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Inference of the Biophysical Impacts of Logging on the Mangroves of the Tristão Islands Based on a Comparative Review of the Scientific Literature

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Abstract

Mangroves are critically important coastal ecosystems that provide a wide range of essential ecosystem services, including carbon sequestration, coastal protection, and support for rich biodiversity. However, these ecosystems are universally threatened, with wood harvesting being a major anthropogenic pressure, particularly pronounced in West Africa leading to profound biophysical impacts. This article aims to characterize the biophysical effects of wood cutting on mangroves, focusing on the specific context of the Tristão mangroves in the Republic of Guinea. In the absence of direct, site-specific biophysical data for Tristão in the available literature, potential impacts are inferred and discussed considering well-documented regional and international trends. A thorough comparative analysis is conducted, comparing inferred observations from Tristão with findings from other regional and global studies, to derive broader implications for conservation and sustainable management in similarly vulnerable coastal regions.

Keywords

Mangroves, Coastal Ecosystems, Ecosystem Services, Carbon Sequestration, Coastal Protection, Biodiversity, Anthropogenic Pressures, Wood Harvesting, Biophysical Impacts, West Africa, Tristão Islands, Conservation, Sustainable Management, Comparative Analysis

1. Introduction

1.1. Global Importance of Mangrove Ecosystems

Mangroves are universally recognized as one of the most productive ecosystems on the planet, providing a multitude of ecological functions essential to the health of coastal areas and human well-being [1]. These functions include soil stabilization, coastal protection against erosion and storms, and the role of habitats and nurseries for numerous species of fish and invertebrates. Beyond their structural and ecological support, mangroves also act as natural filtration systems, retaining, transforming, and recycling nutrients, sediments, and certain pollutants, which helps improve the quality of coastal waters [2]. This function also promotes the protection of adjacent coastal ecosystems, including coral reefs and seagrass beds, by limiting excessive inputs of sediments and nutrients.

Furthermore, mangroves are globally recognized as important "blue carbon" ecosystems due to their exceptional capacity to capture and store atmospheric carbon dioxide in their aboveground biomass, roots, and especially their organic matter-rich soils. Mangroves have some of the highest carbon stocks per unit area of all forest ecosystems. When considering the entire ecosystem (biomass and soils), they can store up to five times more carbon than many terrestrial tropical forests, although this value varies depending on ecological conditions, species, and soil characteristics [3].

This strong sequestration capacity constitutes an essential biophysical function of mangroves. Consequently, their degradation or conversion leads not only to a reduction in carbon stocks, but also to significant greenhouse gas emissions, which reinforces the importance of their conservation in climate change mitigation strategies.

1.2. Mangrove Forests in West Africa and the Republic of Guinea

West and Central African mangrove ecosystems are subject to intense anthropogenic pressures, including logging, agricultural and aquaculture expansion, urbanization, and the effects of climate change. Their conservation remains limited in several countries by shortcomings in governance, management, and the valuation of their ecosystem services. Regional analyses show a continuous decline in mangrove areas in Africa over recent decades, although the extent of losses varies depending on the country, the study period, and the estimation methods used. In the absence of detailed biophysical data for the mangroves of the Tristão Islands, trends observed in West Africa provide a comparative framework for inferring the potential impacts of logging. However, these conclusions are based on a comparative analysis of the literature and not on direct observations made on-site [4].

1.3. The Problem of Logging and Its Biophysical Impacts

Globally, mangroves are under significant human pressure. Studies indicate that approximately 20 - 35% of their original area has disappeared in recent decades, and that annual loss rates have generally varied between 1 and 2% depending on the period and region, although these rates have decreased in several countries thanks to conservation and restoration policies [2]. Historically and currently, the main drivers of mangrove loss include land clearing, logging for timber and fuelwood, the expansion of agriculture and aquaculture, as well as rapid coastal population growth and urbanization. In the West African context, several forms of timber exploitation are recognized as major pressures on mangroves, including overexploitation of wood for fish smoking, fuelwood production, charcoal production, housing and boat construction, as well as illegal logging. The conversion of mangroves for infrastructure, urbanization and construction activities also contributes to their degradation by reducing forest area and fragmenting coastal habitats.

