

Review

# Brazilian Biodiversity as a Source of Power and Sustainable Development: A Neglected Opportunity

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**Abstract:** Six terrestrial biomes and a huge coastline make Brazil one of the most biodiverse countries in the world. However, the potential of Brazilian biodiversity as a valuable and sustainable source of wealth and development is still neglected. In order to reverse this scenario, the country needs to recognize and assume the power of its biodiversity, focusing on (I) industry, science and technology, (II) biological conservation and maintenance of ecosystem services, considering reverberations on agriculture and public health, and (III) ecotourism, conservation and sustainable development of local populations. The joint action of the Brazilian population and scientific community is needed to achieve these goals, which must be translated into the election of politicians committed to sustainable development and an increase in research and technology based on Brazilian biodiversity. Additional reasons for preserving Brazilian biodiversity (e.g., intrinsic, cultural, and ethical values) are also addressed in this article. Finally, we argue that Brazil should recover its global leadership on the environmental agenda and assume its biological diversity as a source of *Soft Power*, as well as develop its neglected capacity in the field of the sustainable bio-based economy (bioeconomy). In brief, Brazil needs to recognize and embrace the power of its biodiversity.

**Keywords:** biodiversity; bioeconomy; Brazil; conservation; science policy; sustainable development



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## 1. Introduction

Brazil is a rich country in several aspects. Brazil's Gross Domestic Product (GDP) is among the largest in the world, being precisely the 12th in the 2020 GDP World Ranking [1]. The Brazilian territory is commonly referred to as 'continental proportions', being the world's fifth-largest country with a total area of 8,515,770 km<sup>2</sup>, having the second largest forest area in the world, and abundant natural resources such as minerals, oil, and water. Of note, 12% of the world's freshwater resources are located in Brazil, mostly in the Amazon Basin [2]. Also following superlative terms, Brazilian biodiversity is the richest in the world [2,3], being distributed along a coastline with approximately 8500 km in extension [4] and six terrestrial biomes: Amazon (tropical rainforest), Caatinga (semi-arid vegetation), Cerrado (savanna-like vegetation), Pantanal (wetlands), Atlantic Forest (system of forests and ecosystems under the influence of the Atlantic Ocean) and Pampa (grasslands), each of them with very specific characteristics in terms of landscape, geomorphology, soil, fauna, and flora. The levels of endemism are high in the country [5–7], and Brazil harbors ~15% of all living species on Earth [8]. The Brazilian coastline also has high biodiversity, being considered the 'Blue Amazon'. Marine and coastal resources contribute 19% to Brazil's GDP [9]. The country has a robust deforestation monitoring system coordinated by the National Institute for Space Research [10] with public data available online (<http://terrabrasilis.dpi.inpe.br/>), accessed on 18 June 2022), one of the world's largest amounts of

protected areas (~18% of the terrestrial territory, considering the six biomes), and advanced environmental protection laws [2,7].

On the other hand, persistent and structural problems in Brazilian society, such as racism, gender inequality, lack of environmental sanitation system, transportation problems, unemployment, difficulties in health access, political corruption, violence, and failures in the basic education system [11–14] contribute to the country's monetary well-being being concentrated in a small portion of the population, making Brazil one of the countries with the highest indices of social inequality in the world [15]. In other words, Brazil is not a poor country. In fact, Brazil is a very rich country in different aspects, but it is inhabited by a majority of poor people [16].

Inequalities in access to environmental services, the disparity between policies announcement and implementation, and insufficient qualified human resources to work on environmental issues expand Brazil's social problems to the biodiversity sphere [2]. In this sense, the lack of professionals to explore Brazilian biodiversity (e.g., taxonomists) is a critical problem in Brazil. As a result, many terrestrial taxa and marine systems are poorly studied or remain unknown [5]. It is also necessary to expand the study of biodiversity considering its various multidimensions (i.e., taxonomic, functional and phylogenetic) and complexities [17].

During the current federal government (2019–2022), the problems affecting the distribution of wealth in Brazil are added to the weakening of environmental protection laws and agencies, including the National Indigenous Peoples Foundation (FUNAI), resulting in the encouragement of illegal activities (e.g., mining, logging) in places such as Indigenous lands and protected areas, and leading to environmental degradation and serious conflicts between illegal workers and Indigenous Peoples [18–20].

