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# Protecting Carbon-Rich Ecosystems through REDD+ in Guinea-Bissau: An impact evaluation of the Community-Based Avoided Deforestation Project – Part 3

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**Abstract**
This study presents the first long-term impact evaluation of a REDD+ initiative in Guinea-Bissau, analyzing the Community-Based Avoided Deforestation Project's impact on ecosystems and local communities. Using satellite imagery and qualitative interviews, this study examines changes in forest, mangrove, cropland coverage, as well as population dynamics between 2000-2020. Results show significant positive effects on forest preservation and reduced agricultural expansion in protected areas after 2017. Mangrove protection shows no significant impact and population effects were not identified. While conservation measures prove to be partially effective, communities face persistent infrastructure gaps and resource constraints, highlighting implementation challenges in financially constrained settings.

**Keywords**
REDD+, Forest Conservation, Sustainability, Guinea-Bissau

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## List of Abbreviations

| | |
|---|---|
| CBADP | Community Based Avoided Deforestation Project |
| CBMP | Coastal and Biodiversity Management Project |
| DID | Difference-in-Difference |
| ESA CCI-LC | ESA Climate Change Initiative Land Cover |
| FAO | Food and Agriculture Organization of the United Nations |
| FBG | BioGuinea Foundation |
| FREL | Forest Reference Emission Level |
| GEF | Global Environment Facility |
| GHG | Greenhouse Gases |
| GIS | Geographic Information Systems |
| GMW | Global Mangrove Watch |
| HDI | Human Development Index |
| IBAP | Institute of Biodiversity and Protected Areas |
| IPCC | Intergovernmental Panel on Climate Change |
| LDC | Least Developed Country |
| LK | Leakage Belt |
| LUCC | Land Use Cover Change |
| MRV | Monitoring, Reporting, and Verification |
| NAPA | National Adaptation Programme of Action |
| NDC | Nationally Determined Contribution |
| PA | Project Area |
| PNC | Cantanhez Forest National Park |
| PNTC | Cacheu Mangrove Forest National Park |
| REDD+ | Reducing Emissions from Deforestation and Forest Degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries |
| RRD | Reference Region for Projecting Rate of Deforestation |
| RSeT | Remote Sensing, Environment and Technology for Development |
| SEAB | Secretariat of State for the Environment and Biodiversity |
| SNAP | Sistema Nacional de Áreas Protegidas (National Protected Areas System) |
| UNFCC | United Nations Framework Convention on Climate Change |
| VCS | Verified Carbon Standard |
| VCU | Verified Carbon Unit |

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# 1. Introduction

*"There is a rapid increase in the water, if there is no dike and no prevention, I cannot say if in 10 or 20 years my village, one day, will disappear"*

Chief of the village, Bolola Community, Guinea-Bissau, Interview November 9, 2024

Our planet's ecosystems are incredibly fragile, facing an era of unprecedented environmental change. As global efforts to meet the Paris Agreement climate goals fall short, the resulting consequences are felt most acutely in Least Developed Countries (LDCs) like Guinea-Bissau. Almost 80% of Guinea-Bissau's population resides in vulnerable coastal zones, where their livelihoods are closely tied to mangrove forests, terrestrial woodlands, and agricultural lands (UN Habitat 2023). As warned by the chief of the Bolola Community, coastal communities face mounting pressures from rising seas and changing weather patterns that threaten generations-old ways of life. For these communities, environmental degradation is not an abstract future threat but a present reality, as these environmental challenges compound existing economic hardships.

Balancing the preservation of Guinea-Bissau's critical ecosystems with local economic needs is particularly challenging. Mangroves and forests are essential for communities and important global carbon sinks. Guinea-Bissau hosts 14% of West Africa's mangrove coverage, storing an estimated 116 million tons of carbon, one of the highest per-hectare rates in the region (Bryan et al. 2020). Its forests provide vital biodiversity habitats, protect coastlines, and support agriculture and fisheries. However, they face severe pressure from climate change impacts and unsustainable practices driven by economic necessity. In response to these intertwined challenges, global frameworks such as REDD+[1], Payments for Ecosystem Services, and

[1] Reducing Emissions from Deforestation and Forest Degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries

voluntary carbon markets have emerged as potential tools for balancing conservation with development needs. These frameworks aim to address market failures by creating economic incentives to preserve ecosystems while supporting local communities. The recent finalization of Article 6 of the Paris Agreement at COP29 in Baku has strengthened these mechanisms by creating standardized frameworks for global carbon markets, enabling more effective financing of conservation efforts in vulnerable regions.

This study investigates how such global frameworks translate into local action by examining the Community-Based Avoided Deforestation Project (CBADP) in Guinea-Bissau. Operating under the REDD+ umbrella, the CBADP aims to significantly reduce deforestation rates in the Cacheu Mangrove Forest National Park (PNTC) and Cantanhez Forest National Park (PNC) while supporting local livelihoods. This study aims to answer the question: to what extent do the measures of the CBADP have a measurable impact on environmental and socio-economic outcomes.

As the first long-term evaluation of a REDD+ initiative in Guinea-Bissau, our research addresses a critical gap in understanding how such projects perform in financially constrained settings. Using satellite imagery, we examine changes in mangrove coverage, forest coverage, agricultural expansion, and population dynamics, evaluating both the environmental and human dimensions of conservation with an event studies approach. To provide a deeper understanding, the quantitative analysis is complemented by qualitative interviews, offering insights into the lived experiences and perspectives of local communities. While previous studies have examined REDD+ impacts in various contexts, few conduct a comprehensive assessment combining environmental changes with socio-economic dynamics, particularly in West Africa's unique coastal ecosystems.

The evaluation is structured as follows: Chapter 2 examines the complex challenges the CBADP aims to address. Chapter 3 reviews the theoretical frameworks underpinning REDD+

and provides detailed context about Guinea-Bissau and the CBADP. Chapter 4 outlines our empirical approach, methodology, and data sources. Chapter 5 presents our findings from both quantitative and qualitative analyses. Chapter 6 discusses these findings within Guinea-Bissau's financially constrained context. Chapter 7 explores policy implications for REDD+ mechanisms. Chapter 8 concludes and gives recommendations for future research.

## 2. Problem Description

As temperatures continue to rise and global efforts fall short of reaching the climate targets outlined in the Paris Agreement, accelerating mitigation and adaptation efforts has never been more urgent. Forests function as one of earth's most important natural carbon sinks, storing vast amounts of carbon in their biomass and soil. Between 1990 and 2020, over 420 million hectares of forests were lost worldwide, with tropical forests being the most affected. Globally, deforestation accounts for 11% of greenhouse gas (GHG) emissions, with agriculture estimated to be the direct driver for approximately 80% of global deforestation (Ometto 2022). Especially in Africa, fuel wood collection and charcoal production are further drivers of deforestation (Bryan et al. 2020). Protecting forests could reduce emissions by 5.56-8.83 gigatons carbon dioxide by 2050, representing about 30% of the reduction needed to limit global warming to 2°C (Project Drawdown 2024). In this context, nature-based solutions offer central methods to both mitigate climate change and protect biodiversity (IPCC 2019).

Tropical mangrove forests are particularly crucial, storing up to five times more carbon per unit area than other terrestrial forests (Donato et al. 2011). The carbon stored in maritime and coastal ecosystems, known as blue carbon, is released when mangroves are destroyed, potentially contributing up to 10% of global carbon emissions from the forest sector (Vasconcelos and Catarino 2022; IUCN 2018a). Beyond carbon storage, mangroves protect coastal communities from floods and storm surges, support fisheries and provide essential resources for local communities (Lovelock et al. 2017, MNRE-FDB 2010).

In Guinea-Bissau, globally vital tropical mangrove ecosystems are experiencing high degradation rates of 2-7% annually in carbon storage (Bryan et al. 2020). Among the anthropocentric drivers, traditional rice cultivation has historically impacted mangroves, as farmers clear them and construct mud dikes for paddies. Additionally, the recent abandonment of rice fields due to changing rainfall patterns and shift from rice cultivation to cashew farming has created degraded landscapes. This has hindered natural mangrove regeneration. Moreover, traditional oyster harvesting practices often damage mangrove roots, and fuel wood collection to meet energy demands continues to drive degradation (IUCN 2020). The expansion of cashew plantations presents another significant challenge. As Guinea-Bissau's leading export, cashew cultivation has driven significant deforestation, with estimates suggesting a loss of 77% of closed-forest and 10% of open-forest between 2001 and 2018 (H. Pereira 2022). The expansion of monoculture decreases land availability, degrades soil, and threatens biodiversity. Moreover, cashew trees' productivity declines after 25 years, raising concerns about long-term economic sustainability for the country.

Climate change further complicates these challenges. In Guinea-Bissau, 70% of the population faces direct threats from sea-level rise (UN Habitat 2023). Rising waters have led to significant losses in agricultural land, particularly affecting near-shore rice fields through increased soil salinity. These impacts disproportionately affect coastal communities, whose livelihoods depend on healthy mangrove ecosystems (IUCN 2020). The degradation of mangrove ecosystems in Guinea-Bissau, driven by rice cultivation, cashew expansion, resource extraction, and climate change, threatens biodiversity, carbon storage, and coastal livelihoods.

Despite financial constraints, as one of the poorest countries in the world, Guinea-Bissau has made significant efforts to protect its biodiversity through international frameworks. However, limited resources hamper implementation, emphasizing the need for sustained international support. Unsustainable practices, resource extraction, and climate change are rapidly degrading Guinea-Bissau's mangrove ecosystems, threatening biodiversity, carbon storage, and livelihoods. This highlights the urgent need for conservation and international support.

## 3. Background

This chapter provides the foundation for understanding Guinea-Bissau’s conservation initiatives, focusing on the CBADP. It examines global frameworks like REDD+, Guinea-Bissau’s environmental, socio-economic, and political context, and the CBADP’s role in conserving mangroves and terrestrial forest, engaging communities, and generating carbon credits. This context is key to interpreting the project’s outcomes in later chapters.

### 3.1 Global Frameworks

The foundations of global climate action were laid with the establishment of the United Nations Framework Convention on Climate Change (UNFCCC) (Shaw 2007). The 1997 Kyoto Protocol introduced mandatory emission reduction targets for industrialized countries, requiring reductions below 1990 levels, laying the groundwork for compliance-based international climate efforts (Böhringer and Vogt 2003). The 2015 Paris Agreement marked a paradigm shift toward a bottom-up framework, where all countries commit to climate action through Nationally Determined Contributions (NDCs). The agreement aims to limit global temperature rise to well below 2°C above pre-industrial levels and promote climate mitigation (Pauw et al. 2018). Article 6 of the Paris Agreement was a key innovation, which provides frameworks for voluntary cooperation between countries to achieve their NDCs through carbon markets. At COP29 in Baku in 2024, after nine years of negotiations, comprehensive rules for Article 6 were adopted, restructuring into an international UN-led carbon market and introducing clear guidelines for authorized and unauthorized carbon credits. These rules emphasize transparency, robust registry structures, and reporting requirements to ensure environmental integrity (Schneider and La Hoz Theuer 2019; Carbon Brief 2024). Moreover, independent standards like Verra's Verified Carbon Standard (VCS) further facilitate carbon credit trading under this framework.

The REDD+ framework focuses on forest-based carbon sequestration. Developed under the UNFCCC, REDD+ provides a voluntary approach to incentivize developing countries to reduce emissions from deforestation and forest degradation (UN-REDD 2016). It operates through three phases: (1) Readiness: developing national strategies and building capacity; (2) Demonstration: testing proposed strategies; and (3) Implementation: executing results-based actions that are measured, reported, and verified (Kim et al. 2021). After successful completion, countries can earn results-based payments for verified emission reductions, financing national and local climate action efforts.

Participation requires establishing National Strategies, and Forest Monitoring Systems and Forest Reference Emission Levels (FREL), which are benchmarks for measuring emission reductions (Grussu et al. 2014). A critical aspect of REDD+ is its emphasis on community engagement. The Cancun Safeguards ensure that REDD+ activities respect indigenous peoples' and local communities' rights, promote biodiversity conservation, and thus, deliver multiple benefits (V. and J.P. 2023). These safeguards require obtaining free, prior, and informed consent from communities before implementing activities affecting their lands or resources (Newton et al. 2015). Ultimately, the success of these frameworks depends on balancing global climate objectives with local development needs.

### 3.2 Literature Review

This chapter reviews the current evidence on the effectiveness, challenges, and limitations of REDD+ initiatives in reducing deforestation, with a focus on findings from remote sensing studies.

The literature on REDD+ initiatives highlights both their effectiveness and the substantial implementation challenges that accompany them. A review of the evidence from remote sensing studies indicates that voluntary REDD+ projects have been effective in reducing deforestation by 47% in the short term. Analyzing a sample of 40 voluntary REDD+ projects in 9 countries certified under the VCS find REDD+ projects to be especially effective in areas at high-risk of deforestation (Guizar-Coutiño et al. 2022). Importantly, the study finds no evidence of deforestation leakage within 10 km of the project boundaries. Malanet al. (2024) report a 30% reduction in deforestation and avoided emissions of 340,000 $tCO_2$ annually at $1.12 per $tCO_2$ in Sierra Leone. Cameroon's experience shows how REDD+ can strengthen community-based forest management and improve local governance, despite persistent challenges in resource access and land tenure (J. et al. 2020;Gakou-Kakeu et al. 2020). While the evidence is positive, many authors suggest reductions are small in absolute terms, and the impact of REDD+ projects vary significantly across regions and contexts (Wunder et al. 2024).

However, critics argue that methodological issues in calculating deforestation baselines often lead to inflated claims of emissions reductions and the over-crediting of carbon offsets. Baseline calculations may rely on flawed assumptions or fail to consider dynamic forest changes, undermining the credibility of REDD+ programs (West et al. 2020; Ollivier 2012). In response, Verra, the leading organization managing the VCS, has announced revised methodologies that aim to improve the accuracy of baseline calculations and more rigorously assess deforestation risks (World Bank 2023). Additionally, carbon leakage risks undermining REDD+ initiatives if deforestation is simply displaced to non-participating areas. Furthermore, weak governance and institutions in the countries targeted by REDD+ may result in rent-seeking behaviour, limiting its effective implementation (Ollivier 2012).

The impact of REDD+ on the livelihoods of local communities has been a further subject of discussion. Critics point out the commodification of nature and its adverse effects on equity and inclusivity. In addition, they argue that putting a value on nature will discourage conservation as soon as payments stop. Moreover, Asiyanbi et al. (2016) argue that such mechanisms often have exclusionary impacts when implemented in weak institutional frameworks. In these contexts, marginalized communities face the risk of further alienation due to their limited participation in decision-making processes. These studies highlight the need for genuinely participatory approaches to improve effectiveness of conservation efforts. On the impact on socio-economic outcomes, Malanet al. (2024) find that REDD+ in Sierra Leone has not significantly improved the economic well-being of the local population in the short-term. Nevertheless, they point out suggestive evidence of a shift towards alternative income sources and a reduced dependence on forest-based activities. Despite the criticisms, REDD+ remains politically relevant, as evidenced by the international community's renewed commitment to tackling tropical deforestation as a nature-based solution to climate change during COP26 (Guizar-Coutiño et al., 2022).

In the West African Region, mangroves are increasingly targeted by REDD+ due to their critical role in global climate change mitigation and their unique ecological and socio-economic value. Initiatives to protect mangroves and generate carbon credits through avoided deforestation have become prominent targets for REDD+ financing, leveraging their exceptional carbon storage capacity, which surpasses that of many other ecosystems (Vasconcelos et al. 2015). Blue carbon under REDD+ is considered as a win-win financial instrument for mitigating climate change while preserving ecosystem services and improving local livelihoods. This holds particular significance for a LDC like Guinea-Bissau, which harbor globally vital ecosystems but lack the financial and technical capacity to ensure their conservation (Vasconcelos et al. 2015). Moreover, the attractiveness of blue carbon for international financing mechanisms has increased in the past years because of substantial advances, which allow more accurate assessments of soil and biomass carbon storage (Herr 2015). Particularly, improvements in remote sensing techniques, have been critical for monitoring deforestation and evaluating the success of REDD+ mechanisms.

Satellite imagery provides a clear and measurable view of forest coverage and its changes over time. Especially in contexts with limited alternative data sources like in Guinea-Bissau, remote sensing approaches serve as an essential tool for assessing land-use changes and their socio-economic impacts, enabling more informed and effective conservation efforts. Particularly, imagery from the NASA/ESA satellites mission's, Landsat and Sentinel-2 is widely used for monitoring land-use changes due to their extensive temporal coverage and spatial resolution (Melo et al. 2018). Nevertheless, estimations of deforestation based on this data yield different results. While satellite-based data on above-ground biomass is generally consistent, deforestation estimates vary substantially, emphasizing the need for higher-resolution and temporally detailed reference data. This is especially relevant in the context of Guinea-Bissau, where remote sensing approaches have difficulties in distinguishing cashew plantations from forest. Pereira et al., (2022) address this limitation by leveraging machine learning techniques tin Sentinel-2 imagery to map cashew orchards in the PNC. They effectively distinguish cashew plantations from forests by integrating spectral and textural metrics. This method provides a valuable approach for land-use monitoring but is temporally constrained to the year 2019. Further improvements in Geographic Information System (GIS) technologies and predictive models, have significantly improved the ability to estimate blue carbon stocks (Jardine and Siikamäki 2014; Patil et al. 2015).

Multiple studies underline the need for holistic approaches combining GIS-based spatial analysis with socio-economic evaluations to ensure a comprehensive evaluation of the effectiveness and relevance of REDD+ initiatives (del Toro and Más-López 2019; Lopes et al. 2023; Chien, Knoble, and Krumins 2024). An example of such a holistic approach is offered by Malan et al. (2024), evaluating the Gola Rainforest REDD+ project in Sierra Leone. Despite the ecological successes, complementary household surveys showed that socio-economic benefits were minimal. Furthermore, studies such as Temudo and Cabral (2017) show the importance of combining qualitative (interviews) and quantitative (remote sensing techniques) methods to analyze mangrove- and land use cover change dynamics and socio-economic implications.

Our research aligns with this methodological rigor, using GIS tools for spatial monitoring and qualitative interviews to capture socio-economic dynamics. While previous studies often focused on deforestation reduction, our study expands the scope beyond environmental outcomes. It addresses broader socio-ecological implications by including populations dynamics and stakeholder interviews in the context of the PNC and PNTC in Guinea-Bissau.

Furthermore, the interplay between forests, cropland, mangroves, and population in Guinea-Bissau remains underexplored, a gap this work seeks to address. Existing studies often examine these factors in isolation, neglecting their interdependence and the unique challenges faced by developing nations. This oversight limits the effectiveness of conservation efforts and the creation of integrated strategies to address ecosystem degradation and its socio-economic impacts. Although many short-term programs have been implemented to address these issues, there is no publicly available evaluation of long-term interventions in the country to date.

This study fills this gap by offering the first long-term impact evaluation of a REDD+ initiative in Guinea-Bissau, focusing on forests, cropland, mangroves, and population dynamics within the CBADP in PNC and PNTC. This comprehensive analysis aims to bridge the gap between global conservation frameworks and the socio-economic realities of developing nations like Guinea-Bissau.

### 3.3 Context of Guinea Bissau

This chapter provides essential context for evaluating the CBADP. Guinea-Bissau is home to extraordinary biodiversity but faces significant political and institutional challenges in its efforts to protect these ecosystems.

Situated in West Africa, the country shares borders with Senegal to the north, Guinea to the southeast, and the Atlantic Ocean to the West (Figure 1). Covering a total area of 36,125 km² in the intertropical zone, the tropical climate is characterized by distinct wet and dry seasons (Geodatos 2024; World Bank 2010).