Studies conducted in Ghana, Cameroon, Nigeria, and other West African countries consistently show that logging, whether for timber, fuelwood, fish smoking, or construction materials, is a major driver of mangrove degradation. Based on these comparable ecological contexts, it is reasonable to assume that similar pressures could also affect the mangroves of the Tristão Islands, although this hypothesis requires validation through field investigations [5] [6]. Other available studies show that intensive logging alters the structure of mangrove stands, reduces aboveground and belowground biomass, diminishes carbon stocks, and compromises several ecosystem services, including coastal protection, biodiversity conservation, and carbon sequestration [7].

General objective

Conduct an inferential review of the scientific literature in order to identify and analyze the potential biophysical impacts of logging on the mangroves of the Tristão islands, based on knowledge acquired in comparable ecological contexts.

Specific objectives

1) Identify scientific publications and technical reports relating to the biophysical impacts of logging in tropical mangroves, particularly in West Africa.

2) Compare published results concerning floristic composition, stand structure, biomass, carbon stocks, biodiversity and ecological processes in mangroves subjected to logging.

3) Analyze the convergences, divergences and limitations of available knowledge in order to identify the main degradation mechanisms reported in the literature.

4) Infer, from studies carried out in comparable ecological contexts, the biophysical impacts likely to affect the mangroves of the Tristão islands, while specifying the uncertainties linked to the absence of specific field data.

Unlike a biophysical characterization study based on field observations, this work relies exclusively on a comparative review of scientific literature. The conclusions drawn for the mangroves of the Tristão Islands result from an inferential approach based on ecological analogies with studies conducted in comparable regional and international contexts. They should therefore be interpreted as scientifically supported hypotheses rather than direct observations.

2. Methods

This study is based on an inferential and comparative review of scientific literature. Due to the lack of recent and directly comparable biophysical field data for the mangroves of the Tristão Islands, the analysis aims to infer the probable impacts of logging from studies carried out in similar ecological contexts.

2.1. Documentary Research Strategy

A systematic literature search was conducted between January and April 2026 in several international scientific databases: Web of Science, Scopus, ScienceDirect, Google Scholar, and JSTOR. Technical and institutional reports published by FAO, IUCN, Ramsar, CIFOR-ICRAF, Global Mangrove Watch, and the World Bank were also consulted to supplement the available information.

The searches were conducted using combinations of the following keywords, in French and English:

- *Mangrove, mangrove forest;*
- *wood harvesting*, *wood cutting*, *logging*;
- *Biophysical impacts*, *ecosystem services*;
- *Carbon stock*, *blue carbon*, *aboveground biomass*;
- *West Africa*, *Guinea*, *Tristão Islands*, *coastal wetlands*;
- *Mangrove degradation*, *mangrove restoration.*

Boolean operators **AND** and **OR** were used to refine searches (e.g., *mangrove AND carbon stock, mangrove AND wood harvesting, West Africa AND mangrove degradation*).

2.2. Criteria for Selecting Studies

The publications were selected according to the following criteria:

- Peer-reviewed scientific articles;
- Technical reports from recognized organizations;
- Studies published mainly between 2000 and 2025, with inclusion of some earlier fundamental references when they were authoritative;
- Works focusing on the biophysical characteristics of mangroves, their carbon stocks, biodiversity, degradation processes or the impacts of timber exploitation;
- Studies carried out in West Africa or in tropical regions with comparable ecological conditions.

Publications that did not provide verifiable scientific data, documents that did not deal with mangroves, or documents that presented redundant information were excluded.

2.3. Comparative Analysis and Inferential Approach

The selected studies were analyzed according to a common framework including:

- Biophysical characteristics of the stands;
- Indicators of biomass and carbon storage;
- Effects of logging on soil stability, hydrological processes and biodiversity;
- Factors of degradation and restoration measures.

The results were then compared to identify convergences and divergences between the different geographical contexts.

The implications for the mangroves of the Tristão Islands were inferred from trends observed in comparable ecosystems. This approach is based on the principle that mangroves with similar ecological characteristics may respond similarly to analogous anthropogenic pressures. Therefore, the conclusions concerning Tristão should be interpreted as scientifically supported hypotheses and not as direct field observations.