The legislation-based mandatory maintenance of a fixed proportion of native vegetation in private properties (Legal Reserves) is threatened, particularly by the agribusiness sector [7]. In Brazil, the agribusiness sector (soy, sugarcane, cattle ranches, and meatpacking conglomerates) still shape the bio-based economy ('biomaterials bioeconomy' [21]). It is an organized group with a powerful parliamentary representation, threatening the interest of small farm producers and sustainable development strategies outside the scope of major agribusiness players and also making room for continuous land-use changes in the country, especially deforestation [22–24]. Only behind the USA, Brazil is the second-largest biofuel (e.g., sugarcane-derived ethanol) producer in the world, putting biofuel as the leading product of the bioeconomy sector in the country, exemplifying the strong connection of current Brazil's bioeconomy with intensive agricultural practices and agribusiness [25]. The environmental agenda of the 2019–2022 federal government (led by Jair Bolsonaro) showed a number of other sensitive actions, including incentives for agriculture and livestock expansion, reduction in funds for forest inspection, facilitation for the use of agrochemicals and pesticides, and cuts and weakening of the Brazilian Institute of Environment and Renewable Natural Resources (IBAMA) and the Chico Mendes Institute for Biodiversity Conservation (ICMBio) [23].

After greenhouse gas emissions declined in Brazil by about 50% between 2004 and 2012 (as measured in millions of tons of CO<sub>2</sub> equivalent) due to a dramatic reduction in forest clearing [2], Amazon deforestation has been increasing again since 2013 [26]. In 2021, Amazon deforestation reached an alarming rate of more than 13,000 km<sup>2</sup>, the highest recorded in the last 15 years [26]. This scenario contributes to environmental degradation and disdains the resources that Brazilian biodiversity can offer for the country's development. Current Brazilian economic models do not contribute to environmental protection. When examining economic sectors, agriculture and livestock are the main greenhouse gas producers in Brazil [23].

Anthropogenic fires in the Pantanal and Amazon biomes, both UNESCO World Heritage Sites [27], have been increasingly frequent in recent years [28,29], with smoke reaching big cities such as Curitiba, Rio de Janeiro, and São Paulo [30]. These fires have a social impact on directly affected populations, hinder tourist activities, threaten the survival

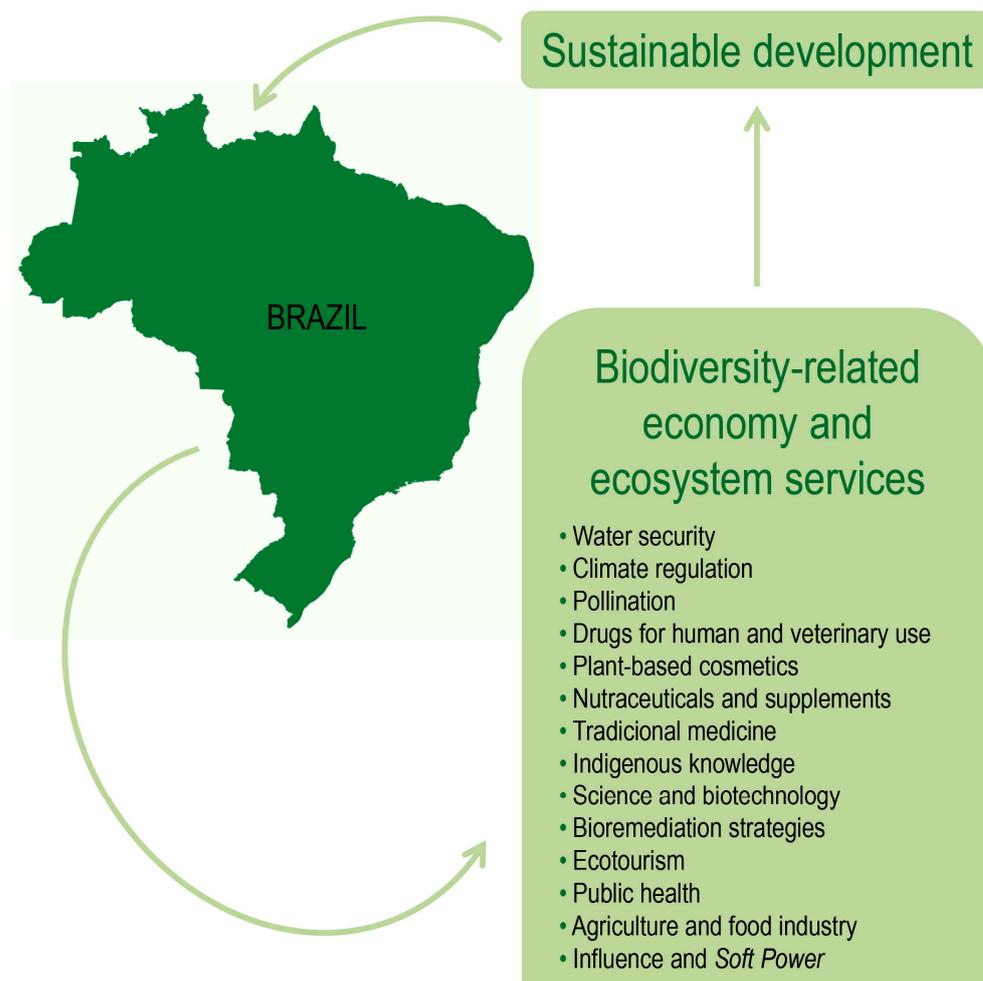
of many animal and plant species, contribute to climate change, and harm the respiratory health of populations that live even at great distances from the affected areas [28,30,31]. In the Amazon forest, fires are strongly connected with deforestation [29]. Recent data shows that since 2001, 103,079–189,755 km<sup>2</sup> (2.2–4.1%) of the Amazon forest has been affected by fires, with multiple deleterious impacts on threatened and endemic species [32]. Fire-related impacts on Amazon biodiversity have been higher since 2019 due to the relaxation of forest protection policies, among other factors [32].