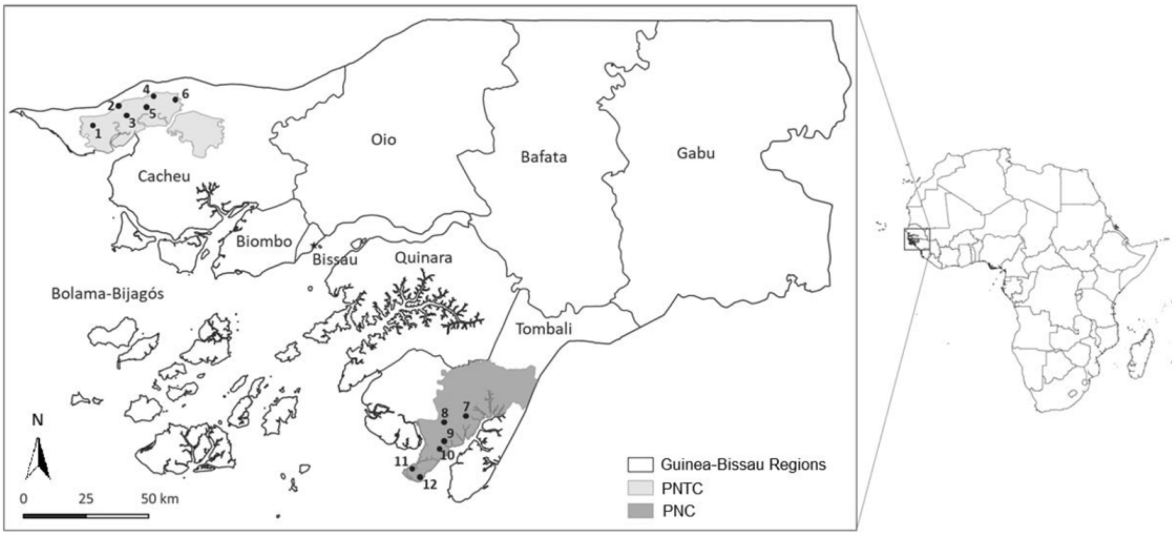


Figure 1: Guinea-Bissau Map (Dias, Vasconcelos, and Catarino 2022)

Guinea-Bissau is a LDC, facing significant poverty levels with two third of the population living below the poverty line (Central Intelligence Agency 2024). The country ranks among the lowest in the world in terms of Human Development Index (HDI), with an HDI of 0.483, ranking 179th out of 193 countries in 2022. Widespread poverty and limited access to education and healthcare contribute to its low ranking (United Nations Development Programme 2023).

The economy is largely based on agriculture, which accounts for 45% of GDP and employs approximately 540,000 people, representing 82% of the labor force (Central Intelligence Agency 2024). Agricultural production capacity has significantly decreased over the past two decades, primarily due to climate change impacts. Rising temperatures and increasingly irregular rainfall patterns have led to shorter growing seasons and reduced crop yields. The rainy season's unpredictability particularly affects rice production, as farmers struggle to time planting effectively. According to climate projections, these challenges are expected to intensify, with annual rainfall potentially decreasing by up to 20% in western regions including Guinea-Bissau compared to 1981-2010 levels (IUCN 2018). The agricultural sector is dominated by two main crops: rice and cashew nuts. Rice is cultivated mainly in mangrove areas, while cashew cultivation has expanded rapidly in terrestrial forest zones over the past 20 years. Agricultural products comprised 93% of exports, with cashew nuts accounting for 99% of these agricultural exports. Cashew production contributes approximately 80-90% of the country's total export revenues, providing essential income to over 40% of rural households (Mendonça et al. 2024). However, heavy reliance on a single crop creates economic vulnerability to global market fluctuations and contributes to environmental degradation through deforestation and soil erosion (Edmundson 2014; Mendonça et al. 2024; World Bank 2024a). Between 2002 and 2012, deforestation was primarily attributed to the growth in cashew cultivation, which accounted for approximately 91% of the total land cleared for agricultural purposes (Seca, Pereira, and Silva 2021). Since 2016, high international price volatility has further threatened rural livelihoods (BELAB 2023). The unpredictable swings in market prices have made it difficult for these farmers to plan their harvest and sales effectively, often forcing them to sell at unfavorable times. This instability has threatened the financial security of many rural households, who already face barriers such as limited access to market information and isolation from reliable news sources (BELAB 2023).

While Guinea-Bissau's economy heavily depends on its natural resources, the country's environmental significance extends far beyond its agricultural output. Its coastal and marine ecosystems are among the most vital in West Africa. The country contains approximately

280,600 hectares of mangroves, representing about 14% of West Africa's total mangrove coverage. These mangroves do not only serve as ecological hotspot but also store up to 116 million tons of carbon which is one of the highest carbon storage rates per hectare in West Africa (Bryan et al. 2020; Central Intelligence Agency 2024).

In order to conserve those critical ecosystems, Guinea-Bissau's National System of Protected Areas (SNAP), which includes seven national parks, was created. Among others, SNAP involves the PNTC and the PNC. These parks protect vital habitats for chimpanzees, primates, and other endangered species (BioGuinea Foundation 2015; SEAB 2019). Despite their importance, investments in conservation in Guinea-Bissau are limited. These range from $2-3 million per year, making biodiversity, forests, and ecosystem services vulnerable sectors (De Almeida Pereira 2018a). The lack of conservation led to increased deforestation and has transformed Guinea-Bissau from being a carbon sink to a net emitter of $CO_2$ (Environmental Investigation Agency 2018, Bird and Gomes 2021).

Besides agricultural expansion, another root cause for deforestation is tied to Guinea-Bissau's political environment, characterized by weak governance and institutional stability. Since gaining independence from Portugal in 1974, Guinea-Bissau has faced persistent political instability marked by multiple coups (Central Intelligence Agency 2024). During the military junta rule from 2012 to 2014, illegal logging surged as military officers were granted logging concessions in place of salaries, leading to severe environmental degradation and record timber exports to China (Environmental Investigation Agency 2018; Bird and Gomes 2021).

Guinea-Bissau is among the countries most vulnerable to the effects of climate change, facing increased risks such as declining crop yields, livestock mortality, reduced fish stocks, floods, droughts, and coastal erosion. These impacts exacerbate existing food insecurity and economic challenges, particularly in coastal and marine ecosystems (Wongnaa et al. 2024).

### 3.4 National Strategies and Key Players

To address these pressing environmental and socio-economic challenges, Guinea-Bissau developed a comprehensive policy framework that aligns national priorities with international commitments, aiming for both biodiversity conservation and sustainable development.

Central to this approach is Terra Ranka, meaning "Fresh Start", the country's long-term strategic and operational plan launched in March 2015. Structured around six pillars: (1) peace and governance, (2) infrastructure, (3) industrialization, (4) urban development, (5) human development, and (6) biodiversity, Terra Ranka integrates national priorities with global sustainability objectives. At its core, the biodiversity pillar emphasizes the expansion of protected areas from 13% to 26% of the country's landmass through the SNAP (Pereira 2022), which aligns closely with international commitments, including REDD+. Guinea-Bissau has received substantial international support to design and establish Terra Ranka, which has been critical in funding the operational plan for 2015 to 2020 (Csomor 2015). Terra Ranka serves as a unifying framework, integrating core policies under its pillars.

Among these are, for instance, the National Adaptation Program of Action (NAPA), which was published in 2006, to address climate vulnerabilities. NAPA has outlined 14 priority projects to improve food security, reduce pressure on forests and fisheries, and enhance access to clean water (IUCN 2018a). Despite efforts, climate adaptation in Guinea-Bissau has remained reactive and insufficiently coordinated due to limited national capacity (Kohli 2021). However, the NAPA is continuously updated with communications to the UNFCCC and its NDC under the Paris Agreement (NAP-GSP 2024). Moreover, in 2019 Guinea-Bissau voluntarily submitted its FREL for deforestation within the SNAP, a requirement to establish a baseline for tracking GHG emissions and access REDD+ results-based payments (SEAB 2019). This commitment aligns forest conservation with socio-economic objectives (IFAD 2023). By aligning these key strategies, Terra Ranka ensures a cohesive approach to addressing Guinea-Bissau's environmental and socio-economic (SEAB 2019).

To complement its national strategies, Guinea-Bissau actively engages in international frameworks to enhance its climate resilience and environmental governance. The country actively participates in the UNFCCC since 1995, the Kyoto Protocol since 2005, and the Ramsar Convention since 1990[2]. Under the Paris Agreement, Guinea-Bissau seeks to strengthen its climate action by enhancing carbon pricing mechanisms and expanding renewable energy capacities through cooperative approaches and international partnerships (IUCN 2018; IFAD 2023)

Building on these strategic frameworks, Guinea-Bissau introduced a series of key environmental laws. These legal frameworks for land, forest, environment, and protected areas aim to balance sustainable resource management with socio-economic development, but face challenges in implementation due to regulatory gaps and enforcement limitations (SEAB, 2019). Aligned with its network of laws and national strategies, the country has implemented several projects to advance conservation efforts. Among the diverse project landscape supported by international donors, especially two projects stand out, as these led to the creation of two fundamental actors: Institute for Biodiversity and Protected Areas (IBAP) and the BioGuinea Foundation (FBG).

The initiative Coastal and Biodiversity Management Project (CBMP) played a crucial role in conservation of coastal mangroves and forests (H. Pereira, Melo, and Yudelman-Bloch 2020). The projects' efforts led to the establishment of Guinea-Bissau's SNAP and of the Fund for Local Environmental Initiatives, a financial instrument to promote sustainable development in and around protected areas (World Bank 2011). But most importantly, the project supported the creation of IBAP in 2004 (H. Pereira, Melo, and Yudelman-Bloch 2020). IBAP is Guinea-

[2] The Ramsar Convention aims to conserve and promote the sustainable use of wetlands globally.

Bissau's primary institution for protected area management and biodiversity conservation. As an autonomous public institution, it plays a crucial role in coordinating conservation efforts and managing SNAP. Their responsibilities include implementing biodiversity conservation programs, coordinating ecological monitoring systems, and developing community-based conservation initiatives. The organization has successfully rehabilitated over 520 hectares of degraded mangrove areas, enhancing coastal protection through community-based conservation measures, sustainable practices, and active patrolling, while also enhancing fisheries. IBAP collaborates with local communities to promote sustainable land-use practices, supports biodiversity research, and leads initiatives to enhance the ecological resilience of vulnerable ecosystems. Under its Strategic Plan for Protected Areas (2014-2020), IBAP focuses on specific goals such as reducing forest degradation and promoting biodiversity in degraded ecosystems (SEAB 2019).

With the aim to strengthen IBAP's capacity to manage the national parks, the Guinea-Bissau Biodiversity Conservation Project builds upon the success of the CBMP and tackles the lack of a sustainable financing mechanism for the national parks (World Bank 2011). As a result, the operation of the FBG was piloted in 2011. The non-profit foundation provides a long-term financing mechanism to support IBAP and its management of SNAP. The FBG was designed to address the challenges of ensuring sustainable financing for biodiversity conservation, particularly during transitions from donor-based funding models. While IBAP leads the implementation of conservation initiatives, FBG ensures their financial sustainability by securing long-term financing through innovative mechanisms like carbon credits and endowment funds.

To address the issue of donor-dependence, the FBG offers a promising solution. Aimed at generating income through the sale of carbon credits from avoided deforestation, it transits CBADP towards a more reliable and sustainable funding (World Bank 2010). Since 2019, the

FBG has provided approximately $780,000 in purpose-based funding to IBAP, helping to strengthen its capacity to manage Guinea-Bissau's protected areas and biodiversity and therefore projects like the CBADP (UN Environment Programme 2024). However, achieving a sustainable, long-term financing model remains a central challenge.

### 3.5 CBADP Project Description

The CBADP in Guinea-Bissau is a REDD+ conservation project aimed at preserving biodiversity and to reducing carbon emissions. The CBADP`s goal is to conserve Guinea-Bissau's critical mangrove ecosystems and terrestrial forests, which serve as vital carbon sinks, support rich biodiversity and provide essential resources to communities in the PNTC and PNC regions.

By avoiding deforestation, it contributes to climate change mitigation through reduced emissions in a high deforestation risk region. These reduced carbon emissions are sold as carbon credits, generating a sustainable revenue stream for conservation efforts and community support (Figure 2) (IBAP 2024;RSeT 2019). The project's goals are centered on both ecological conservation and socio-economic support for local communities (IBAP 2024; RSet 2019). Activities include support for sustainable agricultural and fishing practices, contribution to sustain soil fertility and food security and above all reduced emissions through avoided deforestation (RSeT 2019). Notably, instead of afforestation, the project focuses mainly on protecting existing forest and avoiding future deforestation. The CBADP is just one element of the Guinea Bissau conservation portfolio, but different from other projects it aims to secure self-financing of the conservation efforts through the sale of carbon credits (IBAP 2024).

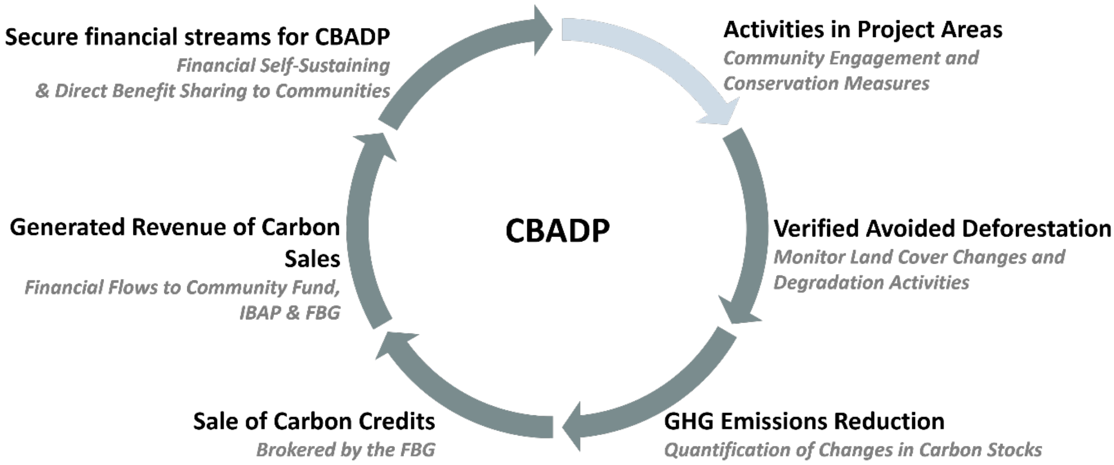


Figure 2: CBADP Process Cycle (Source: Own Illustration)

The CBADP is led and implemented by the IBAP, with the FBG serving as a key partner, who is in charge of the financial management and the REDD+ result-based payments of the project (Pereira 2018). Besides IBAP and FBG, the project has received support from global donors like the World Bank, the Global Environment Facility (GEF), the MAVA Fondation pour la nature, and the French Global Environment Fund, who provided initial funding for REDD+ technical aspects for the Readiness Phase to get the project off the ground. On-ground activities were additionally supported by the UNDP and the European Union (IBAP 2024).

The project officially started on the 31st of March 2011 as a pilot project in the two protected areas PNC and PNTC and after a preparation phase it got validated as a REDD+ Initiative in 2015 according to the VCS (Pereira 2018). In 2017 the first sale of carbon credits began, further sales were completed in 2022 (IBAP 2024). The crediting period spans 20 years from 31st March 2011 till the 30st of March 2031 (RSeT 2019). Every five years Monitoring and Verification will be repeated in order to support the periodic issuance of additional Verified Carbon Units (VCU) (RSeT 2018). The first verification phase was finalized in 2019 and monitored the initial period of 2011-2016. In the second verification period the years 2017-2021 were monitored combined with 10-year update of project baseline 2011 (IBAP 2024).

Figure 3 visualizes the current state of the CBADP timeline till the second Monitoring, Reporting, and Verification (MRV), which will be followed by another verification cycle. This rhythm will repeat till the end of the crediting period in 2031. Due to a methodological evolution in Verra's baseline methodology, the second verification is on hold and an updated baseline needs to be submitted (IBAP 2024).

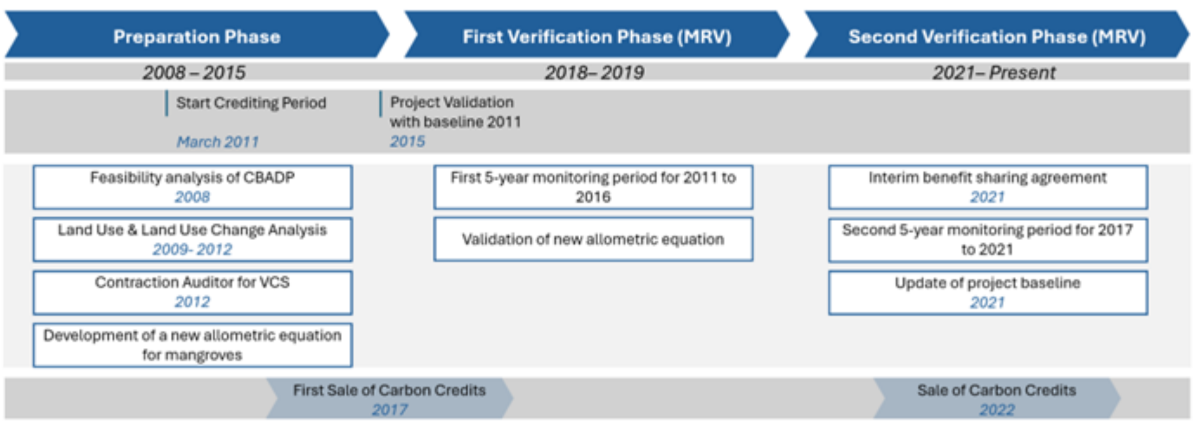


Figure 3: CBADP Project Phases (Source: Own Illustration)

As pictured in Figure 4, the project encompasses two core regions, PNTC and PNC, covering 181,200 hectares in total, of which 145,698 hectares are designated as Project Areas (PA) (Pereira 2018).

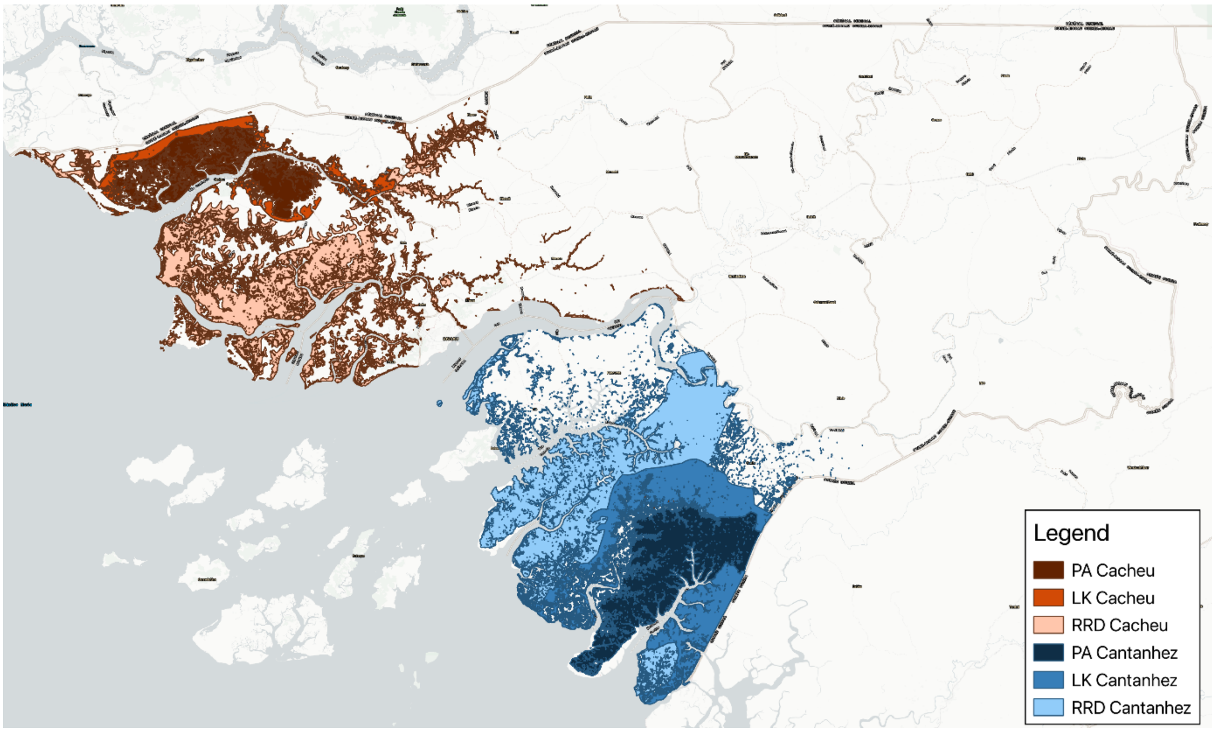


Figure 4: The Cacheu Mangrove Forest National Park (PNTC) and the Cantanhez Forest National Park (PNC) (Source: Own Illustration)

The PNTC covers 74,700 hectares (74% as PA, Figure 5) and is located in northern Guinea-Bissau, and was legally established in 2000 to protect mangrove ecosystems around the Cacheu River estuary (12°18'38.37"N, 16°11'25.19"W) (Pereira 2018).