2.4. Limitations of the Study

This review does not include any biophysical measurements taken directly on the mangroves of Tristão Island. The results depend on the quality, availability, and heterogeneity of the published studies. Differences in methodology, spatial scale, and ecological context among the compared studies limit the generalizability of the results. Therefore, the impacts attributed to Tristão should be considered probable impacts requiring validation through field surveys, dendrometric measurements, and remote sensing analyses.

3. Biophysical Characterization of the Impacts of Logging on Mangroves

3.1. Impacts on Biomass and Carbon Stocks

Studies conducted in different mangrove ecosystems show that logging generally leads to a decrease in aboveground biomass and carbon stocks. In this study, these mechanisms are considered likely to occur in the mangroves of the Tristão Islands, although they have not been directly measured at this site.

This immediate loss of biomass directly translates into a reduction in the ecosystem's carbon storage capacity. Globally, the average aboveground biomass of mangroves is estimated at approximately 184.8 Mg ha^{-1}. Regional studies show variability, with values of around 120.5 Mg ha^{-1} in southeastern Mexico and high carbon stocks in Amazonian mangroves, highlighting the importance of these ecosystems as carbon reservoirs [8].

The removal of trees through logging reduces the continuous carbon sequestration capacity of mangroves, as they are "blue carbon" ecosystems capable of capturing and storing carbon in their living biomass and in their organic matter-rich soils. This function plays an important role in mitigating climate change. Studies conducted in comparable contexts suggest that logging reduces this sequestration capacity [8]. Studies conducted in various mangrove ecosystems show that a reduction in biomass following logging is generally accompanied by a decrease in carbon stocks and the ecosystem's carbon sequestration capacity. These results indicate that logging can compromise an essential biophysical function of mangroves in climate regulation. By analogy with these studies, a similar impact is likely to occur in the mangroves of the Tristão Islands, although it was not directly quantified in this study [4].

3.2. Consequences for Soil Stability and Hydrological Processes

The dense and complex root systems of mangroves play a vital role in dissipating wave energy and stabilizing coastal soils. These plant structures act as natural barriers, helping to reduce the exposure of coastal areas to storms, erosion, and extreme events [3]. Several studies conducted in different tropical regions indicate that the degradation of mangrove root structures can reduce soil stability and increase the susceptibility of coastal areas to erosion [9]. However, in the absence of direct measurements carried out in the Tristão Islands, this relationship is considered a hypothesis based on observations from comparable tropical contexts.

Beyond their physical role in coastal stabilization, mangroves perform several hydrological and biogeochemical functions, including sediment trapping, nutrient retention, and filtration of certain contaminants. The degradation of these ecosystems can alter sediment dynamics and affect the quality of coastal waters [10]. In the Tristão Islands, in the absence of direct measurements of these processes, the potential effects of logging on these ecological functions are considered hypotheses supported by observations made in comparable tropical contexts.

The harvesting of mangrove timber leads to a reduction in vegetation cover and root structures that contribute to soil stabilization and wave energy dissipation [3]. In several tropical regions, mangrove loss is associated with increased vulnerability of coastal areas to erosion, extreme weather events, and sea-level rise [11] [12]. In the absence of direct measurements in the Tristão Islands, the effect of timber harvesting on these processes is considered a hypothesis based on observations made in comparable contexts.

3.3. Impacts on Associated Biodiversity and Ecosystem Services

Mangroves are ecosystems of high biological value, harboring a significant diversity of species and providing essential habitats, including breeding and nursery areas for several species of fish, crustaceans, and other associated organisms. Several studies show that anthropogenic pressures, particularly intensive logging, can lead to habitat degradation and a decline in mangrove biodiversity [9]. In the case of the Tristão Islands, however, these potential effects should be considered hypotheses requiring validation through ecological field observations.

The complex root systems of mangroves constitute structured habitats providing essential refuge and nursery areas for many aquatic species exploited by coastal populations [13]. Degradation of these habitats through logging can lead to a decline in associated ecosystem services, particularly those related to fisheries resources and the livelihoods of local communities. However, for the Tristão Islands, the magnitude of these effects should be considered a hypothesis requiring validation through ecological and socio-economic field observations.