The construction of roads is also threatening biodiversity hotspots (e.g., Iguazu National Park, a UNESCO World Heritage Site) [33] and several Indigenous lands. The Highway BR-319 reopening and eventual paving alone can affect the lives of more than 18,000 Indigenous Peoples in the Amazon region [34]. Beyond the damage caused to natural resources and human and non-human species, this scenario demonstrates that Brazil is wasting its development potential associated with biodiversity. Indeed, despite all the potential in terms of bioeconomy, few products have derived from Brazilian biodiversity so far [8]. Also, beyond the biomaterial bioeconomy (currently Brazil's model), the country should embrace a bioecological bioeconomy, the kind of bioeconomy based on biodiversity [21].

In order to reverse this undesirable scenario mentioned above and put Brazil on the path of sustainable development, it is fundamental to face Brazilian natural resources as much more than sources of basic raw material with low added value, such as 'wood for exportation', which only generate ephemeral gains. Similarly, Brazilian economic development should not be based on the expansion of areas for the production of commodities and livestock [7]. Brazil must embrace sustainable development based on the innovative and bioecological bioeconomy [21].

Sustainable development is classically defined as the ability to meet our present needs without compromising the development of future generations [35]. In this context, the general definition of bioeconomy is the economic model based on bio-based products instead of fossil-based products associated with greenhouse gas (GHG) emissions. Considering its mega biodiversity, Brazil could be a leader in this economic model [8], keeping in mind that most of current Brazil's GHG emissions (~75%) are related to agriculture, deforestation and related land-use changes [36]. It is estimated that up to 7% of Brazil's GDP could be linked to green markets [37]. A strong and durable bioecological economy transition also needs to support actors that are not part of the major agribusiness sector, especially rural family producers and small industries focused on the sustainable development of products from Brazilian biodiversity. Instrumental, structural and discursive power may be used to develop the bioeconomy at the national level and also influence other countries on the path to sustainable development [25].

Brazilian biodiversity is a neglected source of power and sustainable development (Figure 1). Therefore, in this article, we argue that Brazilian natural resources must support sustainable development specifically in three strategic areas: (I) industry, science and technology, (II) biological conservation and maintenance of ecosystem services, considering reverberations on agriculture and public health, and (III) ecotourism, conservation and support to local populations. In other words, Brazil needs to recognize and embrace the power of its biodiversity. The potential of these three strategic areas for economic development, political influence on other countries (*Soft Power*), and preservation of biodiversity are summarized in the next sections. The term 'biodiversity' usually refers to the diversity of species, genetic resources and ecosystems in an integrated manner [38], and we adopted this concept in this article.



**Figure 1.** Neglected Brazil’s virtuous circle of bioeconomy and sustainable development. The Brazilian biodiversity (diversity of species, genetic resources, and ecosystems) provides fundamental ecosystem services to Earth (e.g., water cycle, climate regulation), contributes to public health (e.g., infectious disease control and prevention, pollution reduction), can support the sustainable development of many economic sectors (e.g., pharmaceutical industry, biotechnology, agriculture, ecotourism), and be a source cultural influence and *Soft Power*. Brazil’s map was obtained from MapChart (<https://mapchart.net/>), licensed under a Creative Commons—Attribution-ShareAlike 4.0 International License.

## 2. Industry, Science and Technology

Several drugs and compounds used for medical and veterinary purposes are derived from plants, animals, and fungi. Classic examples are Quinine (anti-malarial from *Cinchona* spp.), Artemisinin (antipyretic, anti-malarial from *Artemisia annua*), Morphine (analgesic from *Papaver somniferum*), Paclitaxel (anti-cancer from *Taxus brevifolia*), Curare (deep muscle relaxant from *Chondodendron tomentosum*), Galantamine (from *Galanthus woronowii*, used to treat dementia), Jaborandi (saliva stimulant from *Pilocarpus jaborandi*), Acetylsalicylic acid (analgesic and antipyretic from *Salix* spp.), and Penicillin (antibiotic from *Pencillium* spp.) [39,40]. In total, ~35% of medicines manufactured by the global pharmaceutical industry are derived from natural products [41].