The PNC spans 106,500 hectares (85% as PA, Figure 6) and was legally established in 2011 to preserve primary sub-humid forest patches extending southward into Guinea Conakry (11°16'29.85"N, 14°59'8.00"W).

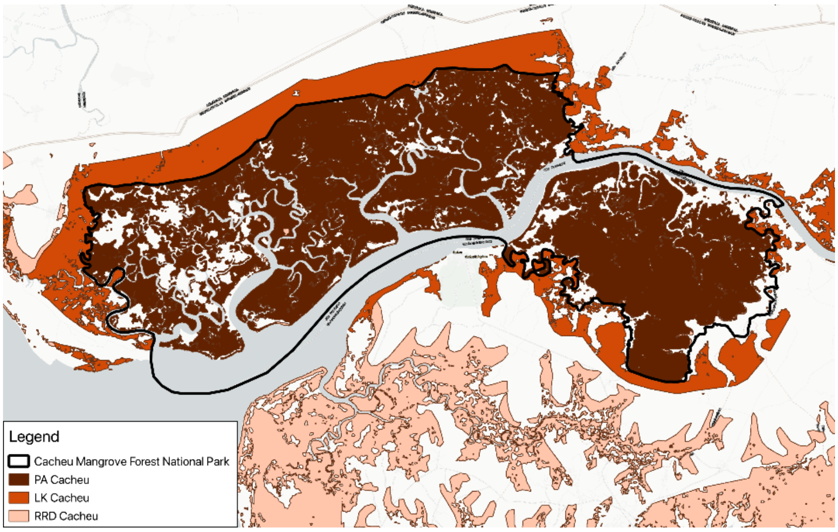


Figure 5: PNTC Project Area and National Park Limits (Source: Own Illustration)

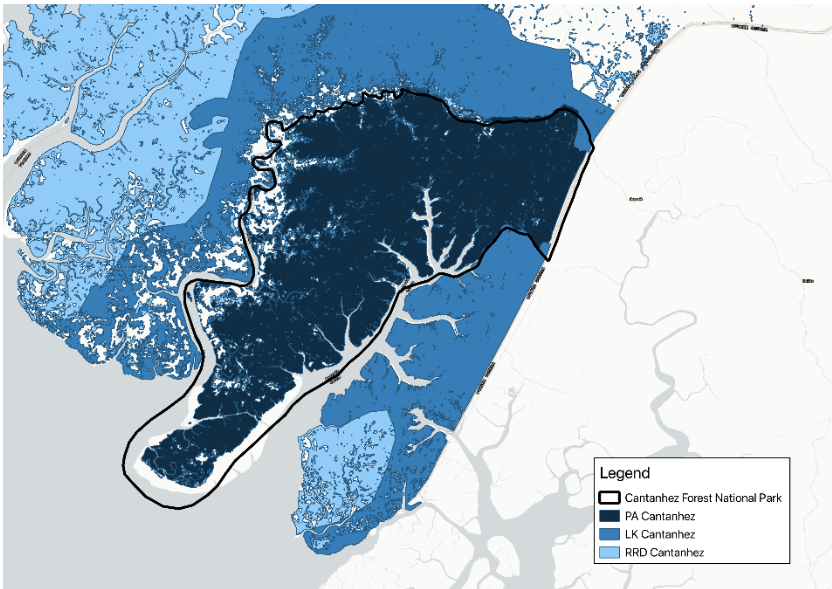


Figure 6: PNC Project Area and National Park Limits (Source: Own Illustration)

The Leakage Belt (LK) and Reference Region for Projecting Rate of Deforestation (RRD) are key components in the CBADP for monitoring deforestation impacts and patterns around the PAs. The LK is a 2 km buffer zone around the PA created to detect "leakage", where deforestation might shift from the protected area to adjacent regions. This helps measure whether conservation efforts in the PA are displacing deforestation towards surrounding areas. The RRD is a baseline region that shows the same ecological characteristics and comparable deforestation patterns as PA and LK. Therefore, it serves as a reference area to PA and can be used for well-grounded ex-ante and ex-post estimations. At the project's start, the RRDs were fully forested, allowing them to serve as a control for deforestation trends. For the PNTC, the RRD includes forestlands in PNTC, Caio, and Cachungo and wetlands along the Cacheu and Mansoa Rivers in Oio, matching the ecological and soil characteristics of the PA and LK. For PNC, the RRD covers southwestern Guinea-Bissau, including the sectors of Buba, Empada, Catio, and parts of Cacine, as well as wetlands along the Geba River in Quinara. This area was chosen for its similar ecological and socio-economic conditions to the PNC (Pereira 2018).

Within these areas, the national parks include 177 communities in PNTC and 326 in PNC. Over 50% of these communities have fewer than 150 residents, and only 38 exceed 600 inhabitants (De Almeida Pereira, 2018; RSet, 2018b). However, in total, more than 50,000 people living within the PNTC (28.052) and PNC (22.505) are directly impacted by this program, benefiting from its conservation initiatives and sustainable livelihood support (IBAP 2024). The protected areas also shelter endangered species like Nile crocodiles, saltwater hippopotamus, and chimpanzees (RSeT 2019). As mentioned, PNC forests are some of the last remaining patches of primary sub-humid forest in the region, forming part of a larger forested area that stretches into southern Guinea Conakry. The park has a mixture of dense mature forests and secondary forests. This landscape has been shaped over time by shifting agricultural practices with periods of cultivation and fallow. The mangroves cover a substantial portion of the park, especially in the southern and western areas along the banks of the Cumbijã River (Verra 2024) .

PNTC harbors 68% of its area in mangrove cover and hosts more than 518 bird species, making it the second-largest mangrove habitat in West Africa after Nigeria (Padjalo Carvalho, IBAP interview, November 9, 2024). Therefore, it has the most significant and well-preserved mangrove ecosystems in Guinea-Bissau. In addition to its mangroves, PNTC is predominantly characterized by open forests and palm groves (RSeT 2019).

PNTC is divided into three distinct zones, each with specific rules for resource use:

1. Terrestrial Zone (Sustainable Development Zone): This area is allocated for community activities that support their livelihoods. Residents can engage in agriculture, cut trees for construction, use wood for cooking fuel and engage in commercial activities.
2. Transition Zone: In this zone, communities can use natural resources like fish and forest products, but only for personal consumption, not for commercial purposes. The transition zone lies beyond the mangroves and ensures sustainable use of resources.
3. Central Zone**:** This is the core conservation area where mangroves are strictly protected. Any activity that damages the mangroves, such as cutting trees, is prohibited. This zone is a sanctuary for various species, including turtles, crocodiles, dolphins, and manatees (Padjalo Carvalho, IBAP interview, November 9, 2024).

The CBADP encompasses a wide range of activities designed to balance environmental conservation with the socio-economic needs of local communities. These activities can strategically be grouped into four main areas: Conservation Measures, Community Engagement and Capacity Building, Infrastructure and Governance, and Carbon Market Activities. Based on the monitoring report from Pereira (2018), each category represents a targeted approach to achieving the project's dual goals of protecting critical ecosystems, such as mangrove and terrestrial forests, while enhancing the livelihoods and resilience of the local population.

1. **Conservation Measures:** Park and agricultural councils were established in 2012 to involve community members in conservation planning, and monthly meetings with fishermen began to promote sustainable practices. Training programs were launched for

park rangers, reforestation agents, and other conservation staff, with advanced training in GIS, forest inventory techniques, and sustainable fishing provided to local communities, including 60 fisherwomen in 2014. This support was extended to women's associations to boost oyster production. Community radio broadcasts, initiated in 2013, became a key tool to educate remote populations on conservation issues. Community meetings helped clarify conservation rules and objectives in protected areas. Surveys were also conducted to gather local insights on deforestation and logging risks. Recruitment and training of conservation personnel are ongoing to ensure these initiatives are sustained.

2. **Capacity Building**: Multiple conservation measures were introduced to safeguard ecosystems and promote sustainable land use. Surveillance activities began in 2012 to monitor illegal activities, complemented by collaborations with rice producers to reduce slash-and-burn agriculture. Electrical fencing was installed to protect crops from hippos, starting with 139.4 hectares in 2013 and expanding to 681.5 hectares in 2014, securing 1,000 tons of rice production. Mangrove and coastal reforestation efforts were launched, with continued support for restoration in subsequent years. Patrolling efforts were intensified, resulting in the confiscation of illegal logging and fishing equipment. By 2015, PNTC earned international recognition as a Ramsar site, which is the official List of Wetlands of International Importance (Ramsar 2024). Surveillance missions increased significantly, with 114 missions conducted in 2015 alone. Data collection on deforestation and illegal logging risks remains a priority, supported by regular patrols and monitoring efforts that continue until today.
3. **Infrastructure and Governance:** Strengthening infrastructure and governance has been crucial for effective conservation. In 2013, PNTC's headquarters were improved, and new patrol stations were constructed to support surveillance missions. Additional technical staff,

including park coordinators and reforestation experts, were hired in 2014 to enhance operational capacity**.**

4. **Carbon Market Activities:** To support long-term conservation financing, $1.3 million in seed funding was secured from the GEF in 2013. VCUs have been generated and marketed, providing a sustainable revenue stream for ongoing conservation and community initiatives.

Integrating local communities is central to the CBADP. This aims to foster a strong sense of project ownership. Communities benefit through both financial support and active participation in decision-making processes. The established councils involve residents in conservation planning, and ensure their voices are represented. Importantly, no population relocation has taken place, and all internal rules for both parks were discussed and agreed upon with the local population to ensure their needs and concerns are addressed. Additionally, a multi-stakeholder forum, which includes representatives from local communities, meets every semester to monitor the project's progress and ensure that conservation activities do not negatively impact residents (Pereira, 2018). The CBADP prioritizes initiatives that align with traditional livelihoods, such as sustainable fishing training for fisherwomen. Moreover, it aims to mitigate conflicts between wildlife and agriculture. Measures like the installation of electrical fences have been implemented to protect crops, ensuring that conservation efforts support, rather than hinder, community needs (Pereira 2018). By actively involving residents in the planning and implementation of conservation activities, the CBADP addresses potential conflicts between conservation goals and local practices. A core benefit of the project are the foreseen cash transfers from carbon credit revenues provide direct financial benefits, helping to support the livelihoods of communities and ensure long-term cooperation and sustainability (Pereira 2022). Moreover, monitoring is a crucial component of the CBADP, as it ensures compliance with the VCS and REDD+ requirements while verifying emissions reductions. Ongoing monitoring and reporting are conducted to track deforestation rates and ecosystem changes, utilizing advanced tools like remote sensing and GIS technology. The monitoring process evaluates land use and tree cover changes to measure the project's impact on emissions reduction. In 2016, monitored parameters included baseline deforestation linked to migrating populations and degradation risks associated with illegal logging. Community surveys are also conducted to supplement remote sensing data, providing localized insights into the ongoing conservation impacts (RSeT 2018). As shown in Figure 3 earlier, MRV cycles are set to repeat every five years and to produce regular reports. These regular reports serve as the foundation for validating carbon credits and enable the project team to refine strategies, ensuring effective responses to emerging deforestation threats.

Overall, monitoring reports show both positive outcomes and implementation challenges during the CBADP's first years. Between 2011 and 2016 the project achieved a reduction in the deforestation rate by almost half, from the 2011 baseline of 0.9% to 0.4%. Moreover, it successfully reduced emissions against the baseline by 335,603 tCO2e (IBAP 2024). This reduction generated around 302,043 VCUs, sold for around $4 million (RSet 2019). Conservation efforts under the CBADP preserved critical habitats for ecologically significant species such as crocodiles and chimpanzees, while supporting sustainable resource use for local communities, including oysters, crabs, and fuelwood (RSet 2019). These achievements align with Guinea-Bissau's commitments to the UNFCCC and its national biodiversity strategy Terra Ranka (RSeT 2019).

Despite these successes, the CBADP has faced numerous challenges, with political instability in Guinea-Bissau being a major factor. The 2012 coup disrupted conservation timelines and delayed essential project activities, making it difficult to maintain administrative and financial support on a steady basis (IBAP 2024). Meeting evolving REDD+ standards has also proven challenging. The need for frequent technical adjustments and extensive staff training, particularly in carbon management and remote sensing, required substantial international expertise due to limited local experience within Guinea-Bissau (RSeT 2019; IBAP 2024) . Funding inconsistency has presented ongoing obstacles. Since the country lacks a dedicated conservation budget, the CBADP relies on carbon credit sales and fluctuating international donor support. Economic factors, such as volatility in the global cashew market, further impact local income sources and complicate the project's financial stability (IBAP 2024). Moreover, environmental factors, like the rainy season, limit field accessibility and add barriers to large-scale forest monitoring. Recent monitoring during the second MRV revealed unexpectedly high rates of terrestrial forest loss, despite positive results for mangrove cover. This finding has prompted a renewed focus on analyzing and addressing the underlying causes of deforestation (IBAP 2024).

## 4. Empirical Approach

To conduct an impact evaluation of the CBADP, this study conducts a comprehensive analysis of changes in forest, mangrove, and cropland coverage, as well as population dynamics in the PNC and PNTC. Using longitudinal satellite data and geospatial tools, the study examines changes in these ecosystems over time and evaluates the effectiveness of the conservation and training practices of the CBADP using an event studies framework. Qualitative interviews with key stakeholders integrate the socio-economic dimension of the CBADP and offer a nuanced understanding of the impacts on communities and sustainable conservation.

### 4.1 Hypothesis

Based on the main anthropogenic drivers of deforestation cited in the literature, and the CBADP's measures to address these issues, four hypotheses are developed. The hypotheses presented in table 1 focus on the main outcomes of interest, assessing the effectiveness of the program on mangrove, forest- and cropland coverage, as well as population count.

| Hypothesis | Outcomes and Variables |
|---|---|
| (**H1**) The measures implemented by the CBADP avoid a decrease in the average mangrove coverage within the project areas. | Avoided deforestation leads to a higher proportion of land that is covered by mangroves compared to controls. *Variable: Average Mangrove Coverage* |
| (**H2**) The measures implemented by the CBADP avoid a decrease in the average forest coverage within the project areas. | Avoided deforestation leads to a higher proportion of land that is covered by terrestrial forest compared to controls. *Variable: Average Forest Coverage* |
| (**H3**) The measures implemented by the CBADP lead to a decrease in the average cropland coverage within the project areas. | The reduced proportion of land covered by crops within the project areas indicates a reduction of agricultural activity, reducing the deforestation for agricultural purposes. *Variable: Average Cropland Coverage* |
| **(H4)** The measures implemented by the CBADP influence population count within the project areas. (a) Population count remains more stable if living conditions are improved or (b) decrease if restrictions hinder economic activity. | Improved economic conditions are reflected by stable population count within the project areas. Conversely, dissatisfaction with restrictions and insufficient improvements to livelihoods are reflected by a lower count of population within the project areas. *Variable: Average Population Count* |

Table 1: Hypotheses

The CBADP measures are designed to address the main drivers of deforestation, such as illegal logging and agricultural expansion. Therefore, we expect that the measures, as for instance, stricter land-use controls, patrolling of illegal logging, and community engagement, reduce deforestation within the PAs. The conservation of mangroves and forests are central to the CBADP. Thus, the first hypothesis states that, if the joint measures are effective, we expect to see a higher proportion of the land in treated areas covered by mangroves, compared to the control areas (H1). This outcome should then indicate the project's success in maintaining these critical ecosystems in a high-risk deforestation area. The second hypothesis follows the same logic for forest coverage. (H2) CBADP's success should be equally reflected by a higher proportion of forest coverage within the PAs relative to control areas. Additionally, these measures are expected to moderate the conversion of forest to agriculture within the PAs, with agricultural activity being a central driver of deforestation. Thus, the third hypothesis examines changes in cropland. CBADP's success in moderating agricultural expansion should be reflected by a reduced cropland coverage within the PAs, compared to control areas (H3). Moreover, we expect forest und cropland coverage to behave conversely, with a higher forest coverage accompanied by a lower cropland coverage. Lastly, the fourth hypothesis examines the average population count as a proxy for assessing socio-economic impacts within the PAs. Due to the lack of disaggregated data on poverty and other socio-economic indicators, population count serves as an alternative to evaluate the effects of CBADP measures. On the one hand, CBADP measures involve community development measures and training that aim to improve the living standard of communities in the PAs. On the other hand, the literature on the socio-economic impacts of REDD+ initiatives is less optimistic. Thus, we explore a two-sided hypothesis. (H4a) Improved living conditions resulting from improved methods for income-generating activities should be reflected by a stable population count within the PAs compared to controls. In the treated rural areas where infrastructure is rudimentary, basic services are not guaranteed, and income generation is limited, improved living conditions should be reflected by willingness to stay in the area. Conversely, if CBADP's measures do not improve living conditions sufficiently, we expect a decreasing population within the treated areas, compared to controls (H4b). Moreover, lower population count in the treated areas may reflect dissatisfaction with restrictions for commercial activities, such as the high enforcement of the three-month fishing ban within the parks. This dual perspective underscores the need to consider both potential outcomes when assessing the impact of CBADP measures.

Overall, these hypotheses provide a foundation for evaluating CBADP's success in addressing the anthropogenic drivers of deforestation, preserving critical ecosystems, and sufficiently involving communities targeted by the project.

### 4.2 Econometric model

The impact evaluation of the CBDAP is conducted using an event study analysis with panel data for each variable of interest. The event study framework, also referred to as Difference-in-Difference (DiD), is particularly well-suited for this analysis given the nature of the intervention. The event study methodology seeks to determine the effect of an event on the dependent variable of interest. A classical DiD approach estimates the average treatment effect by comparing the treated and control group in two time periods, namely pre- and post-treatment. The event study method extends the analysis by explicitly considering multiple time periods and allowing for an examination of dynamic treatment effects, indicating the change in each subsequent year. Unlike the static average treatment effect of traditional DiD, the event study framework allows treatment effects to vary over time. This flexibility allows us to check whether trends between the treated and control group are similar previous to treatment.

This approach assumes that, in the absence of treatment, the average outcomes for treated and control groups would have experienced similar trends in the outcome variables of interest – namely, the parallel trends assumption. In an event study this assumption is evaluated by assessing the coefficients for periods before the intervention begins. Small and statistically insignificant coefficients in the pre-treatment periods should suggest the groups follow similar trends (Marcus and Sant'Anna 2021). Additionally, using panel data to explore the impact of the CBADP on the same regions across different years allows the introduction of fixed-effects to control for any region-specific time-invariant characteristics that might affect the outcomes of interest. By using fixed effects, the estimation focuses on within-region changes, controlling for possibly unobservable factors that do not vary over time and improving the robustness of the estimates.

To assess the dynamic treatment effects of the CBADP before its introduction, the coefficients are estimated relative to the baseline year 2010. Doing so simplifies the interpretation of the program’s impact relative to the pre-treatment levels. Thus, we can determine if and when, mangrove-, forest-, cropland coverage and population count significantly diverged from pre-2010 levels. This offers a more detailed understanding of the program's impact trajectory.

The treatment occurs within the two PAs, where the different conservation measures from the CBADP were implemented, starting in 2011. The two LKs and the two RRDs together serve as control areas (Figure 7). According to the monitoring report, they closely resemble the ecological and socio-economic characteristics of the treated areas. The LK represents a 2 km buffer zone around the PAs, and the RRD is a larger area around the PAs.