Mangroves constitute structured habitats that serve as refuge, feeding, and breeding grounds for numerous aquatic species, including commercially important fish [14]. The degradation of these habitats through logging can lead to a decline in associated ecological functions and indirectly affect the fisheries resources upon which coastal communities depend [5]. In the Tristão Islands, this relationship is a hypothesis derived from the scientific literature and requires validation through local ecological and socio-economic data.

4. Mangrove Degradation in West Africa: A Regional Comparative Analysis

The results presented in this section come exclusively from studies conducted in other regions of West Africa or the world. They constitute a comparative framework intended to shed light on the potential context of the mangroves of the Tristão Islands and should not be interpreted as observations made directly on this site.

4.1. Overview of Degradation Rates and Factors

West Africa is among the regions where the loss of wetlands, particularly mangroves, is of particular concern. In Ghana, several studies report a decline in mangroves attributed mainly to urbanization, agricultural expansion, and logging, with annual rates of degradation varying according to the sites and periods studied (**Table 1**).

The coasts of West and Central Africa are experiencing an average shoreline retreat estimated at approximately **1.1 m/year,** although this value varies considerably across different areas [13]. Projections indicate that, without effective adaptation measures, coastal erosion and sea-level rise could lead to significant land loss and increased vulnerability of coastal populations.

The main causes of mangrove degradation in West Africa are linked to human activities, including the exploitation of wood for smoking fish, firewood, charcoal production and building materials, to which are added, in some contexts, illegal logging and land conversion [15]. The main causes of mangrove degradation in West Africa are linked to human activities, including the exploitation of wood for fish smoking, firewood, charcoal production and building materials, to which are added, in some contexts, illegal logging and land conversion [16]. West African mangroves are subject to multiple anthropogenic pressures, including oil spills, industrial discharges, land conversion for agriculture and urbanization, and the exploitation of biological and forest resources [12]. In some Central African countries, studies have also highlighted links between certain harvesting practices of organisms associated with mangroves, such as the collection of *Lepidophthalmus turneranus*, and the degradation of this ecosystem [16]. Observations made in several West African countries suggest that the mangroves of the Tristão Islands may be exposed to similar pressures. However, this hypothesis will need to be confirmed by specific field investigations. Ghana's mangroves experienced an estimated average loss of **8.1 km^2 per year** during the study period [16]. This value, expressed as an absolute area, cannot, however, be directly compared to relative rates of change reported at the global or regional scale, such as estimates of approximately **0.52%/year** for global wetlands **or 0.18%/year for Southeast Asian mangroves** [12]. Indeed, the former correspond to area losses expressed in absolute units (km^2/year), while the latter describe proportional changes (%/year). In the absence of harmonized units of measurement and calculation methods, the indicators presented cannot be directly compared. They are therefore interpreted separately and used only to illustrate the extent of the degradation observed in different geographical contexts [17].

Table 1 presents a comparison of degradation rates and key drivers in selected regions of West Africa and globally, illustrating the variability and regional specificity of threats. It highlights significant variability in mangrove degradation rates between continents and countries. The highest rates are generally observed in several Asian countries, notably Indonesia, Myanmar, and Thailand, where the conversion of mangroves into aquaculture ponds, agricultural expansion, and coastal infrastructure development are the main drivers of loss. In Africa, degradation levels are more heterogeneous. Countries such as Nigeria and Ghana have relatively high rates due to the combined effects of urbanization, oil exploitation (in the Niger Delta), agriculture, and logging, while others, such as Senegal and Guinea, generally have moderate rates, primarily linked to logging, traditional salt production, and pressures from riparian communities.

Table 1. Rates of mangrove degradation and main factors in selected regions of West Africa and the world.

Continent	Country	Observed degradation rate	Reference period	Main causes	References
Africa	Guinea	0.3 - 0.7%/year (estimates from different studies)	Variable	Timber harvesting, salt production, fishing	The references are listed in the References section.
	Ghana	≈0.8 - 1.2%/year	1990 - 2020	Urbanization, agriculture, logging	
	Nigeria	1.0 - 2.0%/year	Variable	Oil industry, urbanization, forestry	
	Senegal	0.2 - 0.6%/year	Variable	Salt production, drought, logging	
Asia	Indonesia	1.0 - 2.0%/year	1980 - 2015	Aquaculture, oil palm plantations	
	Myanmar	1.0 - 1.8%/year	1978 - 2011	Agriculture, forestry	
	Thailand	0.8 - 1.5%/year	1975 - 2005	Shrimp farming, urbanization	
	Vietnam	0.5 - 1.0%/year	Variable	Aquaculture, coastal development	
Europe	Spain (Andalusia)	<0.1%/year	Variable	Limited local pressures	
	Portugal	<0.1%/year	Variable	Limited local pressures	