The study of animal species occurring in Brazil has already brought some important advances in the medical field. Captopril, a drug used worldwide to treat hypertension, is derived from the bradykinin peptide found in the venom of *Bothrops jararaca*, a snake that occurs in many regions of Brazil. Peptides derived from snake venom and other animal toxins have much potential for drug development in many medical fields [8,42].

If we consider the 2000–2013 period, eight genera of Brazilian venomous animal species were involved in patent applications (i.e., *Crotalus*, *Lachesis*, *Bothrops*, *Loxosceles*, *Phoneutria*, *Tityus*, *Acanthoscurria*, and *Phyllomedusa*), totaling 55 patents [43]. Brazil held the highest percentage of patent applications involving venoms from animal species found in the country (49%), followed by the USA (16%) and Germany (15%), with Russia, France, Argentina, China, Spain, Ireland, Mexico, Singapore and Israel accounting for the rest of the patent applications. Although some advances have been made to explore the Brazilian fauna technologically, they are still very modest, considering the huge fauna diversity observed in the country [43].

The Brazilian flora also provides molecules, compounds, extracts and oils that are used or being investigated for the development of cosmetics, ‘green’ solvents, fragrances, food supplements, nutraceuticals [8,44], phytotherapeutic agents [41], drugs for inflammation, allergic, respiratory, digestive, dermatologic, parasitic, bacterial and viral diseases [45], as well as for the preparation of traditional medicines and remedies.

Many Brazilian medicinal plants already had their effectiveness evidenced by scientific studies [46,47]. Concerning this aspect, *Kielmeyera variabilis* (Clusiaceae) is used in Brazilian folk medicine for the treatment of many types of tropical diseases and is being tested as a potential anti-*Staphylococcus aureus* strains resource [8]. Beyond traditional medicine, ‘Aroeira’ (*Schinus molle*), ‘Andiroba’ (*Carapa guaianensis*), ‘Babassu’ (*Orbignya oleifera*), and ‘Carqueja-doce’ (*Stenachaenium megapotamicum*) are some examples of plants found in Brazil that provide vegetable oils for nano emulsions with varied biological applications, including antibacterial, antiparasitic, antifungal, and anti-inflammatory activities [44]. Furthermore, extracts from Brazilian plant species are being investigated as sources of new drugs for cancer treatment [48,49].

In addition to being important sources for the medical and cosmetic industry, components of the Brazilian fauna and flora have a huge potential to be applied in other fields. For example, limonene (a component of citric fruit oils) is considered an innovative ‘green’ chemical with a variety of applications. Limonene can be used for the production of bio-based solvents, cleaning agents, and plant-based pesticides [8]. Venoms, toxins and derivatives from species found in Brazil have already been cited in patents for ‘methods and kits’ with varied applications [43]. The potential of biodiversity is increasingly attracting industry interest. Currently, a Brazilian biotech company prospects Brazil’s marine chemical diversity for a wide range of industry innovations [50].

The Brazilian Agricultural Research Corporation (Embrapa), the Oswaldo Cruz Foundation (Fiocruz) and other Brazilian institutions maintain collections of germplasm, fungi and microorganisms of agricultural and industrial importance [51]. In this sense, Brazilian fungi diversity has an important potential to be used in biomass degradation processes and other biotechnological applications [52]. Microorganisms can also be used in biological pest control in agricultural practice, a strategy already used successfully in various Brazilian regions [53]. Finally, environment-derived microorganisms, natural molecules and genetic resources can be used to develop technological processes for food production, plant breeding [38,54], and bioremediation strategies [55,56]. The examples mentioned above show applications of Brazilian biodiversity far beyond the classical medical field.

More than 25% of the Brazilian population makes direct use of components of Brazil’s biodiversity. However, this use is generally associated with low-technology extractive activities [57]. In this sense, there is a growing consumption of Non-Conventional Food Plants (*Plantas Alimentícias Não Convencionais* [PANC]) in Brazil. It is estimated that Brazilian biodiversity has more than 3000 PANC species, and the guide to identification, nutritional aspects and cooking recipes of PANC in Brazil lists detailed information concerning 351 species [58]. There is an enormous potential for the use of many of these plants in the food industry, which is still under-explored.