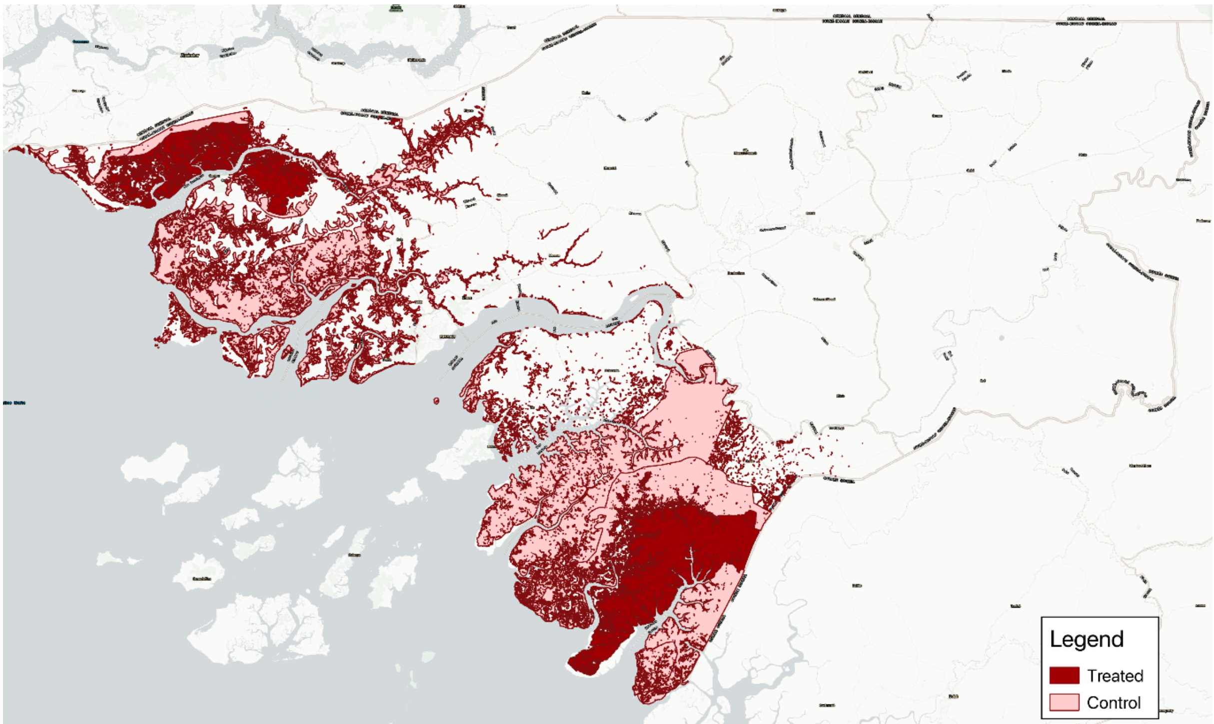


Figure 7: Treated and Control Area (Source: Own Illustration)

To evaluate the impact of the CBADP on the variables of interest the regression models were estimated centered around deviations from the baseline year 2010 as follows:

$$\boldsymbol{Mangrove\ coverage_{it}} = \beta_0 + \sum_t \delta_t(treated_i \times year_t) + \lambda_i + \gamma_t + \varepsilon_{it} \qquad (1)$$

The dependent variable $\text{Mangrove coverage}_{\text{it}}$ represents the average mangrove coverage in area i at time *t*. Given that the raster data is binary, the dependent variable represents the proportion of the area covered by mangroves in each region. Changes in the dependent variable are thus interpreted in terms of changes in percentage points of coverage. $\beta_0$ represents the constant term, reflecting the initial mangrove coverage in baseline year 2010. In order to draw causal conclusions from the CBADP, the interaction $\delta_t(treated_i \times year_t)$ is the key term in the event study analysis. This term represents the average difference in mangrove coverage for the treated area, and thus the impact of the program, relative to the pre-treatment year. The year dummies $\gamma_t$ are the year-specific effects that capture trends across all years. These year fixed effects account for time-specific variations in mangrove coverage that may be unrelated to the treatment. The baseline year 2010 is excluded from the equation and it serves as the omitted category in the regression model to prevent perfect multicollinearity. All other year coefficients are interpreted as deviations from the baseline.

Fixed effects $\lambda_i$ are included to control for area-specific and time-invariant characteristics to address any unobserved heterogeneity that distorts the results. Finally, the error term $\varepsilon_{it}$ represents unobserved factors that may influence mangrove coverage in each area i at each time *t*. The standard error is clustered at the region level to account for within-region correlation.

The econometric models for forest and cropland coverage, as well as population count, follow the same pattern, comparing the change in average forest, cropland coverage and population in the PAs to the baseline year 2010 to assess the impact of the program.

$$\boldsymbol{Forest\ coverage_{it}} = \beta_0 + \sum_t \delta_t(treated_i \times year_t) + \lambda_i + \gamma_t + \varepsilon_{it} \quad (2)$$

$$\boldsymbol{Cropland\ coverage_{it}} = \beta_0 + \sum_t \delta_t(treated_i \times year_t) + \lambda_i + \gamma_t + \varepsilon_{it} \quad (3)$$

$$\boldsymbol{Population_{it}} = \beta_0 + \sum_t \delta_t(treated_i \times year_t) + \lambda_i + \gamma_t + \varepsilon_{it} \quad (4)$$

This methodology allows us to control for time-invariant regional characteristics and common year-specific shocks, isolating the causal impact of the intervention on the variables of interest.

### 4.3 Data Processing Method

Acquiring detailed data in Guinea-Bissau for statistical analysis presents a significant challenge. Due to the limited resources of the country, publicly accessible consistent data on the variables of interest, especially longitude data, is non-existent. Therefore, this paper utilizes satellite imagery to analyze the before mentioned hypotheses. Using satellite imagery for the same regions across years allows us to estimate the environmental impact of the program and assess its effectiveness. Additionally, analyzing the population dynamics allows us to explore its socio-economic impact. For this purpose, various datasets on mangrove-, forest- and cropland coverage, and population dynamics were visualized in the software QGIS[3], focusing on the specific areas of the CBADP. The final datasets were chosen based on their accuracy and validity.

Pre-processing steps in R included reprojecting all raster layers to the Coordinate Reference System EPSG:32628 (WGS 84 / UTM zone 28N) to align with regional vector files. Categorical raster layers were reprojected using the nearest-neighbor method to preserve original classes, while population data, as a continuous variable, was reprojected with bilinear interpolation. To

[3] QGIS is a free, open-source GIS software for mapping, analyzing, and managing geospatial data.

analyze changes in mangroves, forests, cropland, and population over time, zonal statistics were calculated for six distinct areas: PA. LK, and RRD within both PNTC and PNC. Zonal statistics involve calculating values such as means and standard deviations for the pixels within a defined region. This method enables a direct comparison of the average coverage of these variables between treated and control areas. Mean coverage, standard deviation, and pixel counts were extracted by region and year to construct the final datasets for statistical regressions. Verifying accuracy, a sample analysis was conducted in QGIS, involving geometry checks, reprojection, clipping, and zonal statistics. Due to R's higher accuracy in handling irregular region borders during the reprojection and for replicability purposes, the R output was used for the regressions.

### 4.4 Data

The analysis was conducted using geospatial data from the Global Mangrove Watch (GMW), ESA Climate Change Initiative Land Cover (ESA CCI-LC), and WorldPop. The PA, LK, and RRD boundaries were provided by Maria Vasconselos, a researcher directly involved in the technical preparation of the CBADP.

To analyze changes in mangrove coverage data on mangrove extent from the GMW was used (Bunting 2022). This dataset follows the most comprehensive approach to long-term monitoring of mangrove ecosystems globally. It consists of a binary layer indicating where mangroves are present. The dataset is available for the years 1996, 2007-2010, and 2015-2020 with a 25-meter resolution. The GWM methodology utilizes L-band Synthetic Aperture Radar data, ideal for mapping vegetation in tropical regions where cloud cover limits the accuracy of satellite imagery. The method achieves 87.4% overall accuracy and employs one of the most rigorous validation frameworks in global mangrove mapping, incorporating 17,366 reference points across 38 global sites. This comprehensive validation approach allows for reliable accuracy assessment across diverse mangrove environments and change scenarios. The dataset's use by major international organizations, such as UNEP, WWF, and the Ramsar Convention, highlights its significance and reliability. Its broader application in scientific research and policymaking makes it especially relevant for monitoring protected areas like PNTC and PNC.

Secondly, we use data from the ESA CCI-LC to examine the impact of the CBADP on forest and cropland cover. The ESA CCI-LC dataset provides annual land cover maps at 300m resolution from 1992–2022. This dataset offers temporal consistency through rigorous baseline mapping, comparing historical and updated maps, and enabling the analysis of agricultural expansion and forest changes (Harper et al. 2023; ESA 2017). The dataset's technical foundation combines different satellite data, and it uses a sophisticated change detection algorithm that requires changes to persist over multiple years. The dataset's accuracy was assessed using 2,329 global validation points. Overall accuracy is 71.45%, with higher accuracies for key classes like croplands (89-92%), forests (59-96%), and water bodies (92-96%). The land use types are classified according to the Food and Agriculture Organization's (FAO) Land Cover Classification System, ensuring standardized categorization. Additionally, the dataset includes a practical mapping of ESA CCI-LC classes to the six Intergovernmental Panel on Climate Change (IPCC) Land Use categories, enabling more accurate analysis of conservation efforts and land-use changes. This dataset provides precise data for analyzing changes in land cover, relevant to conservation strategies and sustainable land-use management in PNTC and PNC. Thus, it directly contributes to the evaluation of CBADP activities. The adoption of the ESA CCI-LC dataset by the IPCC, World Bank, FAO and others highlights its validity and reliability for land cover monitoring and climate-related research.

With regards to socio-economic outcomes, night-time light data is commonly used as a proxy. However, significant differences in spatial resolution and radiometric quantization between the VIIRS Night Lights and DMSP Night Lights missions create substantial challenges for conducting reliable temporal analyses within our study period. Given the lack of disaggregated data on other socio-economic indicators in Guinea-Bissau, our study instead explores population count as a proxy for the potential socio-economic value generated for local population. Therefore, to examine the impact on socio-economic outcomes, population dynamics are explored using Lloydet al. (2019) WorldPop dataset. This data contains high-resolution gridded population maps at a 100m resolution for the period 2000–2020, addressing gaps in traditional census data in regions lacking robust demographic records. The units are measured in number of people per pixel with country totals adjusted to match the corresponding official United Nations population estimates. This is particularly critical in countries like Guinea-Bissau, where the last national census was conducted in 2009. By integrating data from sources such as the Global Human Settlement Layer, Global Urban Footprint, and ESA CCI-LC, the model captures an unprecedented level of detail in demographic analysis and provides a comprehensive and relevant estimation of population numbers. The dataset's adoption by major international organizations, like the WHO, UNDP and conservation groups, further validates its utility. Thus, this dataset represents a critical tool for systematic analysis of demographic patterns and their implications for conservation and sustainable development.

An overview of the variables included in the regressions using this data is presented in the table below.

| Variable | Description | Dataset | Timespan for Event Study |
|---|---|---|---|
| **Mangrove cover** | Average mangrove coverage | Global Mangrove Watch | 2007-2010, 2015-2020 |
| **Forest cover** | Average forest coverage | ESA Climate Change Initiative Land Cover | 2000-2020 |
| **Cropland cover** | Average cropland coverage | ESA Climate Change Initiative Land Cover | 2000-2020 |
| **Population count** | Population projection per pixel | WorldPop | 2000-2020 |
| **Regions** | Cantanhez, PA<br>Cacheu, PA<br>Cantanhez, LK<br>Cacheu, LK<br>Cantanhez, RRD<br>Cacheu, RRD | Geospatial data from IBAP's monitoring operations developed by Vasconselos (2015) | static |

Table 2: Summary of variables used for impact evaluation

### 4.5 Interview Questionnaire

To provide additional depth and context to the quantitative findings, five semi-structured interviews were conducted in November 2024, adopting a multi-stakeholder approach to capture diverse perspectives on conservation efforts and community engagement.

The interviews comprised expert interviews with key institutional stakeholders and focus groups with local communities. These included the Didier Monteiro, Executive Secretary of FBG (70 minutes), Padjalo Carvalho, an IBAP technician and park ranger (60 minutes), community groups in the Bolola (49 minutes, 6 participants) and Elalabe villages (50 minutes, 4 participants) in the PTNC, and representatives from the Fishermen's Association in the region of Cacheu (77 minutes, 8 participants). Due to limited accessibility to the PNC park, interviews were only possible in the PNTC PA and its surroundings. Community interviews were facilitated in Creole and Portuguese with professional interpreters, while expert interviews were conducted in English. Discussions focused on themes directly relevant to conservation efforts, including the socio-economic impacts of projects, local perceptions of environmental change, and operational challenges for stakeholders. Transcriptions were prepared using the software Otter.ai and manually reviewed together with the audio to ensure precision and preserve contextual nuance. Ethical protocols were rigorously followed, with participants providing informed consent. Community sensitivities were respected throughout, and data protection adhered to GDPR standards[4]. These interviews shed light on nuances and practical challenges that quantitative data alone could not capture, enhancing the interpretation of results.

## 5. Results

The following chapter starts by providing critical context on the impact of the CBADP measures stemming from the qualitative interviews. In the following a summary of the key insights from the interviews and the results of the quantitative analysis are presented.

### 5.1 Qualitative Interviews

The institutional perspectives from the FBG and IBAP revealed the complexity of implementing conservation measures to preserve ecosystems in a financially constrained setting. The FBG, represented by its Executive Secretary Didier Monteiro (Appendix Graphic A8), highlighted the vital role of these ecosystems and the financial challenges of sustaining preservation efforts. "The National Parks are of extreme importance to biodiversity […] but they are very fragile ecosystems. […] In Cantanhez, we still have some trails of primary forest, untouched by man". Particular conservation challenges are posed by the necessity of income generation for the local communities often realized through land conversion to cashew plantations, even within protected areas. Additionally, rotational rice farming practices further

[4] GDPR standards ensure the protection of personal data by regulating its collection, use, and storage while granting individuals control over their information.

strain ecosystems, as abandoned fields (Appendix Graphic A3) do not naturally regenerate, particularly mangroves, which require active restoration. While the government of Guinea-Bissau grants the national parks the "protected area" status, funding for conservation activities is entirely dependent on international donors and NGOs. The FBG, founded to provide long-term financing to IBAP's activities, achieved approximately $4 million in revenues from REDD+ carbon credits. Moreover, interest payments from the foundation's endowment are used to fill IBAP's financing gaps. As Mr. Monteiro explained, "If we had no other funding at all, they wouldn't be able to cover operations of the park, let's say for three, four years".

The active involvement and benefit of communities is central to the CBADP. Currently, the FBG is developing benefit-sharing agreements with IBAP to distribute the carbon credit revenues. This agreement will empower communities to decide how funds are used, such as for schools, water access, or fishing equipment. Mr. Monteiro emphasized, "the idea is not to impose a model of distribution", but to reach out to communities and address the most urgent needs. Moreover, he highlighted the awareness of communities on the implications and deforestation, telling a story of a time when members of a community in PNC sought IBAP's authorization to cut down a single tree for a canoe. "They understand that even for a single tree, they must ask IBAP". He further highlighted the high risk of deforestation in the national parks, as they are "richer and well preserved". On the benefits of the project, he stated the impact on forest has been positive, while on mangroves more moderate. Regarding biodiversity, "we have evidence of the animals [returning], elephants and buffaloes coming back to Cantanhez". Looking at conflicts between preservation and economic subsistence, he mentioned that the measures take into consideration communities' needs. Not every tree is forbidden, hunting specific species is allowed, but there are rules for sustainable fishing "not to constrain people, but to compel them to do it sustainably". Overall, Mr. Monteiro highlighted significant challenges in guaranteeing continuous funding, limited technical capacity, and the political instability that delayed the implementation of some measures in the initial part of the project. Despite these challenges, conservation measures have inspired communities outside protected areas to adopt similar practices, demonstrating an “outside-inside effect” that expands preservation efforts voluntarily. For example, one community’s self-implementation of conservation rules inspired IBAP and FBG to expand the PA into a biosphere region covering much of the Cacheu area.

This view was complemented by Padjalo Carvalho, one of IBAP technicians and park ranger native to the PNTC region. He confirmed that conservation measures, such as dividing the park into three zones and the biological rest periods, have yielded positive outcomes. Mr. Carvalho explains that IBAP enforces strict fishing restrictions in PNTC, such as a three-month annual ban to allow fish populations to reproduce. Fishing is only allowed for residents who have lived in the park for at least three years. Nevertheless, adapting to the conservation measures is not always easy for communities, and it takes time to change decades-long traditional practices. Importantly, to accept restrictions on the areas where communities can conduct the activities they live from, they need to see the tangible benefits of conservation efforts. As an IBAP technician, Mr. Carvalho played a crucial role in explaining his own village the benefits of joining the conservation efforts, he states “At the beginning, they thought it was unfair. […] there were restrictions on some of the activities that they can do in this area, but this and belongs to them”. Now, he expresses that IBAP has made a difference with his community. They work closely with communities, offering training programs, involving a representant actively in participatory councils, and providing infrastructure supported by international donors’ financing. For instance, he mentions that alternative oyster harvesting methods that avoid cutting down mangroves, and beekeeping activities as additional income-generating activities are essential measures to reduce dependence on natural resources. Moreover, the community radio, Rádio Voz do Rio Cacheu, plays a crucial role in raising awareness about conservation.

He states, “People are beginning to see the long-term benefits of protecting the park, though it’s a gradual process”. In his opinion the most impactful measure has been the biological rest period, where fishing is temporarily halted allowing fish and marine species to reproduce and replenish. However, the resource constraints make enforcement partly inconsistent. "IBAP conducts surveillance with two boats to monitor activities, but limited funding can make enforcement challenging", the ranger states.

The two interviews with communities in the park and one interview with a fishermen association (Appendix Graphic A6) outside of the park, revealed existential concerns about the lack of basic infrastructure and services, their vulnerability to the sea level rise, and the nuanced effect the project had on their daily lives. The communities in the Bolola (Appendix Graphic A5) and Elalabe (Appendix Graphic A7) villages within the PA stem from the Felupe ethnic group and joined the CBADP at a later stage of implementation. The residents of both villages emphasized their reliance on mangroves for fishing, agriculture, and housing, as mangroves provide wood for construction, “because everyone knows that they survive because of these mangroves, without these mangoes there is no life in this village”. The communities are directly involved in conservation efforts, and they appreciate some of the benefits. For instance, IBAP has provided housing, water pipes to irrigate crops, and vegetable gardens, among others. However, the support they have received is insufficient to alleviate the rudimentary living conditions they face while they adapt to the conservation measures. In both communities, the absence of a protective wall or dike has left residents and fields vulnerable to flooding. In Elalabe the community explained that farmland had shrunk from 6,000 to 2,000 hectares, due to the rise in water. The chief of the Bolola community warned that, if they do not receive help to build a dike, the village might disappear in 10-20 years. Both communities face major challenges due to declining fish populations caused by overfishing, and limited regulation of external fishers, including those from neighboring countries like Senegal. Reduced rainfall, rising water levels, and unequal access to resources further disadvantage local fishers, driving the need for alternative solutions and support. Overall, the lack of infrastructure is a severe concern of the Bolola and Elalabe villages. Both communities also struggle with access to clean drinking water, relying on isolated springs or rainwater. One woman from Elalabe warned that without improvement, water shortages might soon force them to abandon their town, "So how can somebody live without drinking? She said, [...] if not one day, they will leave this place".

The members of the fishermen association in PNTC expressed a nuanced attitude towards the conservation measures. They face significant challenges from depleted fish stocks and overfishing, forcing them to travel longer distances, up to over 160km, and increasing fuel and equipment costs. This creates serve financial instability, as fishermen explain that "it is too much expensive to for them to catch the fish […] and then bring to market to sell". Additionally, restrictions like the fishing ban for outsiders of the PNTC and the three-month biological rest period enforced by IBAP, create additional economic pressures. However, it remains uncertain whether restrictions on foreign fishers are effectively enforced, "because there [is] not too much control". While these measures aim for long-term sustainability and increased fish stocks, fishermen struggle to survive during restrictive periods without alternative income sources. A fisherman noted that although the rest period helps fish recover, it leaves them without viable livelihood options. The lack of infrastructure, such as freezer trucks and reliable transportation to markets, further worsens the situation, as spoiled fish reduce income potential. The Fishermen's Association provides credit for boat engines and supports community resilience by assisting during hardships and organizing maintenance activities, but its financial capacity is limited. "It is not easy even to give that credit, because to gather all the credits is too […] difficult." Moreover, the Association reports that "what they see is a lack of trees" in the past years in the national park. Although the problems along with the tree loss are widely recognized, the economic reliance on fishing and agriculture leaves communities with limited alternatives, often driving deforestation for cashew cultivation or charcoal production. The three-month biological rest period further exacerbates the situation, “because [the people] don't have another way to live their own life.”