Continued

America	Brazil	0.2 - 0.5%/year	Variable	Urbanization, aquaculture
	Mexico	0.3 - 0.7%/year	1970 - 2015	Agriculture, tourism
	Ecuador	0.8 - 1.5%/year	1970 - 2010	Shrimp farming
	United States (Florida)	<0.3%/year	Variable	Urbanization, hurricanes

In the Americas, degradation rates are generally low to moderate, although some areas, particularly in Ecuador, have experienced significant losses due to the development of shrimp farming. Conversely, the United States (Florida) and some regions of Brazil have relatively low rates, partly due to strengthened conservation policies and the creation of protected areas. In Europe, mangroves are virtually absent from the continent; the reported values mainly concern a few subtropical territories where mangrove areas are limited and losses remain very low.

These regional differences reflect not only the intensity of human pressures, but also the socio-economic contexts, management policies, regulatory frameworks, and environmental conditions specific to each country. However, these values should be interpreted with caution, as they are derived from studies conducted at different times and using varying methodologies. They therefore represent useful orders of magnitude for general comparison, rather than directly comparable estimates across all countries.

Guinea falls into a category of moderate to locally high degradation. In the Tristao Islands, the main pressures identified in the literature concern the exploitation of mangrove wood for fuelwood and construction materials, as well as traditional salt production and fishing activities. Although these pressures are significant locally, the available quantitative data remain limited, justifying a comparative analysis with other West African countries to better understand the observed level of degradation.

Classification used

Annual rate of deterioration	Classification
<0.10%	Very low
0.10 - 0.30%	Weak
0.30 - 0.70%	Moderate
0.70 - 1.00%	High
>1.00%	Very high

4.2. Socio-Economic Dimensions of Degradation

In West Africa, mangrove degradation is closely linked to the heavy reliance of coastal communities on natural resources, particularly for fuelwood, fishing, construction materials, and other forest products [18]. This heavy reliance can lead to unsustainable exploitation patterns, including timber extraction, agricultural expansion, and certain fishing practices, especially when opportunities for economic diversification are limited. Several studies also show that socioeconomic factors such as household income, household size, gender, and education level influence the intensity and patterns of forest resource use [19].

Numerous studies show that mangrove degradation results not only from direct biophysical pressures, such as logging, but also from underlying socio-economic factors, including poverty, dependence of populations on natural resources, low levels of education, and a lack of income-generating activities [20]. Consequently, the sustainable conservation of mangroves requires integrated approaches combining ecosystem protection, improved livelihoods, and local development [12].

Numerous studies show that mangrove degradation results not only from direct biophysical pressures, such as logging, but also from underlying socio-economic factors, including poverty, dependence of populations on natural resources, low levels of education, and a lack of income-generating activities [21]. Consequently, the sustainable conservation of mangroves requires integrated approaches combining ecosystem protection, improved livelihoods, and local development [22].

Several studies conducted in West and Central Africa show that mangrove degradation is associated with socio-economic factors such as local communities' dependence on natural resources, poverty, and limited economic alternatives [23]. In the context of the Tristão Islands, this relationship is considered an explanatory hypothesis based on observations from comparable regions, but it requires validation through specific socio-economic surveys and field observations.

The literature shows that ecological restoration actions for mangroves, such as replanting, can have limited effectiveness when not accompanied by a reduction in the socio-economic factors causing degradation [24]. Thus, sustainable conservation strategies require an integrated approach combining ecological restoration, participation of local communities, and the development of economic alternatives that reduce dependence on mangrove resources.

