production in restoration areas. With this in mind, we have highlighted key areas in which future research in Brazil could focus to advance the technical and scientific knowledge in this area. There is a clear need for further studies to investigate the long-term effects of different forest management practices in restoration plantations [19]. This includes assessing how these practices affect biodiversity, community structure, and the overall health of the restored ecosystems [113]. It is also imperative that additional studies are conducted to improve our understanding of the ecological and biological dynamics of commercial native species in forest restoration plantations [114]. This is because native species have unique environmental requirements that include factors such as soil conditions, nutrient needs, light preferences, and shade tolerance [61]. These studies could contribute to the development of effective species-specific management techniques and to the selection of native species that are not only economically viable but also have ecological and biological characteristics that make them suitable for use in mixed plantations.

There is a need for further research on the social and economic impacts of sustainable production in restoration areas [82,84]. This entails assessing the livelihoods of local communities, income generation, job creation, cost–benefit analysis, and the market potential of products [1,52]. Additionally, a comprehensive understanding of market dynamics is essential to align restoration goals with market demand [115]. This includes analyzing market trends, understanding the demand for sustainable products, and exploring pricing strategies. Such research efforts could enable the production of restoration-based products that can compete effectively in a dynamic marketplace [116]. Furthermore, research that evaluates the impact of policies and regulations on sustainable production is of paramount importance. It is necessary to assess the effectiveness of current policies and their trade-offs with respect to sustainable production in restoration areas, while suggesting improvements to create an enabling environment for sustainable practices [29].

Addressing these key research areas is essential for Brazil to align its sustainable production efforts in restoration plantations with international restoration goals. The success of these future directions depends on the collaborative efforts of researchers, practitioners, and policymakers, recognizing that the path to large-scale restoration requires a harmonious integration of ecological, economic, and social dimensions.

4. Conclusions

This study provides a comprehensive overview of the current state of knowledge on the potential of forest restoration in Brazil to meet the global demand for forest products while contributing to the achievement of ambitious restoration goals. Our results highlight the knowledge gaps and trends across the biomes and forest product categories (timber, NTFPs, and PES). There is a clear disparity in the number of publications addressing timber, NTFPs, and PES. Brazil's forest restoration has a great potential to provide a wide array of forest products, including oils, resins, medicines, food, timber, and ecosystem services such as water-related services and climate change. This has the potential to diversify the market for forest products by identifying new uses and applications, particularly in emerging fields such as biotechnology, bioenergy, and sustainable construction materials. However, there is still a significant need for additional research efforts to fill gaps in the potential uses, markets for these products, and other related issues.

The lack of information on the socioeconomic impacts of sustainable production in forest restoration plantations is a widespread problem in many publications. This deficiency hampers the ability to conduct thorough socioeconomic and financial analyses, such as cost–benefit assessments and feasibility studies. It underscores the need for a more comprehensive approach to assessing the socioeconomic impacts of restoration programs. Our review highlights the availability of numerous commercial native species that can foster sustainable production in Brazilian restoration plantations. This should be achieved through a greater focus on species-specific studies of their silvicultural performance and potential uses.

Finally, this study has shown that Brazil has a significant natural potential to become a green economy powerhouse through the sustainable exploitation of natural resources in restoration plantations. Three key factors make this possible, as follows: (I) its natural potential, along with the economic use and innovative prospects of its abundant natural resources [117]; (II) Brazil is a restoration hotspot where restoration efforts are expected to generate and amplify multiple benefits [2,10]; and (III) Brazil has approximately 60 million hectares of degraded pastureland with a low agricultural suitability that could benefit from restoration activities [10,16]. This area is equivalent to a large portion of what is needed, for example, to meet the global timber demand by 2050 [16].

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su152215782/s1, Supplementary File S1: Figure S1. Geographic location of the Brazil and its five biomes according to IBGE (2012). Figure S2. Schematics of the screening process of bibliometrics. Table S1. Native species cited among studies. Supplementary File S2.

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