These findings underscore the importance of integrating community priorities into conservation planning to ensure the long-term success of REDD+ initiatives. Moreover, it demonstrates the difficulties of implementing conservation measures in low-income contexts where the reliance on nature is existential.

### 5.2 Mangroves

This trend analysis explores the available data for the years 1996, 2007–2010, and 2015–2020. Exploring the trends of annual change in mangrove coverage in the six areas of study shows stable trends for the PNTC between 2007 and 2020. For the PA Cacheu the coverage is stable at 60% across all years (Appendix Figure A3). Trends for of mangrove extent in PNC show a higher volatility, with a slight decline starting around 2009 and continuing to the present. However, overall, the extent remains relatively stable. In the PA Cantanhez specifically, mangrove coverage consistently ranges between 19% and 20% (Appendix Figure A4).

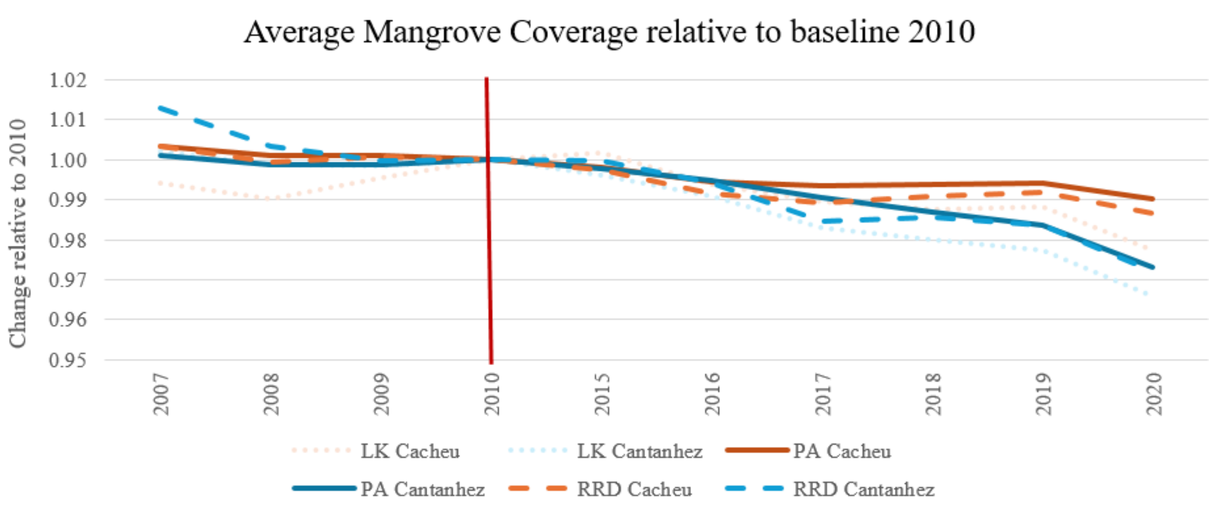


Figure 8: Descriptive Trends of Mangrove Coverage relative to baseline (Source: Own Illustration)

To better illustrate the change in mangrove coverage we explore the change in extent relative to the baseline year 2010, before the project started (Figure 8). The graph illustrates the annual mangrove coverage across three different zones relative to baseline for PA, RRD, and LK in the two regions PNTC and PNC from 2007 to 2020. The trends exhibit a general declining trend after 2010, but there are slight differences between the regions in the rate and magnitude of decline. The most notable period of decline seems to have started around 2015-2016, which might coincide with changes in external pressures affecting all areas. This decline is more pronounced in the PNC region compared to PNTC. For example, mangrove cover in PA Cacheu drops by 1 percentage point while PA Cantanhez experiences a drop of 3 percentage points in the last decade. Although these changes are relatively minor, the overall trend clearly indicates a decline in mangrove coverage across all areas compared to the baseline level of 2010. It is worth noting that after the start of the CBADP, both PAs appear to have experienced less mangrove coverage loss compared to their respective LK and RRD areas, as seen in Figure 8.

Using the event studies approach, the first regression analyzes the impact of the CBADP treatment on mangrove coverage in PA areas across the available years 2007-2010 and 2015-2020. To examine dynamic treatment effects, the model includes an interaction between the treatment and specific years relative to the 2010 baseline. This comparison evaluates the PA areas as treated regions against the control groups, represented by RRD and LK (Table 3). It is important to note that we can only evaluate the combined effect of the measures within both treated areas, rather than assessing their individual impacts separately.

| VARIABLES | Mangrove |
|---|---|
| **Treated*year** | |
| Treated group x year = 2007 | 0.000492 |
| | (0.00153) |
| Treated group x year = 2008 | 0.000857 |
| | (0.00134) |
| Treated group x year = 2009 | 0.000567 |
| | (0.000661) |
| Treated group x year = 2015 | -0.000454 |
| | (0.000608) |
| Treated group x year = 2016 | 4.42e-05 |
| | (0.00134) |
| Treated group x year = 2017 | 0.000926 |
| | (0.00107) |
| Treated group x year = 2018 | 0.000665 |
| | (0.000688) |
| Treated group x year = 2019 | 0.000466 |
| | (0.000317) |
| Treated group x year = 2020 | 0.00104 |
| | (0.000793) |
| Observations | 60 |

Robust Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3: Mangrove Coverage

The parallel trends assumption holds, as reflected by the insignificant interaction coefficients in the pre-treatment period, indicating same trends across all areas. The interaction coefficients for the treated areas show no statistically significant results in any year, as indicated in the regression table above (Table 3). This suggests that the CBADP did not have a measurable significant effect on mangrove coverage during the analyzed years. Considering t-statistics coefficients, we cannot reject the null hypothesis as these coefficients are equal to zero. Therefore, the hypothesis (H1) on mangroves, suggesting that the measures implemented by the CBADP avoid a decrease in the average mangrove coverage within the PAs compared to the control group, has to be rejected for the study period. Therefore, we can assume that the measures to stop deforesting mangroves did not have a significant effect. Moreover, the small positive coefficients further imply that the treatment did not lead to substantial increase in mangrove coverage. The estimated change relative to baseline is small, suggesting that, if there is any effect, it is quite marginal.

Furthermore, the graph below (Figure 9) visualizes the difference of mangrove coverage between PA to LK and RRD from 2007 to 2020, where the average change is measured relative to the baseline year 2010.

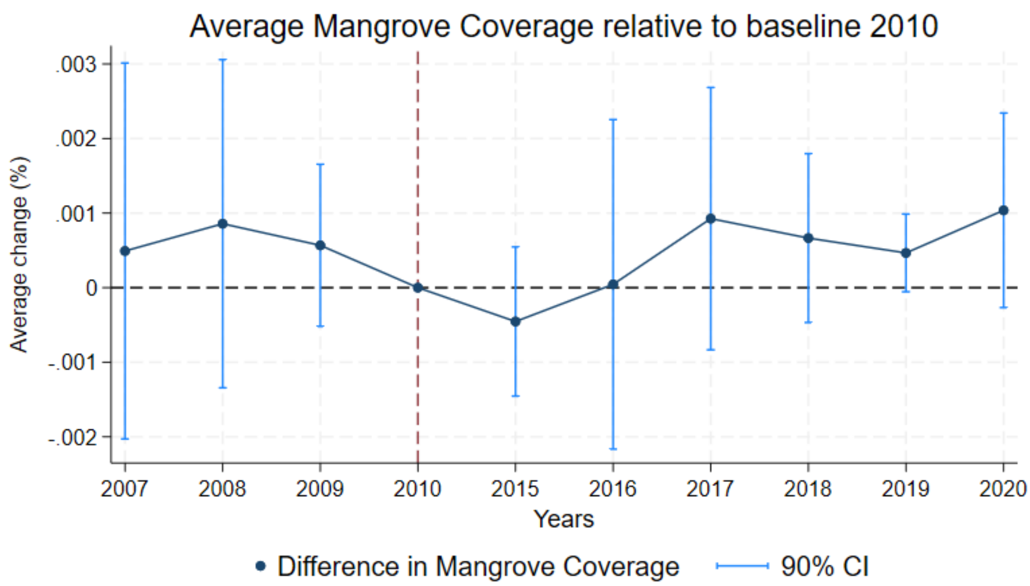


Figure 9: Average Mangrove Coverage relative to baseline 2010 (Source: Own Illustration)

For the years 2007-2009 the graph shows very small positive deviations from the baseline. The wide confidence intervals throughout most of the years reflect the considerable degree of uncertainty in the estimates of average mangrove coverage change relative to the baseline in 2010. The overlap of the confidence intervals with the horizontal zero line suggests that the observed deviations from the baseline are not statistically different from zero. The impact of the CBADP is therefore not captured effectively. However, it is notable that the years 2019 and 2020 show coefficients close to statistical significance. Nevertheless, a possible explanation for the lack of statistical significance overall may be attributed to limitations in the available data. The small sample size (N=60) reflecting the average value of pixels in each area categorized as mangrove, combined with missing data for the period 2011-2014, limit the precision of the model. Additionally, the post-intervention analysis timeframe may be too short to fully assess the CBADP's effectiveness. Extending the study period in the future could provide a clearer understanding of the program's impact on mangroves, especially since mangrove ecosystems often require several years to show signs of recovery and growth (Zimmer et al. 2022).

One possible reason for the lack of significant effects on mangrove coverage is the dual role mangroves play in the lives of local communities. While their ecological importance is recognized, mangroves remain a crucial resource for daily needs, serving as a source of fuel and coal. Also, some traditional agricultural practices involve harmful methods towards mangroves, such as clearing of mangroves forest for the development of rice paddies or for oyster harvest. Adapting to more sustainable methods, such as improved oyster farming, requires time as communities gradually adjust to project rules. This might further explain the results.

Another possible explanation for our observations is that mangrove reforestation efforts were only launched in 2014. Following these measures, the slight upward trend after 2017, combined with the coefficients observed in 2019 and 2020 close to significance, could suggest an emerging positive effect on mangroves in the treated areas. Therefore, the natural growth cycle of mangroves is a critical factor. As mangrove trees require several years to grow, too young and small mangroves might not be detectable by remote-sensing method. This implies that newly afforested or reforested mangroves might only become visible in satellite imagery after a significant delay. While a statistically significant conservation impact cannot be observed, the slight upward trend hints at a potential positive effect. Moreover, IBAP reports positive avoided deforestation outcomes for mangroves from 2017–2021, suggesting that the lack of statistical significance may be attributable to data limitations in our study rather than the absence of a conservation effect (IBAP 2024).

## 5.3 Forest

The trend analysis examines the annual forest cover across the three different zones in the study regions PNTC (Figure 10) and PNC (Figure 11) from 2000 to 2022. The two regions show distinct patterns in their forest dynamics, with PNC exhibiting higher absolute forest cover across all zones compared to PNTC, though with notably different preservation patterns. A general negative trend in forest cover is observable, pointing to forest loss across all areas.

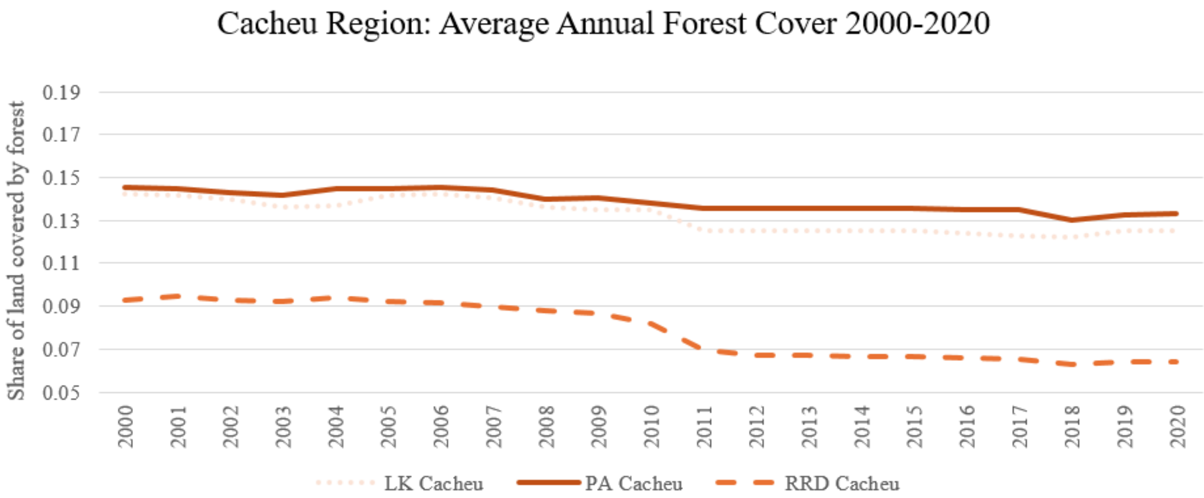


Figure 10: Average Annual Forest Cover in PNTC (Source: Own Illustration)

In PNTC, the PA shows the highest forest cover at the beginning of the period with a slight decline over the observation period (Figure 10). RRD Cacheu shows the lowest initial forest cover and experiences a decline of 2.2 percentage points. The PA shows the lowest decline in forest cover among the three areas with 1.3 percentage points of forest loss. A notable characteristic is that the PA maintains the most stable forest cover throughout the entire period.

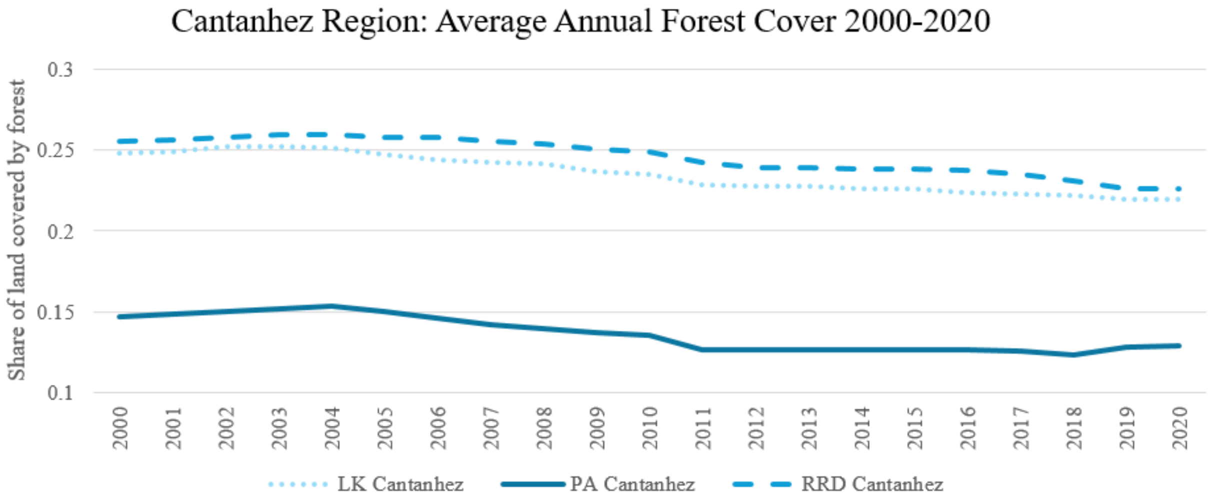


Figure 11: Average Annual Forest Cover in PNC (Source: Own Illustration)

In PNC, forest cover is generally higher across compared to PNTC and shows more stability over time (Figure 11). RRD Cantanhez maintains the highest coverage among all zones across both regions throughout the period. However, LK has almost identical coverage and follows patterns similar to the RRD, though showing minimal decline over the period. PA Cantanhez demonstrates stability, maintaining forest cover around the 12-15% level. A notable characteristic of the PNC region is the relative stability of all three zones compared to PNTC. To better illustrate the change in forest coverage we explore the change in extent relative to the baseline year 2010, as depicted below (Figure 12).

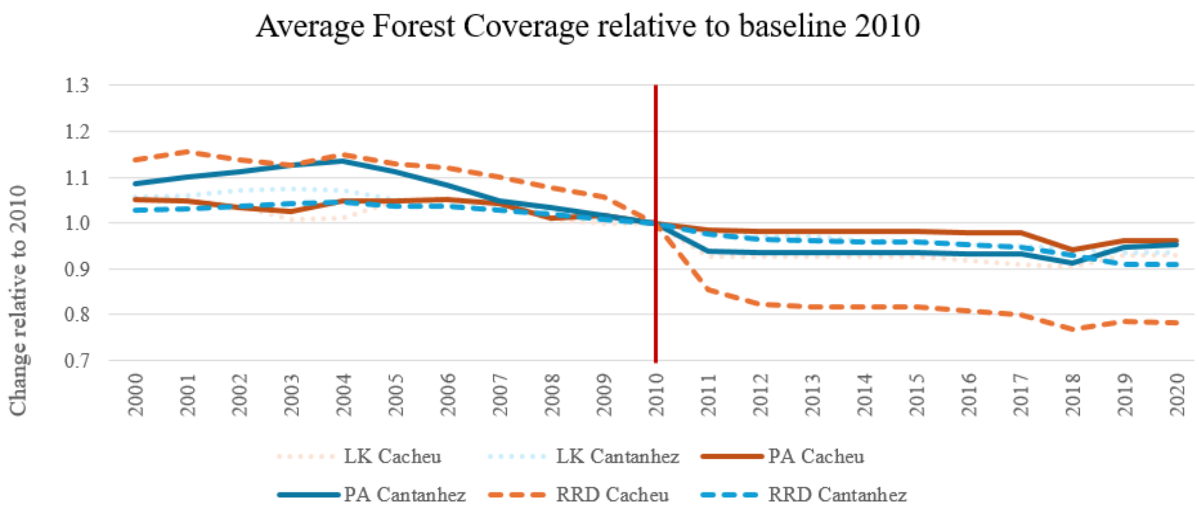


Figure 12: Annual Forest Coverage Relative to Baseline 2010 (Source: Own Illustration)

Figure 12 illustrates the annual forest coverage relative to baseline for PA, RRD, and LK in the two regions PNTC and PNC from 2000 to 2020. Before 2010, most zones show forest coverage levels notably higher than their 2010 values. Post-2010, all zones show declining trends but with varying intensities. RRD Cantanhez shows the slightest declining trend compared to its PNTC counterpart, maintaining close proximity to its baseline level throughout the post-2010 period. The forest cover in RRD Cacheu experiences the most substantial reduction, falling to approximately 75% of its 2010 level by 2018, before showing a slight recovery to 85% by 2020. The PAs in both regions demonstrate more moderate declines, with PA Cacheu and PA Cantanhez maintaining levels between 93% and 95% of their 2010 values by 2020. The data reveals a general downward trend across all zones relative to 2010 levels, with the most substantial declines occurring after 2017. However, from 2018 onward, most zones show signs of slight recovery or stabilization, though remaining below their 2010 levels.