4.3. Regional Conservation and Restoration Efforts

Despite the extent of mangrove degradation in West Africa, several restoration initiatives have shown encouraging results. Community-based restoration programs, particularly in Senegal and The Gambia, have restored several hundred hectares of degraded mangroves through the involvement of local communities and the regeneration of stands [24]. In Liberia, mangrove restoration initiatives have also been developed to strengthen coastal protection and restore certain ecological functions [25]. Successful restoration experiences in West Africa show that the recovery of mangrove ecological functions is possible when interventions are based on coordination between public institutions, international organizations, local communities, and scientific actors [6] [24]. These initiatives demonstrate that the biophysical impacts of mangrove degradation are not necessarily irreversible, but that restoration strategies must be adapted to the ecological and socio-economic characteristics of the sites concerned [15] [22]. Thus, similar approaches could be considered in the Tristão Islands, subject to a prior assessment of local conditions.

5. Global Perspectives on Mangrove Ecosystems and Carbon Dynamics

5.1. Comparative Estimates of Carbon Stocks

Mangroves are recognized as ecosystems with a high carbon storage capacity, ranking among the most carbon-rich tropical forest formations, notably due to the significant accumulation of carbon in organic soils [4]. However, carbon stocks vary considerably depending on the region, dominant species, stand structure, edaphic conditions, and assessment methods used [17].

The high spatial variability of mangrove carbon stocks reflects the combined influence of floristic composition, stand structure, environmental conditions, and the assessment methods used [8]. Mangrove degradation through activities such as logging can lead to a decrease in these carbon stocks and compromise a major ecosystem service in the context of climate change [17] [26]. **Table 2** below provides a comparative view of carbon stock estimates in mangrove ecosystems at regional and global scales.

Table 2. Comparative estimates of carbon stocks in mangrove ecosystems (regional and global).

Region/Country	Type of carbon stock	Estimated value	Dominant species (if specified)	Reference
World (average)	aerial biomass	184.8 Mg ha^{-1} (dry weight)	Various species	The references are listed in the References section.
Tropical mangroves (general)	Total carbon stock of the ecosystem	≈1023 Mg C ha^{-1}	Various species	
Amazon (Brazil)	Total carbon stock	361 - 746 Mg C ha^{-1}	Rhizophora spp., Avicennia spp.	
Central Africa (slightly disturbed forests)	aerial biomass	≈538 Mg C ha^{-1}	Rhizophora racemosa, Avicennia germinans	
Southeast Mexico	aerial biomass	≈60.25 Mg C ha^{-1}	*Rhizophora mangle*, *Avicennia germinans*, *Laguncularia racemosa*	
Pasar Banggi (Indonesia)	Average carbon stock	≈737.2 Mg C ha^{-1}	*Rhizophora apiculata* , *R. Stylosa* , *R. mucronata*	

Continued

Kerala (India)	Plant biomass	≈58.56 Mg C ha^{-1}	Various species
Southeast Asia (general)	Total carbon stock	500 - 1000 Mg C ha^{-1}	Rhizophora spp., Avicennia spp.

5.2. Global Degradation Rates and Dominant Factors

Globally, mangroves have experienced a significant decline in recent decades. Several studies estimate that a considerable proportion of historical mangrove areas have disappeared, with annual loss rates generally ranging from 1% to 2% depending on the period and region considered [10]. For all wetlands, global estimates also indicate significant rates of decline, on the order of 0.52% per year [7]. However, the dominant causes of degradation differ across regions: logging in West Africa, agricultural conversion, aquaculture, urbanization, or coastal infrastructure in other contexts [2]. Urbanization also constitutes a localized but significant pressure factor. Globally, wetland losses are particularly significant in several low-income regions, notably in Africa, Latin America, and the Caribbean, where socioeconomic factors contribute strongly to the degradation of coastal ecosystems [27]. The differences observed between regions demonstrate that mangrove conservation strategies cannot be based on a uniform approach. The literature emphasizes that interventions must be adapted to local ecological, institutional, and socio-economic contexts, including resource use patterns and the needs of riparian communities [28] [29]. Therefore, management measures planned for the Tristão Islands will need to consider the specific factors related to mangrove timber harvesting and local livelihoods. In Southeast Asia, mangrove losses observed between 2000 and 2012 averaged approximately 0.18% per year. The main causes identified were conversion to aquaculture (30% of cover changes), rice cultivation (22%), and oil palm expansion (16%), with significant variations between countries [30].