Increasing the participation of Brazilian biodiversity in the development of processes and products of high technological content will help to expand and consolidate the participation of bio-based products in the Brazilian economy and also contribute to advances in

the social sphere [57]. Brazil has less than 700 scientists per million inhabitants, which is a low proportion compared to those observed in countries with high technological, social and economic development, such as South Korea (6.457/million), Denmark (7.265/million), and Finland (7.188/million). These data indicate that social and economic development is linked to scientific and technological advances [59]. For these reasons, the bioeconomy should be seen as an opportunity to advance economic, scientific, technological and social aspects in Brazil in an integrated manner [60]. Brazil has a competitive advantage in this regard, as it has much more expressive biodiversity than that observed in several other countries [57].

In this context, basic scientific knowledge is fundamental for sustainable development to be implemented on a national scale. Looking at the data from the period between 1996 and 2021 by world countries, Brazil is currently the 14th country according to the number of published scientific articles [61]. Considering only the production of the year 2021, Brazil maintains the 14th position [61]. The study of Brazilian biodiversity can contribute to Brazil increasing both the number of scientific articles as well as the quality of science developed in the country [62], which is still necessary once Brazil's h-index (=690) is the 23rd in the world ranking [61]. Actions focused on 'smart' development are still concentrated in big Brazilian cities [63], and it is also necessary to move these actions to smaller cities. This can be done, for example, by strengthening public universities and research institutes located in these cities.

Brazilian natural products have an important impact on the national bioeconomy, although this potential is underused [8]. Recently, Brazil has been considered one of the main countries concerning the potential for the future discovery of terrestrial vertebrate species [64]. The prospection of natural compounds from the Brazilian fauna and flora should be seen as a way to generate high-value-added products and development of new drugs and biotechnological processes, contributing to the advancement of industry, science and technology. This strategy would value the Brazilian biodiversity and generate low environmental impacts when compared to the extraction of wood and minerals for exportation, a pervasive and archaic practice in the country, especially in regions like the Amazon forest.

Strategies such as The Amazon Third Way initiative ('Amazonia 4.0') help to promote the Brazilian biodiversity as a driving force for a technological and sustainable economy, using the Amazon's biological and human resources to produce new materials, processes and knowledge to promote social inclusion and respect for Indigenous Peoples and local communities, moving Amazon forest beyond initiatives for environmental conservation (The First Way) and a source of land for crops and livestock (The Second Way). The Amazon Third Way initiative connects conservation purposes with physical, digital and biological technologies, a strategy aligned with the 4th Industrial Revolution [65]. Açai (*Euterpe oleracea*) agroforestry systems add significant gains to the economy of the Amazon region each year, in addition to contributing to the conservation of the Forest [66,67]. In addition to being exported to different countries for human consumption, açai is already used in the manufacture of cosmetics and medical products [68]. The economic gains and jobs generated by the collection, processing, export and domestic demands of Brazil nut (*Bertholletia excelsa*) products, as well as the production of Amazon biodiversity-derived cosmetics by a Brazilian multinational company [65,69], are just a few successful examples aligned with The Amazon Third Way, involving the participation of local communities, especially during the collection and processing stages, and technological development [65]. Similar strategies should embrace other Brazilian biomes, helping to diversify the bioeconomy in different regions of Brazil.

### **3. Biological Conservation and Maintenance of Ecosystem Services: Reverberations on Agriculture and Public Health**

The world population has progressed significantly, considering the reduction of poverty and the increase in the global GDP, which has doubled since 1970 [70]. How-

ever, these advances in living conditions have not been accompanied by the maintenance of environmental quality. It is estimated that 90% of biodiversity loss and water stress is a result of the extraction and processing of natural resources [70]. Most of these resources are removed from developing countries' ecosystems and destined for developed countries, fueling environmental degradation, social inequalities, and environmental injustice. In this sense, Brazil is among the world's leading extractors and exporters of natural resources, which has a huge impact on its biodiversity and ecosystems [70].

Brazilian biomes are responsible for several ecosystem services fundamental to the maintenance of life on Earth. For example, the Amazon rainforest contributes to the capture of atmospheric carbon, maintaining carbon stocks in the trees and soil (around 100 billion tons), thus regulating the Earth's climate and preventing climate change [71]. In addition, the Amazonian biome is responsible for cycling an immense volume of water and maintaining the so-called 'flying rivers' (moisture corridors) [23,72]. The Amazon basin releases ~20 billion tons of water into the atmosphere each day. Only one large tree can put 1000 L of water into the atmosphere/per day through evapotranspiration [73]. The Amazon's flying rivers carry atmospheric water to the South and Southeast regions of Brazil, a pivotal process for agricultural production and Brazilian water security [23,72]. The Amazon is estimated to contribute 70% of the annual mean input of water vapor to the La Plata basin [74]. Therefore, agricultural activities in Brazil would be enormously impacted if the Amazon-associated water cycle is deregulated.