Following the event studies approach, the next regression explores the impact of the CBADP treatment on forest coverage across the years. In order to examine dynamic treatment effects, the average change in forest coverage within the PAs (PNTC and PNC) is compared to the control group (RRDs and LKs) relative to baseline levels. It is important to note that we can only evaluate the combined effect of the measures within both treated areas, rather than assessing their individual impacts separately. The regression in table 4 shows the annual interaction effects with the treatment on forest coverage relative to 2010.

| VARIABLES | Forest |
|---|---|
| **Treated*year** | |
| Treated group x year = 2000 | -0.000566 |
| | (0.00284) |
| Treated group x year = 2001 | -9.62e-05 |
| | (0.00397) |
| Treated group x year = 2002 | -0.000426 |
| | (0.00587) |
| Treated group x year = 2003 | 0.000490 |
| | (0.00764) |
| Treated group x year = 2004 | 0.00196 |
| | (0.00684) |
| Treated group x year = 2005 | 0.00126 |
| | (0.00445) |
| Treated group x year = 2006 | 0.000445 |
| | (0.00215) |
| Treated group x year = 2007 | -0.000815 |
| | (0.000761) |
| Treated group x year = 2008 | -0.00179 |
| | (0.00206) |
| Treated group x year = 2009 | 0.000257 |
| | (0.00119) |
| Treated group x year = 2011 | 0.00339 |
| | (0.00330) |
| Treated group x year = 2012 | 0.00463 |
| | (0.00352) |
| Treated group x year = 2013 | 0.00483 |
| | (0.00357) |
| Treated group x year = 2014 | 0.00563 |
| | (0.00337) |
| Treated group x year = 2015 | 0.00563 |
| | (0.00337) |
| Treated group x year = 2016 | 0.00636 |
| | (0.00317) |
| Treated group x year = 2017 | **0.00736*** |
| | (0.00318) |
| Treated group x year = 2018 | **0.00579*** |
| | (0.00254) |
| Treated group x year = 2019 | **0.0101**** |
| | (0.00331) |
| Treated group x year = 2020 | **0.0106**** |
| | (0.00321) |
| Observations | 126 |
| R-squared | 0.998 |

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 4: Forest Coverage

Previous to treatment, the coefficients remain close to zero and are not statistically significant. This confirms the underlying parallel trends assumption. No meaningful deviation from zero suggests that all regions followed similar trends in forest coverage before the introduction of the CBADP. Thus, this indicates the lack of any pre-existing trend biases the treatment.

After the introduction of the CBADP the coefficients show a steady upward trend. Although not significant, the positive coefficients for 2011-2016 suggest that forest coverage in treated regions showed higher values than the control regions in the first years after the implementation of the program. Using 90% confidence intervals, we observe a significant increase in the relative average forest coverage within the PAs from 2017 onwards. In 2017, the average forest cover within the PAs is 0.73 percentage points higher compared to the control areas and relative to baseline. This result is significant at the 10% level. Moreover, in 2019, the forest cover in the treated areas is 1.01 percentage points higher, while in 2020, it increases by 1.06 percentage points; both estimates are significant at the 5% level. The general negative trend in forest cover across all areas seen in the descriptive trends, combined with the positive significant coefficients of the treatment effects, indicates that the decrease in forest was stronger in the control than in treated regions. This finding is especially interesting, as it indicates that, while measures to halt deforestation may not have been effective in increasing forest in absolute terms, they were effective in reducing the deforestation rate within the PAs relative to the control group. Hence, our results confirm the second hypothesis (H2). The measures implemented by the CBADP avoided a decrease in the average forest coverage within the PAs compared to control regions and relative to baseline. We can reject the null hypothesis in favor of H2.

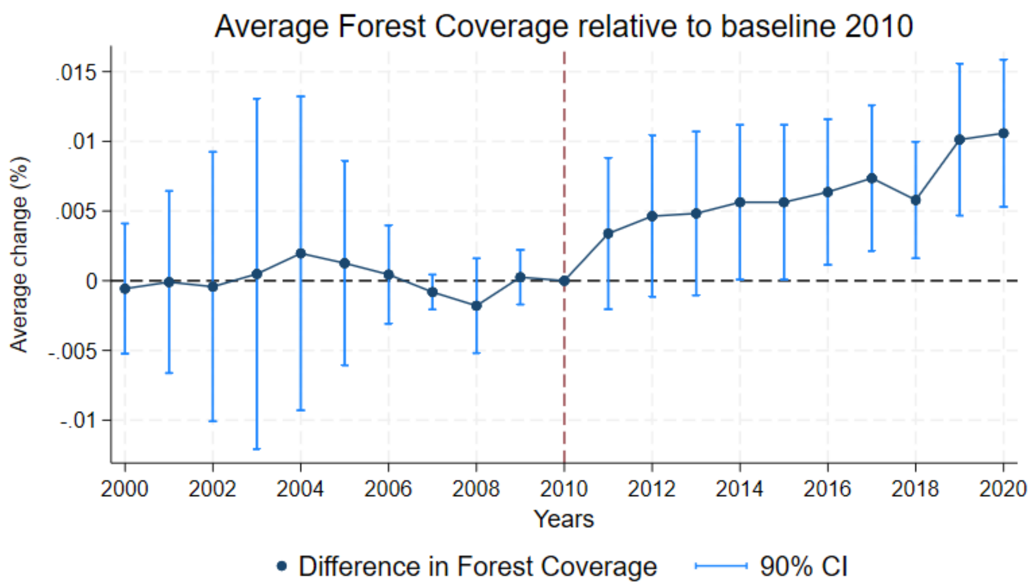


Figure 13: Change in average Forest Coverage relative to baseline 2010 (Source: Own Illustration)

Figure 13 visualizes the time-series plot for average forest coverage from 2000-2020, relative to the baseline 2010. The vertical line in 2010 marks the baseline. Prior to the introduction of the program, the changes are of small magnitude and fluctuate around zero, indicating no clear difference in forest coverage between treated and control regions. After 2010, the consistent upward trajectory becomes evident. Between 2012 to 2015, the confidence intervals almost cross the threshold of statistical significance. Between 2016 - 2020 the values are still positive and start to be significant. In 2020 we observe the highest value with the highest forest coverage relative to the control areas.

Overall, these results indicate the effectiveness of the conservation and training measures implemented in the CBADP. While the CBADP did not halt deforestation completely, it was effective in reducing deforestation within the PAs compared to the RRDs and LKs. While the CBADP officially started in 2011, a delayed effect of its measures is expected due to the time required for implementation and enforcement. This aligns with IBAP's monitoring report, which highlights intensified patrolling efforts starting around 2014 to combat illegal activities, which are a major driver of deforestation within the project areas. The prohibition of commercial logging, combined with enhanced surveillance and increased community awareness, likely played a critical role in reducing deforestation rates. The delayed but observable positive effects suggest that the measures implemented under the CBADP contributed effectively to forest conservation within the protected areas.

### 5.4 Cropland

The descriptive trends of cropland coverage in Guinea-Bissau reveals distinct patterns between the PNC's and PNTC's PA, RRD and LK regions from 2000 to 2020. The PA Cacheu varies between 14-18% in cropland coverage and shows more variation between the three different zones compared to PNC. In contrast, the proportion of land used for agriculture is consistently higher in PA Cantanhez with a range between 45-49%, with stable hierarchical relationships between the PA, LK and RRD zones.

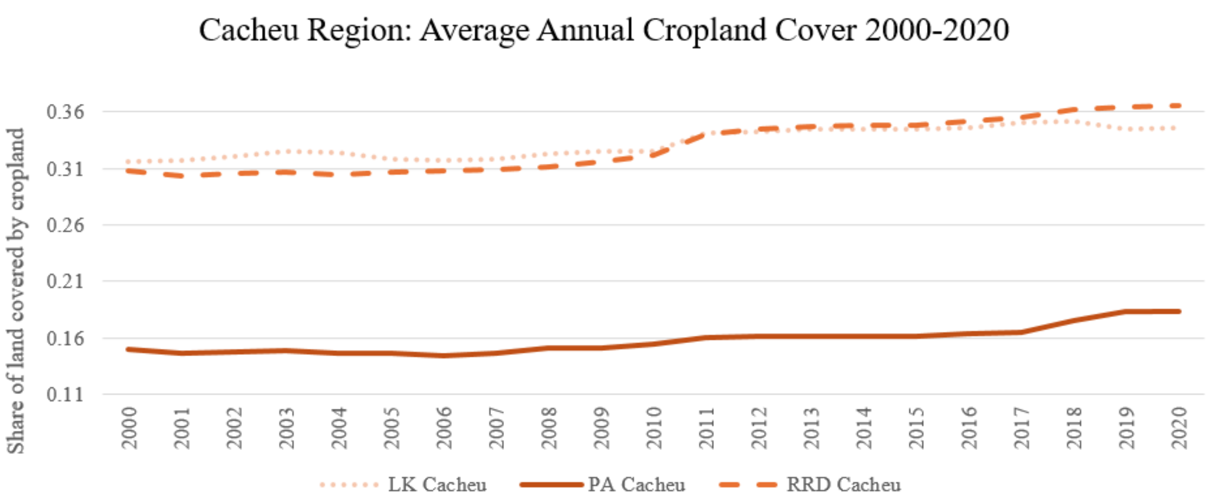


Figure 14: Average Annual Cropland Coverage PNTC (Source: Own Illustration)

The PNTC presents significant differences in cropland coverage within the regions (Figure 14). While PA Cacheu maintains consistently lower coverage, the relationship between LK and RRD zones shows notable overlaps. Specially, the increase in the LK after 2000 coincides with the first formal establishment of the protected area PNTC, potentially reflecting immediate adjustments in land-use patterns. Moreover, the trends in the LK and RRD increase notably after the year 2011, the start year of the CBADP measures. Interestingly, RRD overtakes LK, with LK showing similar patterns as PA.

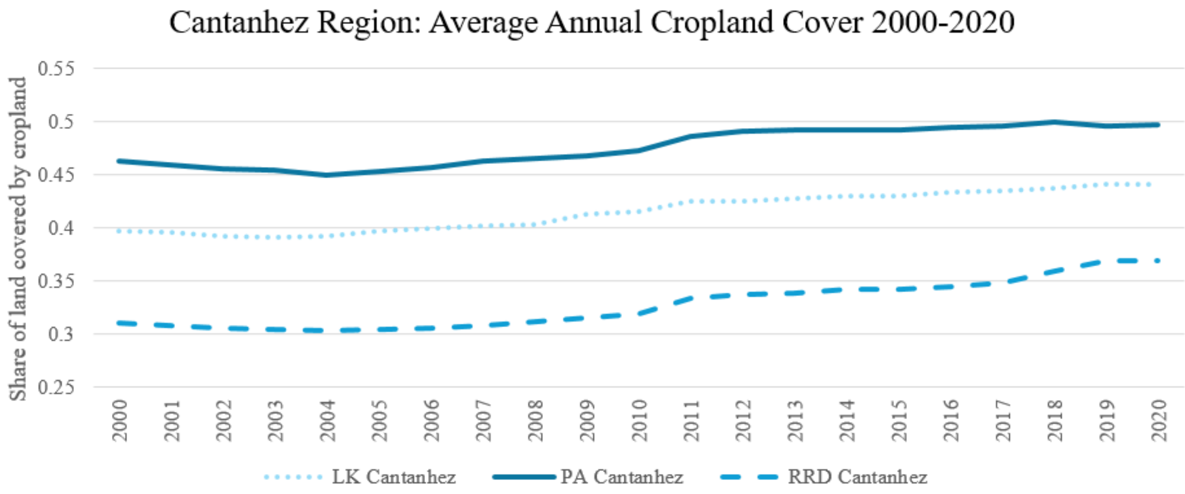


Figure 15: Average Annual Cropland Coverage PNC (Source: Own Illustration)

In the PNC (Figure 15), the PA maintains the highest proportion of land used for agriculture throughout the study period of this evaluation 2000-2020, while LK shows lower agricultural activity and RRD contains the lowest proportion of cropland. All three zones maintain their relative positions throughout the observation period, showing parallel movements, possibly in response to respective external temporal changes. During the observation period the RRD has the strongest variations, showing a change of 6 percentage points between the highest and minimal value in the observation period. The PA and LK have similar changes of 4 percentage points for the observation period. Interestingly, in 2011 the coverage of PNC accelerated, indicating a greater expansion of agricultural land across the three areas. Afterwards it shows only a modest growth of coverage until 2020.

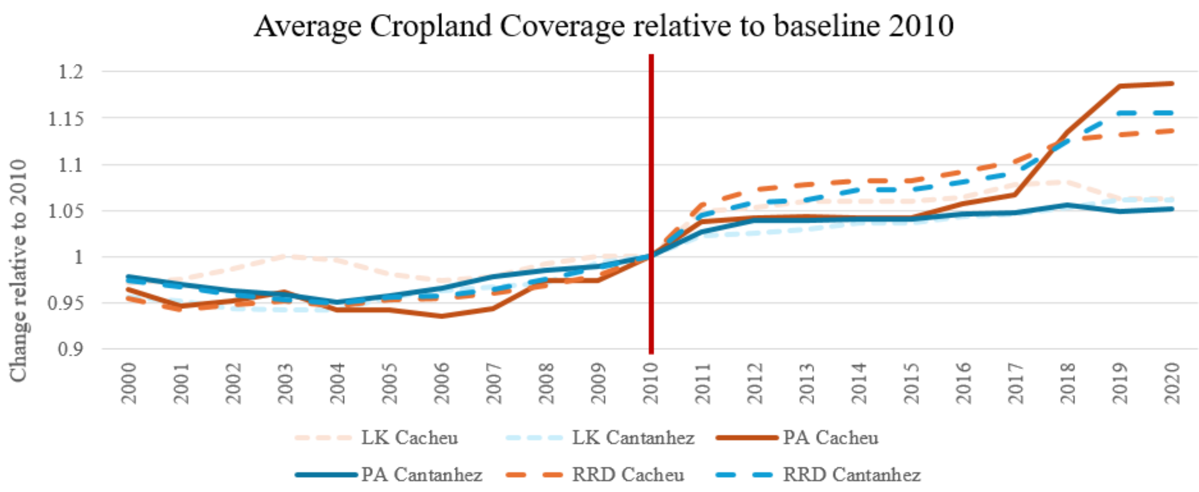


Figure 16: Annual Cropland Coverage relative to baseline 2010 (Source: Own Illustration)

Figure 16 shows trends in cropland coverage across LK, PA, and RRD for both regions, with all values presented relative to 2010 levels. When compared to the baseline, the trends in cropland coverage exhibit distinct patterns across parks and areas.

All zones experienced notable growth beyond their 2010 baseline values in the post-2010 period, with subsequent convergence of growth patterns after 2015. RRD values consistently show the highest increase above baseline after 2010 compared to LK's and PA's, while LK's demonstrate the most modest changes, staying closer to the baseline. The most pronounced regional difference appears between the two PAs, with PA Cantanhez maintaining relative stability after 2010, while PA Cacheu shows dramatic increases of up to 120% around 2020 of its baseline value before declining steeply. Generally, PNTC exhibits more volatility than PNC across all indicators, though patterns between regions are most similar during 2010-2015, before showing greater divergence.

In order to conduct an impact evaluation of the CBDAP we assess the dynamic treatment effects on cropland for the years 2000 - 2020. The following regression explores the potential impact of the CBADP on cropland coverage across the years and relative to the baseline 2010, and is illustrated in the plot below (Figure 17). Using an event-studies approach, the average change in forest coverage within the PAs (PNTC and PNC) is compared to the control group (RRD and LK). It is worth noting, that we only study the effect of the joint measures within the treated areas, relative to the control group, and not the differences between PNC and PNTC (Table 5).

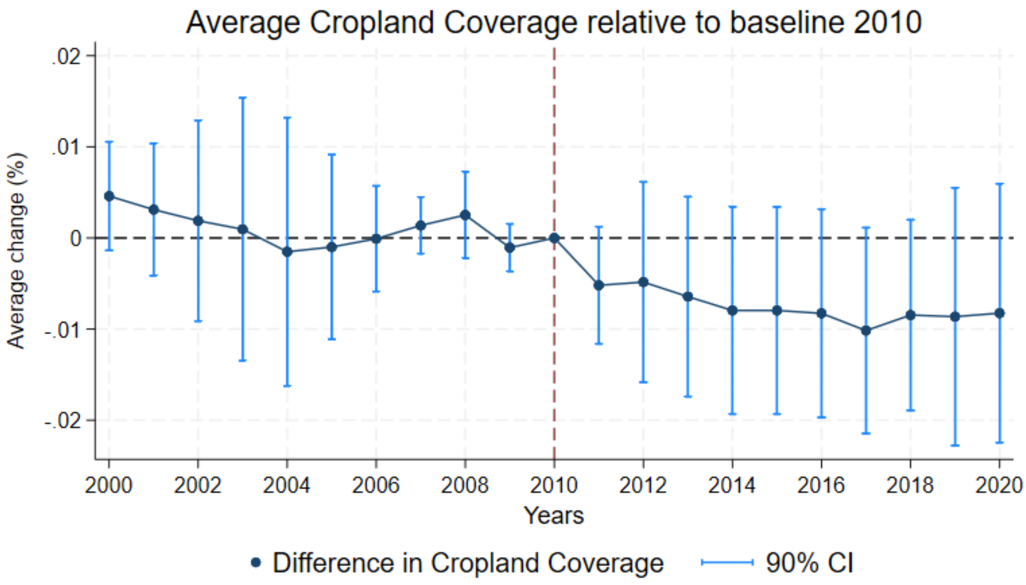


Figure 17: Average Cropland Coverage relative to baseline 2010 (Source: Own Illustration)

Previous to 2011 the start year of the treatment, the coefficients remain statistically insignifcant and fluctuate around zero. This supports the parallel trends assumption, suggesting similar trends in cropland coverage previous to the start of the CBADP. In the post-treatment years, the coefficients show a downward trend in the average cropland coverage relative to the LK and RRD, although no result is significant. Throughout the period, 90% confidence intervals consistently overlap zero, indicating no statistically significant treatment effects. Although the decrease in cropland coverage is not significant in any year, the estimates indicated a decrease within the PAs relative to the LKs and RRDs combined. Considering that agriculture is the main driver of deforestation, our hypothesis (H3) states that, if the CBADP measures are effecting in preventing deforestation, we would observe a significant decrease in the proportion of land used for agriculture within the PAs relative to the control areas. Although no significant effect is found at first sight, the inclusion of robustness checks show a different picture. By checking the robustness of the models, we examine explicitly the possibility of spill-over effects from the treatment to the LK. Given the proximity of the LK to PA, it is possible that individuals in LK behave as in treated areas, fearing restrictions for agricultural expansion. Although some spill-over might exist, this cannot be generalized to the whole LK area. Therefore, the initial lack of a significant difference between the treated and control area might be driven by a spill-over of the treatment. When conducting robustness checks for all our variables of interest, only cropland showed such an anomaly. This implies that some communities outside the direct park boundaries abide to the specific rules of the treated PA. The exclusion of LK from the control group strengthens the analysis by removing confounding influences. Therefore, we conduct a second regression with only the RRDs as control areas, as shown in table 5.

| VARIABLES | (1)<br>**Cropland, including LK** | (2)<br>**Cropland, Excluding LK** |
|---|---|---|
| **Treated*year** | | |
| Treated group x year = 2000 | 0.00459 | 0.00341 |
| | (0.00363) | (0.00436) |
| Treated group x year = 2001 | 0.00312 | 0.00341 |
| | (0.00441) | (0.00543) |
| Treated group x year = 2002 | 0.00189 | 0.00240 |
| | (0.00670) | (0.00593) |
| Treated group x year = 2003 | 0.000953 | 0.00253 |
| | (0.00877) | (0.00750) |
| Treated group x year = 2004 | -0.00151 | 0.000700 |
| | (0.00895) | (0.00807) |
| Treated group x year = 2005 | -0.000994 | 0.000108 |
| | (0.00616) | (0.00628) |
| Treated group x year = 2006 | -8.62e-05 | 0.00104 |
| | (0.00352) | (0.00348) |
| Treated group x year = 2007 | 0.00137 | 0.00220 |
| | (0.00189) | (0.00123) |
| Treated group x year = 2008 | 0.00252 | 0.00329 |
| | (0.00289) | (0.00230) |
| Treated group x year = 2009 | -0.00106 | 0.000762 |
| | (0.00158) | (0.00149) |
| Treated group x year = 2011 | -0.00519 | -0.00692 |
| | (0.00391) | (0.00426) |
| Treated group x year = 2012 | -0.00484 | -0.00846 |
| | (0.00668) | (0.00738) |
| Treated group x year = 2013 | -0.00644 | -0.00973 |
| | (0.00667) | (0.00754) |
| Treated group x year = 2014 | -0.00795 | -0.0117 |
| | (0.00691) | (0.00754) |
| Treated group x year = 2015 | -0.00795 | -0.0117 |
| | (0.00691) | (0.00754) |
| Treated group x year = 2016 | -0.00827 | -0.0124 |
| | (0.00695) | (0.00755) |
| Treated group x year = 2017 | -0.0102 | -0.0146 |
| | (0.00686) | (0.00729) |
| Treated group x year = 2018 | -0.00846 | **-0.0166*** ** |
| | (0.00636) | (0.00339) |
| Treated group x year = 2019 | -0.00863 | **-0.0201** ** |
| | (0.00860) | (0.00511) |
| Treated group x year = 2020 | -0.00825 | **-0.0201*** ** |
| | (0.00864) | (0.00424) |
| Observations | 126 | 86 |
| R-squared | 0.998 | 0.999 |

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 5: Cropland coverage

Similarly, pre-2010 treatment coefficients remain statistically insignificant, maintaining support for the parallel trends assumption. However, specifying the regression without the LK yields a significant decrease in the relative cropland coverage within the PAs compared to control regions and relative to baseline is evident starting in 2018. Between 2018 and 2020, the proportion of land used for agriculture sunk significatly between 1.66 and 2.01 percentage points respectivly. The 2018-2020 values are significant at the 1% level. Therefore we reject the null hypothesis and conclude the treatment had a statistically significant negative effect on cropland expansion in the PA relative to the RRD (H3).