5.3. Loss of Biodiversity and Risk of Extinction

The global degradation of mangrove ecosystems poses a significant threat to the biodiversity associated with these environments. According to [31], approximately 16% of assessed mangrove species are at high risk of extinction, primarily due to habitat loss and degradation. These pressures result from land conversion, overexploitation of resources, and changes in coastal land use [9]. The degradation and progressive disappearance of mangroves worldwide pose a significant threat to the biodiversity associated with these ecosystems. A global assessment has shown that approximately 16% of the mangrove species evaluated are at high risk of extinction, primarily due to habitat loss and anthropogenic pressures [20]. The reduction in species and genetic diversity can affect the resilience of mangrove stands and compromise their ability to maintain their ecological functions and ecosystem services [32].

The loss of species and genetic diversity associated with mangrove degradation can reduce their ecological resilience and their capacity to adapt to environmental changes. This decrease in the functional integrity of ecosystems can also affect the provision of essential ecosystem services, such as coastal protection, maintenance of fish habitats and carbon storage [5] [33].

6. Discussions: Implications for the Tristão Mangroves and Future Research

6.1. Inference of Biophysical Impacts at Tristão

Studies conducted in West Africa regularly identify the exploitation of mangrove wood for domestic fuel, fish smoking and construction materials as one of the main anthropogenic factors in the degradation of mangrove ecosystems [23] [29]. However, in the absence of specific quantitative data on the intensity of logging and its ecological effects in the Tristão Islands, these mechanisms cannot be considered as directly demonstrated impacts in this area. Rather, they should be interpreted as impact hypotheses based on observations made in comparable tropical contexts, particularly in Guinea, Ghana, and Senegal [34], as shown in **Table 1**. If similar logging practices are confirmed in Tristão, the scientific literature suggests they could potentially lead to several biophysical consequences, including:

- **A decrease in plant biomass and carbon stocks,** resulting from the reduction of forest cover and the extraction of woody material [9];
- **A disruption of soil stability and a potential increase in vulnerability to coastal erosion,** due to the reduction of physical protection provided by vegetation and mangrove root systems [16];
- **A degradation of habitats and a possible decrease in associated ecosystem services,** including nursery functions for aquatic species, coastal protection and maintenance of biological productivity [18].

6.2. Socio-Economic Factors and Management Challenges in the Context of Tristão

Several studies conducted in West Africa show that mangrove exploitation is influenced by socio-economic factors such as dependence on natural resources, energy needs, fishing activities, income levels, and limited access to economic alternatives [24] [35]. In the context of the Tristão Islands, these factors are considered potential explanatory hypotheses, but their actual influence will need to be assessed through socio-economic surveys of local communities.

The literature highlights that sustainable mangrove management requires addressing the root causes of their degradation, including socio-economic and institutional factors, as well as natural resource governance models [24]. In several tropical regions, management challenges are associated with fragmented governance, limited institutional capacity, and a lack of data necessary for planning and monitoring conservation actions [36]. In the case of the Tristão Islands, these constraints represent potential issues that will need to be assessed through institutional analyses and specific field investigations [34].

Although biophysical data specific to the Tristão Islands remain limited, documented trends in several tropical regions show recurring relationships between resource exploitation, socio-economic factors, and mangrove degradation [12]. In this context of uncertainty, an adaptive management approach may be preferred, combining immediate measures aimed at reducing identified anthropogenic pressures with the implementation of biophysical monitoring to progressively improve local knowledge [33]. Thus, regional experiences can guide initial conservation actions in Tristão, while specific studies remain essential to define management strategies adapted to local ecological and socio-economic conditions [37].

6.3. Limitations of Inferences and Research Priorities for the Mangroves of Tristão

The inferences made in this study are scientific hypotheses based on available knowledge from regional and international literature on the dynamics of tropical mangrove degradation. However, they cannot replace direct field observations and measurements, which remain essential for accurately characterizing the biophysical state of the Tristão Islands mangroves and confirming the existence, extent, and nature of the potential impacts identified [35] [38]. A significant gap remains in the availability of recent and spatially accurate biophysical data on the Tristão mangroves. The necessary information includes changes in mangrove cover, the structure and floristic composition of the stands, levels of natural regeneration, and estimates of biomass and associated carbon stocks [36] [39]. The production of this baseline data is an essential step in establishing a reliable ecological diagnosis and guiding future conservation strategies.