Biodiverse environments also sustain pollination, ensure biological control of crop pests, and promote food security [7]. Moreover, maintaining the richness and abundance of Brazilian biodiversity (less human-disturbed habitats) contributes to the control of infectious diseases through the dilution effect and other ecological mechanisms, reducing the abundance and diversity of zoonotic vertebrate animals, disease vectors and pathogen transmission in a given area. As a consequence, these processes reduce the risk of spillover events (cross-species pathogen transmission) and the emergence of zoonotic infectious diseases. On the other hand, biodiversity loss increases the risk of such diseases [75–77]. Around 75% of emerging infectious diseases result from pathogens that 'jump' from an animal species into the human population [75,77]. In association with biodiversity loss, climate change will favor spillover events. It was recently projected that by the year 2070, climate change could trigger more than 4000 spillover opportunities [78]. These data reinforce that risks for the emergence of new disease outbreaks and even pandemics are on the rise.

Simply put, the preservation of Brazilian biodiversity is essential for maintaining ecosystem services and natural resources that contribute to economic development [8] and multiple aspects of public health, including the reduction of pollution and infectious disease prevention and control [79]. Low-carbon agriculture, precision agriculture and payments for ecosystem services in agricultural systems are some emerging strategies that can help develop a sustainable economy in Brazil [80–82]. From a global perspective, a Brazilian development model focused on the conservation and maintenance of ecosystem services would contribute to global stability in terms of climate, water, food production, and planetary health. This approach is in line with the 'Nexus concept' of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), which recognizes the 'interlinkages among biodiversity, water, food and health' [83].

#### **4. Ecotourism, Conservation and Sustainable Development of Local Populations**

The Brazilian diversity in terms of fauna, flora and geological aspects creates exuberant and exotic landscapes, making Brazil a tourism hub, although ecotourism activities are still underdeveloped in the country [84,85]. Ecotourism activities occur in only 4% of the Brazilian private reserves [84]. Brazil also has specific ecotourism niches (e.g., primate watching) that are still poorly explored [86]. Tourism is a driving force for the creation of protected areas in many countries (e.g., USA, Canada [87]), although the main focus of protected areas in Brazil is on environmental conservation, without necessarily excluding public use for

tourist activities in accordance with conservation rules [87]. According to Souza et al. [88], tourism activities in protected areas support more than 43,000 jobs. However, there is still a lot of room for growth, with significant economic benefits. It is estimated that USD 7 is generated for each USD 1 invested in protected areas [88]. Ecotourism in protected areas currently represents USD 473 million in value added to Brazil's GDP. These values are generated by the economic contributions of visitor spending in accommodation, meals, local transportation, guided tours, retail stores, and other expenses [88]. Examples from other countries show that the potential for ecotourism-related gains can be even higher. In the USA and Canada, the economic significance related to ecotourism in protected areas represents USD 32 billion and USD 2.5 billion per year, respectively [88]. Costa Rica harbors 5% of the world's biodiversity and is a leading ecotourism destination, with ecotourism-related activities playing a huge role in the country's economy (USD 2.85 billion annually), benefiting low-income and rural communities [89]. Of note, nature-based tourism activities are not limited to protected areas and can be developed at national, regional and local levels. The development of sustainable tourist activities with the participation of local communities has the potential to bring a source of income and development to these communities, in addition to sensitizing tourists and local populations concerning the broad value associated with biodiversity and environmental conservation [86,87,90]. Ecotourism can be considered a win-win strategy since it associates conservation and human needs [90].

In Brazil, specific ecotourism projects (e.g., 'Projeto TAMAR', the Brazilian Sea Turtle Conservation Program) and places like the Pantanal region and Bonito (a city in Mato Grosso do Sul State) are good examples of how ecotourism can work properly, with important economic and social gains to the local populations, showing that biodiversity can be a driving force of economic and social security [38,90], although there are an amazingly low number of such ecotourism sites considering Brazil's enormous biodiversity. Incentive policies for ecological and sustainable tourism should gain prominence in the Brazilian development model.