The dynamic treatment effects on cropland coverage excluding LK from the analysis are illustrated in the graph below (Figure 18).

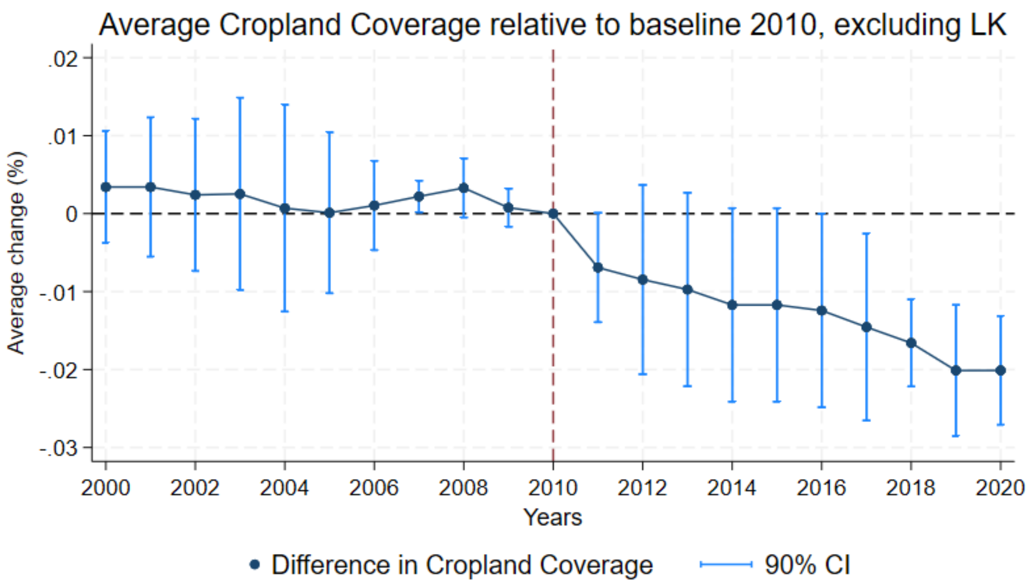


Figure 18: Average Cropland Coverage relative to baseline 2010, excluding LK (Source: Own Illustration)

Figure 18 pictures the regression findings: the exclusion of LK from the control group reveals clearer treatment effects while maintaining the validity of parallel trends. The well-defined downward trend and significant coefficients after 2017 provide compelling visual evidence that the treatment effectively moderated cropland expansion in treated areas. It shows that after the treatment was implemented, the confidence intervals for all subsequent years were close to the threshold of statistical significance, with statistical significant coefficients starting after 2017.

Moreover, the emergence of significant treatment effects after excluding LK from the model suggests its inclusion was obscuring the effect on cropland dynamics. This in turn suggests that cropland coverage dynamics in the PAs and LK are not significantly different from each other. By conducting the regression excluding LK, the analysis is able to capture more precise treatment effects.

Overall, the CBADP has demonstrated an increasing level of effectiveness over time in moderating the expansion of cropland within the protected areas. The effect is particularly notable in spite of the increased pressures of agricultural expansion across all areas as seen in the descriptive trends. It seems reasonable to posit that the project's measures, including the installation of electrical fencing, the protection of agricultural areas from wildlife, and the establishment of community agricultural councils, played a significant role in reducing cropland expansion. The delayed emergence of treatment effects can be linked to the gradual adoption of conservation measures, community adjustments, and political stability as it will later be discussed in detail in chapter 6.

The results demonstrate that CBADP has been effective in significantly moderating the expansion of cropland within protected areas in comparison to the control group. The significant results after excluding LK demonstrate spill-over effects from treatment, with LK behaving as if it were treated. This similar behavior of PA and LK for cropland is also evidenced in the descriptive trends. The increase in cropland coverage in LK in comparison to RRD in PNC after the year 2000 indicates adjustment in land use that coincide with the official establishment of the protected areas. The similar behaviour is even more evident after 2011, where the higher expansion of cropland in RRD coincides with the introduction of the CBADP.

### 5.5 Population

The annual population count is observed from 2000 to 2020 across the three different zones in PNTC (Figure 19) and PNC (Figure 20). The regions of interest show similar patterns in their population dynamics, with PNTC exhibiting higher absolute population count across all areas compared to PNC.

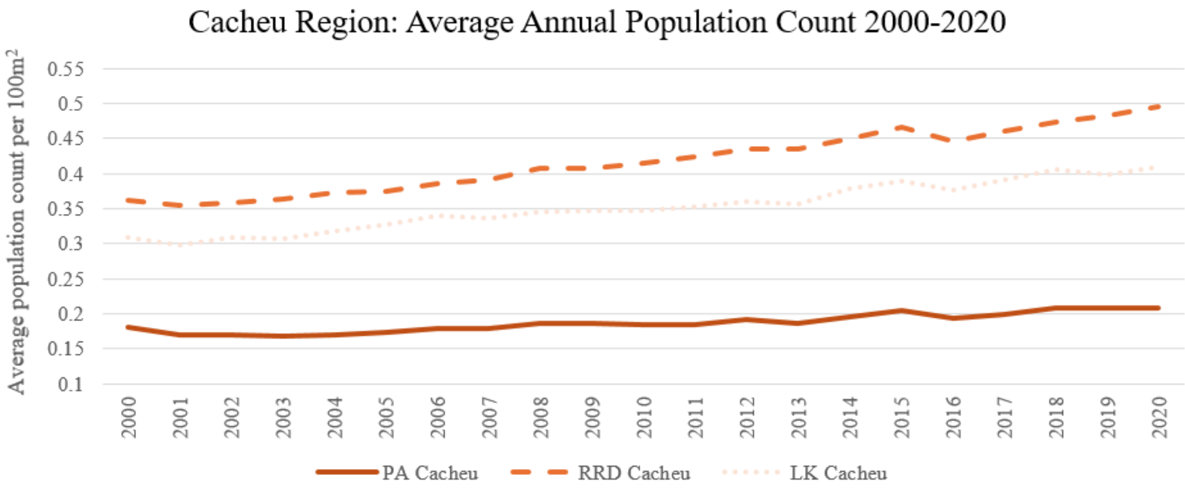


Figure 19: Average annual Population Count PNTC (Source: Own Illustration)

RRD Cacheu shows the highest population count within the PNTC region, demonstrating a steady upward trend. LK Cacheu follows a similar upward pattern but at lower levels. A notable characteristic is that the trends for population count in RRD and LK maintain a fairly consistent gap between their values throughout the entire study period. PA Cacheu maintains the lowest population count within the region. In contrast to the control groups RRD and LK, the population count in the PA shows remarkable stability over time.

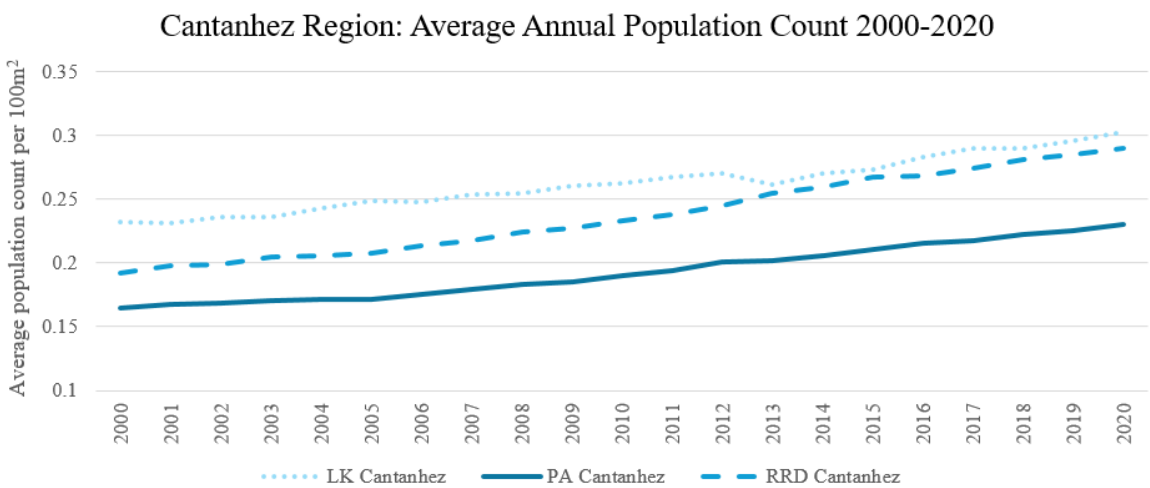


Figure 20: Average annual Population Count PNC (Source: Own Illustration)

In PNC (Figure 20), population counts are generally lower than in PNTC but shows more consistent and uniform growth patterns across the three zones. Notably, the trends for all areas (PA, LK,  RRD) run parallel, with gaps between them remaining stable over time. However, starting around 2013/2014, the population counts in LK and RRD begin to converge, reducing the gap between these two areas. The graph in Figure 21 illustrates the annual population counts across PA, LK, RRD for the PNTC and PNC, with all values shown relative to their respective 2010 levels.

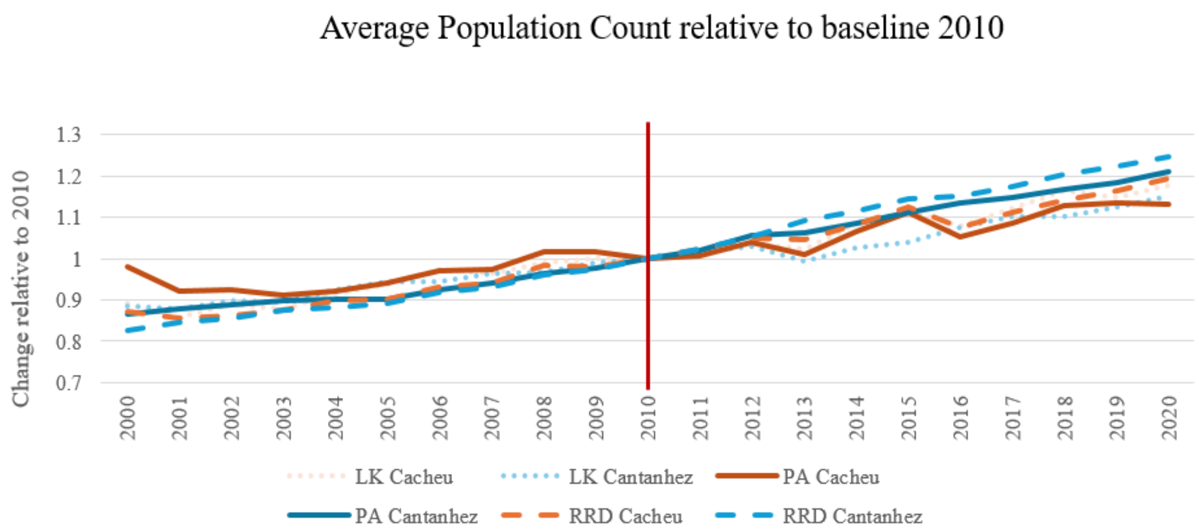


Figure 21: Annual Population Count relative to baseline 2010 (Source: Own Illustration)

As observed, the pre-2010 trend of population dynamics persists even after the project implementation. However, after 2010 distinct growth patterns in the regions emerge. The PNC region demonstrates a slightly stronger growth across all its zones, and PNC's PA demonstrates a more analogous trend to its control areas. The PNTC region shows moderate growth but experiences notable volatility. These overall trends are consistent with reports of increasing population growth in the country (World Bank 2024b).

In order to asses any measurable effects of the CBADP on population dynamics we conduct a regression following the event studies approach. To examine dynamic treatment effects, the model interacts treatment with the specific years, relative to the 2010 baseline. This comparison evaluates the treated PA areas to the controls RRD and LK. The regression table is presented in Appendix Table A4. The regression results are better illustrated in the time series plot below (Figure 22). This illustrates a downward trend in population count within the PAs, compared to the control regions and baseline. And although the coefficient intervals are narrow, this plot visualizes solely a descriptive trend of the possible effect of the CBADP on population. The narrow coefficient intervals previous to treatment year 2010, suggest the parallel trends assumption does not hold. The parallel trends assumption is crucial for causal inference in event studies designs, requiring that treatment and control groups would have followed similar trajectories in the absence of treatment. However, the pre-treatment trend continues after the treatment year. Thus, the regression indicates no change in population trends, and the trend is solely descriptive.

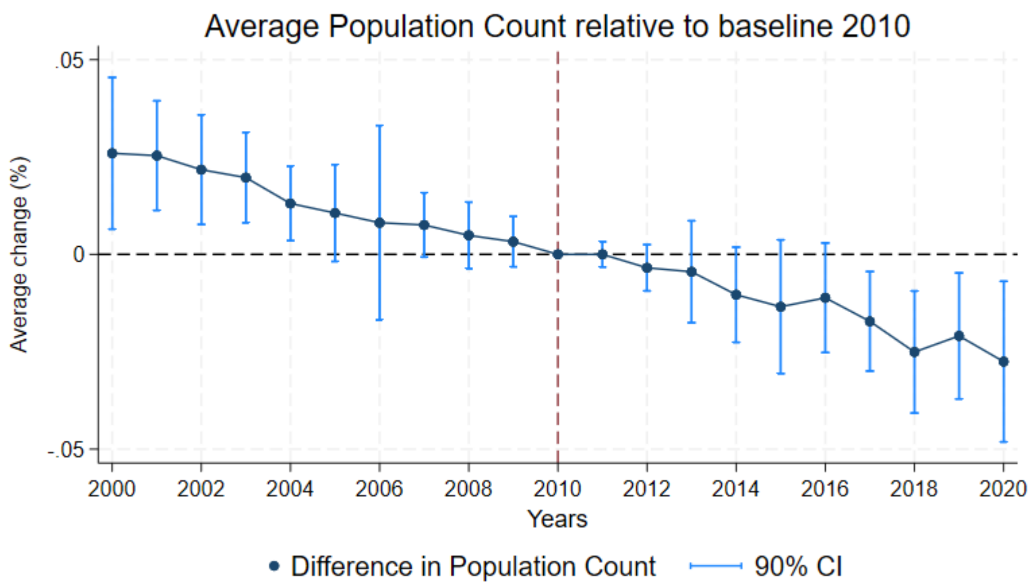


Figure 22: Average Population Count relative to baseline 2010 (Source: Own Illustration)

The implications of these results are the following. First, the graph clearly shows a consistent downward slope in population changes. The positive coefficients in the early 2000s transitioning to negative values suggest systematic differences in population dynamics between treated and control areas previous to the treatment. Regardless of the treatment, these areas may have been on fundamentally different developmental trajectories. Therefore, we can neither reject nor accept our hypothesis (H4) about the CBADP's effects on population dynamics. Second, the pre-existing declining trend means we cannot separate any potential treatment effect from trends that were already in motion before the intervention.

We hypothesized that CBADP's "community-based" measures should impact both natural resources used for subsistence and income-generating activities such as agriculture, oyster harvesting, and fishing. These could influence population dynamics in the PAs. If the measures are perceived as significant restrictions on primary livelihoods, such as agriculture and fishing, population decline in treated areas may have indicated dissatisfaction and insufficient improvements to living standards. Conversely, if sustainable practices and complementary development initiatives (e.g. infrastructure and clean water) effectively enhance living conditions, a positive effect on population count would have been expected in the project areas.

Overall, the descriptive trends in figure 21, and the timeseries plot in figure 22 clearly illustrate that the pre-2010 trend of population dynamics persists even after the project implementation, indicating that the measures did not change the existing trajectory. Exploring the descriptive trends in figure 21 provides additional insights. This shows that pre-existing trends are particularly pronounced in the PNTC, where the relatively flat population trajectory in the PA diverges notably from control area. In contrast, PA Cantanhez demonstrates a more parallel trend with its control areas, following more closely overall population growth patterns. Other underlying factors might have been already influencing population dynamics in these areas. This demonstrates that the regions in PNTC (PA, LK, RRD) have been primarily selected by the program's technicians on the base of ecological similarities and not on basis of socio-economic similarities.

Population dynamics within a region are influenced by various factors, such as migration patterns, birth, and death rates. Investigating the specific drivers of changes in population dynamics is beyond the scope of this study. Moreover, given the lack of disaggregated data on socioeconomic indicators we explored population dynamics as a proxy for the impact of the CBADP on the communities in and surrounding the treated areas.

While methodological limitations prevent causal claims about the impact of the CBADP on population, qualitative evidence from interviews with key stakeholders and particularly from the communities in the Cacheu region give a clearer picture. First, interviews reveal a broader migration pattern from the drier north to the more rainfall-rich south of Guinea-Bissau. This north-south migration trend aligns with the observed downward trend in population in the northern PA compared to the control regions. As the population in PA Cacheu remains constant, across other areas it increases. Second, critical infrastructure deficits emerge as a significant factor influencing population dynamics, suggesting that the lack of infrastructure may be hindering population growth and the ability of communities to maintain sustainable livelihoods in the protected areas.

## 6. Discussion

Overall, the results of this impact evaluation provide numerous insights into the value and the implementation challenges of the CBADP as a REDD+ initiative. Throughout this study, we aimed to answer the research question: to what extent have the measures of the CBADP a measurable impact on environmental and socio-economic outcomes? By evaluating the effects of CBADP's conservation, training, and community development measures, we examined changes in mangrove, forest, cropland, and population dynamics.

The findings suggest that, although absolute forest coverage declined between 2005 and 2020, deforestation rates within the PAs were effectively reduced compared to the control groups.

This general decline aligns with IBAP reports about substantial forest loss in the periods from 2017–2021, as reported for the second MRV (IBAP 2024). This general decline aligns with IBAP's observations about substantial forest loss in the periods from 2017–2021, as reported for the second MRV (IBAP 2024). While the program did not fully stop deforestation, the positive treatment effects indicate that deforestation in the PAs was successfully curbed. This has not been the case for mangrove forests. Despite their acknowledged ecological and economic importance, the analysis found no significant treatment effect in avoiding mangrove deforestation. This finding contrasts with IBAP's more recent reports on positive effects on avoided deforestation results for mangroves between 2017 and 2021. The discrepancy may be attributed not to a lack of conservation effect, but to limited data availability in our analysis between 2010 and 2014. Interestingly, the study highlights the program's success in curbing agricultural expansion, a key driver of deforestation, within the PAs. Since forest loss is mainly driven by agriculture, and in particular, by the conversion of forests into cashew plantations, trends in forest cover and cropland are inversely related. A decline in agricultural activity should thus lead to a reduction in deforestation. The combination of relative higher forest cover and simultaneous slower agricultural expansion in treated areas highlights a key mechanism underlying the effectiveness of the CBADP. The turning point in the reduction of deforestation and cropland cover becomes apparent around 2017/18, with both indicators demonstrating the inverse relationship. The success of the CBADP lies in its ability to curb deforestation driven by agricultural land conversion, highlighting the importance of collaboratively managing agricultural activities within PAs alongside local communities. This pattern suggests that agricultural expansion, particularly cashew plantation growth, might be a more significant driver of deforestation in PNTC and PNC than fuelwood consumption for energy needs.