From this perspective, future research should primarily focus on:

- **The implementation of biophysical field inventories coupled with the analysis of satellite images and remote sensing tools,** in order to determine the current extent of mangroves, to analyze spatio-temporal changes in vegetation cover, to assess historical and recent trends in degradation and to characterize the main structural parameters of the stands [12] [13].
- **Conducting in-depth socio-economic studies with riverside communities** to identify the factors determining the exploitation of mangrove wood, the associated uses (fuel, fish smoking, construction), the modes of dependence on natural resources and the constraints influencing local management practices [40] (**Table 1**).
- **The analysis of governance arrangements and local mangrove management practices,** to assess their effectiveness, to identify existing institutional mechanisms and to define participatory approaches effectively involving local communities in the conservation and sustainable use of resources [6] [19].
- **The study of the natural regeneration dynamics of mangrove species,** including the assessment of the renewal capacity of exploited stands, the identification of factors limiting regeneration and the determination of the potential

of local species for possible ecological restoration programs adapted to the context of Tristão [15] [22].

Thus, future research will need to combine ecological, spatial and socio-economic approaches in order to move from an understanding based on regional analogies to a specific assessment of the dynamics specific to the mangroves of the Tristão islands.

7. Conclusions

This study, based on an analysis of regional and international scientific literature, highlighted the ecological, economic, and social importance of mangrove ecosystems, as well as the main pressures likely to affect their functioning. The harvesting of mangrove wood, primarily for domestic fuel, fish smoking, and construction, appears to be one of the major factors of degradation identified in several tropical regions, particularly in West Africa.

Current knowledge shows that intensive mangrove exploitation can lead to significant changes in their structure and ecological functions, including reduced plant biomass, a potential decrease in carbon stocks, disruption of natural regeneration, habitat degradation, and a reduction in associated ecosystem services. Mangrove root systems also play a crucial role in soil stabilization, sediment retention, and coastal protection against erosion. Their degradation could therefore increase the vulnerability of coastlines to environmental changes.

In the context of the Tristão Islands, the biophysical impacts discussed in this study should be considered inferences based on observations made in comparable settings, rather than results directly demonstrated by field measurements. Indeed, the current lack of specific quantitative data on stand structure, biomass, carbon stocks, regeneration dynamics, and spatial evolution of mangroves limits the ability to accurately assess the magnitude of the effects related to logging.

The analysis also highlights that mangrove degradation cannot be addressed solely from an ecological perspective. Socio-economic factors, including local communities' dependence on natural resources, energy needs, fishing activities, and the lack of economic alternatives, are key elements in the dynamics of mangrove exploitation. Therefore, any sustainable conservation strategy in Tristão must integrate ecological, economic, social, and institutional dimensions.

The future management of the mangroves of the Tristão Islands should therefore be based on an integrated and adaptive approach combining:

- The completion of detailed biophysical inventories and regular monitoring of the evolution of the populations;
- The use of remote sensing tools and geographic information systems to track spatio-temporal changes;
- The assessment of biomass and carbon stocks in order to quantify the ecological functions of mangroves;
- Conducting socio-economic studies to identify the local drivers of the operation;

- The development of participatory approaches involving communities in the conservation and sustainable management of resources.

Ultimately, the mangroves of the Tristão Islands represent a major ecological heritage for Guinea, but their conservation requires moving beyond an approach based solely on habitat protection to adopt an integrated strategy that reconciles the preservation of ecological functions, the improvement of local livelihoods, and the sustainable governance of natural resources. Future research must provide the essential baseline data to transform current assumptions into specific scientific knowledge that can effectively guide management decisions.

Author Contributions

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Conceptualization: Author 1 and Author 2; Methodology: Author 1, 2and 3; Software: Author 1; Validation: Authors, 3,1; Formal Analysis: Author 3 and 1; Investigation: Author 1; Resources: Author 2; Data Management (Data Curation): Author 2; Drafting—First Version: Author 1; Drafting—Revision and Correction: Authors 1, 2, and 3; Visualization: Author 1; Supervision: Author 2; Project Management: Author 1; Funding Securing: Author 1.

All authors have read, revised, and approved the final version of the manuscript and agree to assume scientific responsibility for it.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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