Beyond ecotourism, conserved forest areas can support forest carbon trading. The selling of carbon emission credits can generate economic profits equivalent to or even greater than environmentally harmful activities, like logging [91,92], preventing deforestation-related ecological damages and directly benefiting populations and landowners involved in the conservation of these areas. Profits from the carbon market may replace profits from exploratory activities (e.g., cattle ranching, logging) even in the Amazon region [92,93]. Brazil has more than 566,100 hectares of road margins with potential for restoration, corresponding to USD 202 million to USD 26.5 billion in the carbon market [94]. The carbon emission trade is mostly neglected in Brazil [94], but it should be popularized and gain relevance in the country as an additional way to ensure the development of the bioeconomy. It was estimated that by 2030 the potential of Brazil's carbon markets would represent values ranging from USD 493 million to USD 100 billion if considering the entire country [95]. There are issues in the carbon market that need to be solved, including regulation and pricing control [96]. However, beyond the potential economic profits associated with the carbon trade, the maintenance and even restorations of Brazilian natural landscapes could contribute to containing biodiversity loss and reduce the risks of extreme climate events [71,97] and the spread of zoonotic diseases [79].

## 5. Additional Reasons for Preserving Biodiversity

Biodiversity brings other benefits in addition to those mentioned above, but they are often overlooked because non-utilitarian benefits are difficult to measure, such as the contribution of natural landscapes and green areas to human well-being, sustainable lifestyles and many aspects of health, including improvements in respiratory, mental, immunological, and cardiovascular health [98,99]. Beyond that, the aesthetic and cultural value of natural landscapes should be enough to justify conservation actions [100]. Brazilian biomes are part of the culture of Brazilians and must be preserved for such reasons. Highlighting the

aesthetic value of natural landscapes can help engage people in initiatives of biodiversity conservation [100].

Plant, animal and even microbial diversity have intrinsic value. In other words, species simply have a right to exist, far beyond their potential utilitarian value to industrialized populations. The same is true for Indigenous Peoples and local communities living in biodiverse areas like the Amazon forest. These populations have a strong intrinsic value, and this should be enough to justify their protection [38,101].

In brief, biodiversity has (I) instrumental, (II) relational and (III) intrinsic values [102]. Based on this model, the Amazon forest contributes to the climate regulation and maintenance of the water cycle (instrumental value); it is an area of rich and ancient interactions between humans and nature (rational value); and also has value by itself regardless of any human interest (intrinsic value). Similarly, Brazil's Pampa biome [103] is fundamental for carbon capture and preservation of grass species with importance for livestock (instrumental value); it is a biome that is part of the *Gaúcho* culture or 'man of the field' (rational value) and has right of existence without any other justification (intrinsic thanks). The same model of 'biodiversity values' [102] can be applied to other Brazilian biomes and species in particular.

Finally, it is essential to emphasize that traditional knowledge, especially from Indigenous Peoples, is a source of cultural wealth resulting from centuries and even millennia of sustainable interaction between human beings and the natural environment. This knowledge can help humanity to face challenges in the spheres of conservation, sustainability, development, climate change adaptation, food security, and many others [104–107]. As mentioned earlier, the Brazilian federal government has systematically weakened regulations for the protection of traditional peoples and Indigenous lands. The effects of the detrimental political agenda for these populations were intensified due to the COVID-19 pandemic [18,19]. Neglecting these populations, in addition to inflicting humanistic and ethical issues, means losing an additional source of biodiversity-related wealth.

## 6. Final Considerations: Looking Ahead

If we think in historical terms, the COVID-19 pandemic could be considered the final milestone of the 20th century, just as World War I marked the end of the 19th century in 1918 [16]. The Brazilian nation must rethink how it will deal with its biodiversity throughout the 21st century. Brazil has already played an important role as a global leader in the environmental area, as exemplified by Brazil's leading role in 'Rio 92' (Rio de Janeiro Earth Summit 1992) or by reducing the Amazon deforestation by over 80% between 2004 and 2012 [26]. During this period, Brazil was considered a leading country in sustainable development. However, Brazil's influence on the environmental agenda has been systematically reduced [20,35,108]. According to the 2019 Global Ranking of Soft Power ('The Soft Power 30' index), Brazil holds the 26th position in the world [109]. However, Brazil may have a greater influence on the global scenario. Brazilian biodiversity is an important but neglected source of *Soft Power* [35]. If improved, it could contribute to the country's image as a global leader, influencing the environmental policy agenda again. Beyond that, Brazilian biodiversity could be translated into abundant resources for economic, scientific and technological development with the potential to strongly influence the international scenario in several areas.

Some innovative initiatives are already contributing to achieving these goals; others need to be expanded. The Amazon Institute of Technology (AmIT, see <https://amit.institute/>), aims to involve Brazil and other countries of the Amazon basin in projects for sustainable development based on natural resources and traditional knowledge [110]. Also, the project 'Amazônia: bioeconomy connections' aims to facilitate Brazil–German partnerships focused on the bioeconomy in the Amazon region [111]. Documents such as the National Biodiversity Strategy and Action Plan (NBSAP) are important to guide Brazil's actions on the path of sustainable development and environmental protection [112]. Brazilian institutions such as *Embrapa Agroenergia* are contributing to national sustainable develop-

ment with high-value-added products produced from renewable raw materials [113]. The participation of BNDES, the Brazilian development bank, in the financing of bioeconomy-related initiatives is also relevant [114]. Finally, the expansion of technology parks and greater support for *startups* are critical actions to translate ‘biotechnological potentials’ into high-value-added products and services available on the market [115]. Table 1 summarizes solutions and initiatives to protect Brazilian biodiversity and advance sustainable development (in a complementary way) based on the documents cited throughout this article and also on experiences from other countries (e.g., Germany, Denmark, France, Costa Rica, and the USA [116]).

**Table 1.** Potential solutions and initiatives to protect Brazilian biodiversity and promote sustainable development.

Main Area	Solutions and Initiatives <sup>1</sup>
Industry, science, and technology	Promotion of dialogue with society for the definition and implementation of bioeconomy policies
	Creation of an inter-ministerial group responsible for the national bioeconomy policy, with regional governments developing regional policies, funding and mobilizing actors for policy implementation
	Increase and train human resources (scientists and technicians) qualified to recognize, classify and attribute value to biodiversity
	Reduce social inequalities and environmental injustice
	Direct more resources to the ‘bioecological bioeconomy’ and not only to the ‘biomaterial bioeconomy’
	Explore the potential of biodiversity applications beyond the medical field, including agriculture, veterinary medicine, technology industry, among others
	Ensuring the continuity of national scientific production and putting more effort into the quality of scientific publications
	Increase funding for universities and research institutes
	Expand technology parks and provide basic conditions for the development of new startups
	Face scientific and technological development as a mechanism to improve the social sphere
Biological conservation and maintenance of ecosystem services	Control the Amazon deforestation and anthropogenic fires in the Brazilian biomes
	Protect Traditional Peoples and Indigenous lands
	Professionalize workers involved in extractive activities
	Prioritize family farming and agroecological systems in agricultural development programs
	Invest in low-carbon agriculture, precision agriculture and payments for ecosystem services in agricultural systems
	Control land-use changes (e.g., mining, deforestation) in areas of high biodiversity
	Reduce human-animal interactions that favor spillover events, such as wild animal hunting
	Increase food and nutrition security by reducing poverty and social inequalities
Expand environmental education programs	

Table 1. Cont.

Main Area	Solutions and Initiatives <sup>1</sup>
Ecotourism, conservation and sustainable development of local populations	Develop ecotourism activities in both protected and non-protected areas at national, regional and local levels
	Explore ecotourism niches (e.g., primate watching)
	Professionalize local populations to explore the touristic potential of the regions where they live
	Recognize the usefulness of Traditional Peoples' knowledge for sustainable development
	Explore the potential of Non-Conventional Food Plants ( <i>Plantas Alimentícias Não Convencionais</i> [PANC]), valuing traditional knowledge and contributing to innovation in the food industry (especially for small family production/industry)
	Consolidate and expand policies for ecological and sustainable tourism
	Encourage public-private partnerships and the participation of NGOs in ecotourism activities
	Consolidate, regulate and expand Brazil's participation in the carbon market

<sup>1</sup> Some solutions cited within a 'main area' may also apply to another area. The division made in this table is for didactic purposes only.

To strengthen these (Table 1) and other similar initiatives, the Brazilian population must elect politicians committed to environmental conservation policies, sustainable development strategies, and the continuous supply of resources for science and technology, putting in practice a translational ecology [117]. Advances in the areas of education, democracy, and social mobilization are also essential. The recent election of a new federal government (2023–2026, led by Luiz Inácio Lula da Silva) has brought optimism towards Brazil's development in several pivotal areas, such as science, education and environmental preservation, especially considering the Amazon forest [118,119]. It is essential that Brazilian society monitor government actions in the next years, demanding ecologically sustainable solutions for national problems. Along with this, the scientific community should increase the number of studies focusing on Brazilian biodiversity. If this does not happen urgently, Brazil will lose valuable development resources and opportunities to act as a global leader in the environmental area. Following this undesirable path, Brazil will continue to be a rich country inhabited by mostly poor people.

Finally, Brazil needs to overcome the dominance of agribusiness as the main influencer of biomaterial bioeconomy policies in the country [25] through the strengthening of a greater number of small actors linked to sustainable development. Brazil also needs to move away from pseudo-development models that consider natural resources to be cheap and raw materials of a primary economy. The country will not reach full development by mostly exporting products such as grains, meat, wood or minerals to other countries. Brazil must recognize and intelligently embrace its natural wealth, developing the powers of biodiversity sustainably.

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