While the CBADP effectively balanced the agriculture-conservation trade-off, the observed spillover effects in cropland coverage indicate that communities in buffer zones partially adopted conservation practices, even without formal project involvement.

Key mechanisms underlying the program´s impact on deforestation may be the intensified patrolling efforts, enforcement of the prohibition of commercial logging, and increased community awareness and engagement within the PAs. For mangroves and forest, this resulted in the confiscation of logging equipment in 2014 and 2015, as indicated by IBAP's monitoring reports. Also, in 2014 surveillance was intensified and in PNTC reforestation measures for terrestrial forest and for mangroves were implemented. Moreover, the interview with IBAP's technician highlighted the influence of patrolling and training initiatives in reducing logging for commercial agriculture, aligning with the observed relative reduction in cropland within the PAs. Additionally, measures such as the installation of 681.5 hectares of electrical fencing and the securing of 1,000 tons of annual rice production demonstrate efforts to stabilize cropland coverage and protect agricultural lands for park communities. These interventions suggest a dual benefit: safeguarding cropland while addressing food security and improving agricultural productivity. Optimizing agricultural output within existing croplands can reduce the need for spatial expansion, helping communities meet their agricultural needs without expanding on new land. Moreover, the increased stability and productivity of protected agricultural areas may encourage communities to remain within these zones rather than seek new cultivation sites. As a result, CBADP efforts could significantly lower deforestation rates by enabling communities to sustainably support themselves within the designated agricultural areas of the protected zones.

Furthermore, the participatory approach for local communities is a central mechanism of the CBADP. For both mangroves and forest, awareness campaigns in participatory councils supported the gradual shift towards the acceptance of park rules and the use of sustainable farming methods. Anecdotal evidence from interviews highlights the community's adoption of conservation protocols. Mr. Monteiro shared a notable example of community members seeking official permission to cut down a single tree for canoe-making, demonstrating increased environmental awareness and compliance. This transformation extends beyond PAs, as seen in PNTC where communities voluntarily adopt similar conservation measures. Hence, this demonstrates positive spill-over effects of the CBADP. In this process the local radio programs played a critical role, as it spread awareness through transmitting valuable conservations practices, rules and guidelines.

However, the adoption of new conservation measures is not instantaneous. Firstly, changing traditional practices, which are deeply ingrained in the communities' livelihoods and dependence on resources, is a gradual process that requires time. Additionally, the willingness to transition to sustainable methods hinges on the perception of tangible benefits and the trust that these measures will improve community well-being. Therefore, the integration of sustainable practices can also require extensive negotiation. As illustrated by Mr. Carvalho's work in Bolola communities initially viewed restrictions like three-month fishing bans as an interference with their traditional practices and their already strained livelihoods. While this adaptation takes time, it has led to the replacement of some traditional practices to more sustainable methods, such as improved oyster farming and rice cultivation (Appendix Graphic A4 and A2). Hence, adaptation time could further explain the delay in visibility of the positive effects, and the non-significant upward trend for mangroves.

Second, the delayed effects of conservation measures likely result from the time needed for ecosystems to recover and the gradual implementation of interventions. These changes are expected to become more pronounced over time, underscoring the importance of long-term assessments to accurately evaluate complex projects. For instance, Mr. Monteiro noted that abandoned rice fields require active restoration, as dams prevent natural mangrove regeneration. This helps to explain why mangrove recovery might only become visible in later years.

Lastly, the delayed effects of conservation outcomes seem to be closely tied to Guinea-Bissau's political instability between 2012 and 2014. During this period, reduced implementation capacity and unauthorized deforestation undermined conservation efforts and hindered project progress, as highlighted in the interviews. During the military junta illegal logging surged, with 80% of illicit activity in 2013. Military officers were granted concessions, leading to exports of nearly 100,000t of timber to China in 2014 (Environmental Investigation Agency 2018; Bird and Gomes 2021). Such logging activities likely impacted all areas of our examination in the same way. The interview with FBG’s executive secretary Didier Monteiro suggested that logging is more attractive in protected areas because resources are larger and better preserved (Didier Monteiro, FBG interview, November 7, 2024). Therefore, PAs may have been especially impacted during this period of void in governance and surveillance.

The absence of governance exposed the vulnerability of conservation initiatives due to political and financial instability. Gaps in enforcement capacity were reflected for instance in limited boats for monitoring illegal fishing during closed seasons. Capacity-building for IBAP and FBG also remains critical, as highlighted by Mr. Monteiro, who noted the lack of personnel in their active search for consultants to support these processes. This aligns with literature’s findings pointing out the connection between weak enforcement in weak governance systems and increased deforestation (Ollivier 2012) .

Beyond governance difficulties, severe financial constraints further hinder effective implementation. Even though some carbon credits have already been sold, direct financial transfers to communities have not yet been realized. This may minder the perception of tangible benefits. The infrastructure gaps pose serious risks to livelihoods, leaving entire villages at risk of displacement. The absence of dikes to protect rice fields from flooding, cold storage facilities to preserve fish, and adequate transportation to sell crops and fish, further threatens local livelihoods. Therefore, the lack of decent living conditions may make it harder for communities to accept restrictions. In Elalabe, one woman described the fear of abandoning their village due to agricultural land loss and the lack of drinking water. Having joined the PA only last year, the community views CBADP benefits as essential to sustaining their traditional way of life. Delays in implementing the benefit-sharing agreement under the CBADP risk weakening local support for conservation and could lead to negative spill-over effects, reducing the interest of communities outside the PAs in participating in similar initiatives. Moreover, these financial transfers are essential for making conservation efforts both effective and inclusive.

Projects, as CBADP, serve as both a crucial lifeline for preserving community livelihoods and a source of reliance, as communities might become increasingly dependent on its financial and infrastructural benefits. This dependency underscores the importance of ensuring that these benefits are delivered consistently and effectively. As Mr. Monteiro from FBG emphasized, such a situation calls for sustained, long-term funding and capacity-building to enhance and advance community development measures. Such efforts are essential to reduce dependency while ensuring that conservation initiatives remain impactful and equitable.

Regarding the CBADP's impact on population dynamics, we observed a continuation of the declining pre-intervention trends in PAs. Qualitative evidence highlights two key factors: a broader north-to-south migration trend driven by rainfall differences, aligning with the observed population stability in PA Cacheu and growth in PA Cantanhez, and significant infrastructure deficits, which hinder population growth and sustainable livelihoods in protected areas. The mentioned infrastructure challenges faced by communities could also partially explain the continuation of the declining population trends observed in treated areas. Although the exploration of population dynamics revealed no clear impact, the qualitative interviews point to its impact on the income-generating activities and communities' perceptions and satisfaction.

However, the welfare implications of the conservation interventions remain an open question. While communities acknowledge the ecosystem services provided by protected forests, the impact of reduced agricultural activity on livelihoods is ambiguous. It remains uncertain whether significant reductions in cropland indicate improved efficiency and stable food security or reflect restricted access to essential resources leading people to move away. Addressing these uncertainties will be crucial for designing conservation strategies that effectively balance ecological preservation with socio-economic needs.

Additionally, considering the impact climate change has on resources, which are the very foundation of the communities' livelihoods, is essential. Communities reported severe impacts from rising river and sea levels, with farmland in Elalabe shrinking dramatically from 6,000 to 2,000 hectares and Bolola's village chief warning about the need for dikes to protect rice fields. Altered rainfall patterns, with heavy rains in typically dry northern regions were reported in qualitative interviews (Didier Monteiro, FBG interview, November 7, 2024; interview Elalabe, November 9, 2024). Additionally, irregular rainfall and increased flooding have caused crop losses. The resulting reduction of potential income from crop loss might be a reason for the observed stagnant growth in population count in the PA Cacheu. Furthermore, the absolute loss in forest coverage across all areas may be influenced by shifts in precipitation and temperature caused by climate change.

While the findings partially support the effectiveness of the CBADP in meeting its conservation objectives, observing its magnitude is necessary. The findings are small in magnitude. Nevertheless, given the short period studied after treatment, this shows a growing impact in the right direction. Community voices affirmed the importance of these measures while also underlining the need for more holistic support to fully realize livelihood benefits.

Finally, issues of fairness and transboundary resource governance also emerge as critical challenges. As Mr. Carvalho explained, initially the community felt the restriction on certain activities were not fair, as suddenly some activities in their land and home were limited. In addition, interviews with the fishing association revealed that stricter conservation regulations often disproportionately affect nearby communities relying on the same natural resources but receiving no project-related benefits. For instance, the Fishermen's Association outside the PA Cacheu expressed concerns about being forced to take longer fishing routes due to restrictions on fishing within the park, exacerbating their struggle to make a living and increasing the potential for social conflict. Moreover, fishers in PNTC voiced frustration over better-equipped foreign vessels from Senegal that continue to deplete fish stocks just outside protected area boundaries. Furthermore, the socio-economic impact of these regulations highlights the need for coordinated cross-border conservation strategies. These unaddressed dynamics risk undermining both the legitimacy and the effectiveness of ongoing conservation efforts.

The CBADP demonstrates Guinea-Bissau's extensive efforts to protect its carbon-rich ecosystems. Although small in magnitude, demonstrated progress offers a foundation for a sustainable future for the forests, mangroves, and communities of PNC and PNTC. Moreover, realizing this potential and safeguarding these critical ecosystems will require addressing the challenges outlined earlier to ensure both environmental and financial sustainability.

Lastly, this evaluation and the interviews underscore Guinea-Bissau's remarkable efforts to preserve vital ecosystems despite severe financial constraints. While these conservation efforts are crucial for global mitigation, they might come at a cost to local communities, who must adapt their livelihood activities to sustain protected areas. This raises questions about comparable sacrifices in the global north and emphasizes the need to consider climate justice concerns within REDD+ frameworks. Moreover, this underscores the urgent need for greater support from developed countries, the largest emitters of greenhouse gases, to finance conservation efforts in tropical regions. Such support should aim to minimize the economic trade-offs faced by local communities, who are among the most vulnerable to climate change yet bear the greatest burden of its impacts.

## 7. Policy Implications

The findings of our study provide key insights for strengthening REDD+ initiatives like the CBADP. Despite the positive outcomes on forest and cropland, challenges persist concerning capacity building, community involvement, and financial sustainability. Addressing these barriers could amplify the project's potential.

Our findings underscore the importance of integrating benefit-sharing mechanisms with local communities in conservation projects. Direct, tangible benefits can foster trust and promote long-term engagement. Failing to implement the benefit-sharing mechanism in a timely manner risks local support for conservation efforts. To accelerate the benefit-sharing process in the future, it is essential to invest in capacity building. Developing a well-trained workforce capable of managing key tasks such as carbon credit preparation, verification, and accreditation will help streamline the process. Establishing clear procedures and strengthening institutional frameworks will also be crucial to avoid delays and ensure that financial benefits reach communities more efficiently. An essential factor for the success of REDD+ initiatives widely cited in the literature is the active engagement of local communities (Temudo 2012). Building on the importance of community engagement, our findings suggest that treating communities as active conservation partners rather than passive beneficiaries is key to long-term success. Community-led initiatives, supported by education and recognition, can foster shared responsibility and pride in conservation achievements. Awareness programs through community radio and schools have already proven valuable in raising environmental consciousness. Publicly recognizing villages that practice sustainable management could further strengthen local commitment to conservation initiatives.

Balancing the needs of different communities both inside and outside PAs remains also critical. If communities within the PA receive financial support through benefit-sharing agreements, they may gain a comparative advantage in agricultural and fishing products over communities outside the PA. These potential conflicts could be avoided by expanding the current measures into a whole Biosphere project, as suggested by Mr. Monteiro from FBG. He explained, that in the Cacheu region communities have already initiated their own conservation efforts, motivated by environmental benefits. Building on this momentum, both groups could benefit from conservation-related revenues and community development projects. Expanding eligibility for certain project benefits and fostering collaboration between affected communities would promote fairness, reduce tensions, and strengthen overall conservation efforts.

Improving infrastructure within protected areas has also emerged as crucial. Inadequate facilities, such as limited access to clean water, lack of energy supplies, insufficient transportation networks and schools, increase communities' dependence on natural resources and put additional pressure on the environment. Investments in essential infrastructure, including protective measures like dikes as well as storage facilities and transport systems, could significantly reduce unsustainable resource use. To address critical infrastructure needs, we recommend a community-driven implementation model supported by targeted technical capacity building. IBAP staff should receive specialized training to guide communities in implementing standardized designs for essential infrastructure like dikes and water systems. Communities could form joint construction teams, share tools and equipment, and exchange knowledge about successful projects. By pooling resources and coordinating efforts between villages, communities can tackle larger infrastructure projects through collaborative action. The focus should be on simple, replicable designs using locally available materials, supported by practical guidelines. This model would help communities develop self-sufficiency in infrastructure maintenance while making efficient use of limited technical expertise and financial resources. Improving infrastructure would enhance community resilience, support sustainable income and livelihoods, and ease the burden on ecosystems facing conservation restrictions.

Moreover, limited capacity, caused by funding gaps, and political uncertainty, significantly weakens the long-term effectiveness of conservation efforts. Ensuring consistent enforcement of conservation regulations is essential, particularly during periods of political instability. Expanding ranger patrols, providing necessary equipment and training, and securing emergency conservation funding can maintain operations during instabilities. For these efforts to be sustainable, emphasis on comprehensive capacity building within the country and the key institutions is essential. For instance, following Padjalo's successful example, implementing competitive recruitment programs and investing in local talent through targeted training initiatives can bridge traditional knowledge with modern conservation practices. This approach strengthens IBAP's operational capacity while promoting conservation success through community integration in decision-making and implementation. Additionally, further strengthening IBAP directly is crucial. Expanding their capacity to autonomously manage complex procedures needed to adhere to REDD+ rules and Verra verification cycles would accelerate the overall process. This would support both the planned expansion of protected areas and the transition of Cacheu to a Biosphere region, while enabling faster redistribution of benefits to communities.

Furthermore, the government's role must extend beyond recognition of protected areas toward providing stable, long-term funding for IBAP. This should be seen not as a cost but as a critical investment in national infrastructure aligned with Terra Ranka, offering direct socio-economic benefits. Extending the existing governmental Fund for Local Environmental Initiatives could support local livelihoods through income-generating activities. The government and IBAP should collaborate closely with community leaders to identify and implement those activities tailored to each area, such as agroforestry or ecotourism. By providing targeted training and start-up resources funded through the Fund for Local Environmental Initiatives, and ensuring regular community engagement, IBAP can design projects that align conservation goals with local needs. This participatory approach will ensure that the fund benefits all stakeholders by boosting incomes, strengthening community commitment to conservation, and protecting the critical ecosystems. In addition, sustainable financing must include expanding carbon credit initiatives. IBAP should actively secure additional carbon credit projects, not only in PNTC and PNC but also across other protected areas, optimally creating new national parks where learnings from the CBADP are implemented. This aligns with the vison of FBG to develop the Biosphere project soon. The expansion could unlock other funding streams while aligning conservation goals with global climate change mitigation efforts. However, prompt and transparent distribution of carbon credit revenues remains critical for ensuring local community support.

Lastly, expanding research and monitoring efforts is crucial. Consistent data collection is essential for understanding ecological changes and informing adaptive strategies. Establishing permanent monitoring plots, utilizing high-resolution satellite imagery, and integrating local ecological knowledge could improve environmental assessments. Strengthening collaboration with research institutes or universities could support capacity and knowledge sharing. Moreover, expanding community-based monitoring initiatives could enhance data collection while creating employment opportunities and strengthening community identification with the project. Regular surveys within and outside the PA would enable rigorous analysis of socio-economic development. These efforts ultimately relate to strengthening the continuous acquisition of skills and knowledge within local communities to sustain conservation efforts over the long term.

The implications drawn from our findings in the CBADP project reveal valuable lessons for enhancing conservation initiatives. By tailoring these approaches, conservation efforts can balance environmental protection with community well-being, ensuring ecosystems continue delivering essential services while supporting economic resilience for frontline communities. These lessons can guide policymakers and project designers in scaling similar initiatives within and beyond Guinea-Bissau.

## 8. Conclusion

This study provides the first long-term impact evaluation of the CBADP as a REDD+ initiative in Guinea-Bissau. We explore the impact on ecosystems and local communities by combining satellite imagery and qualitative interviews. The research assesses changes in forest, mangrove, and cropland coverage, as well as population dynamics between 2000-2020. The results reveal both successes and persistent challenges.

Our findings present a nuanced view of the CBADP's conservation outcomes. Overall, we observe a trend of general absolute decrease in forest and in mangrove cover across all investigated areas, whereas cropland cover shows a steady growth over the observation period. However, the project demonstrates significant positive impacts on forest conservation. Treated areas maintained a relative higher forest coverage, compared to control regions starting in 2017. This forest preservation was accompanied by a significant reduction in agricultural expansion within protected areas, revealing an important inverse relationship. Our results therefore suggest that the reduction in the deforestation rate is likely achieved through the moderation in agricultural expansion. However, mangrove conservation outcomes remain inconclusive and show no statistical effects but some qualitative indications of recovery. The slight upward-trend post 2019 aligns with the project's gradual implementation of community-based conservation measures and the slow natural recovery cycles of mangrove ecosystems. Population dynamics show no measurable impacts, but the respective trends combined with qualitative interviews provide a first impression of the socio-economic impact of the program. While the project introduced sustainable practices and alternative livelihoods, communities continue to face significant infrastructure gaps and resource constraints. Moreover, their already fragile livelihoods are threatened by the effects of climate change. These realities emphasize the importance of integrating development priorities into conservation strategies to ensure long-term success.

The partially positive effect of the REDD+ initiative has important implications for financing the protection of carbon-rich ecosystems in Guinea-Bissau. Considering that over 70% of Guinea-Bissau is covered by forests and that emissions mainly come from land conversion, the findings highlight the mitigation potential of the CBADP. Avoided deforestation have thus the potential to generate income through additional carbon credits under the REDD+ initiative.

Moreover, Guinea-Bissau's extensive mangrove ecosystems present significant potential for generating blue carbon credits, offering a promising revenue source. However, unlocking this potential demands balancing conservation efforts with local community needs. Addressing governance, financial constraints, and capacity-building challenges will be crucial to ensure the sustainable management of these valuable ecosystems.

Furthermore, the findings highlight the CBADP's partial success in addressing key deforestation drivers while illustrating the complex realities of implementing conservation measures in resource-constrained settings. To amplify the project's impact, the next steps should prioritize mobilizing funding from both local governments and international donors to support capacity-building initiatives and expand the PAs. The project should focus on scaling up the sale of carbon credits to generate additional revenues. Simultaneously, streamlining the verification and benefit-sharing processes will ensure that financial support reaches communities efficiently and effectively.

Future research should focus on capturing delayed conservation effects, particularly for slow-recovering mangrove ecosystems, and on analyzing spillover impacts between protected and non-protected areas. Broadening qualitative methods to capture diverse perspectives and employing longitudinal approaches could help assessing long-term trends accessing REDD+ initiatives. Additionally, integrating direct measures of community welfare, such as income, food security, and health, would provide a more comprehensive understanding of socio-economic impacts. Studies exploring long-term scenarios could improve the assessment of conservation efficacy. This is especially insightful after the distribution of carbon credits revenue in the context of the benefit sharing mechanism.

Bolola chief's warning serves as a powerful reminder of what is at stake: the livelihoods of vulnerable communities and the preservation of globally significant ecosystems. The international community must step forward moving beyond short-term project funding to long-term partnerships that enable countries like Guinea-Bissau to design and implement their own conservation solutions. With such collaborative efforts, initiatives like the CBADP offer perspectives for achieving global climate goals while delivering tangible benefits to the communities most affected by environmental change. To scale up success, a more comprehensive approach that integrates conservation, socio-economic development, and climate resilience is needed. Guinea-Bissau has demonstrated through the CBADP that effective conservation is achievable even in resource-constrained settings. The successful preservation of carbon-rich ecosystems under challenging circumstances, offer optimism for similar initiatives across West Africa and the world.

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# Appendix

## Figures, Tables and Graphics

Figure A1: PA, LK, RRD Cacheu Mangrove Forest National Park (PNTC), (Source: Own Illustration)

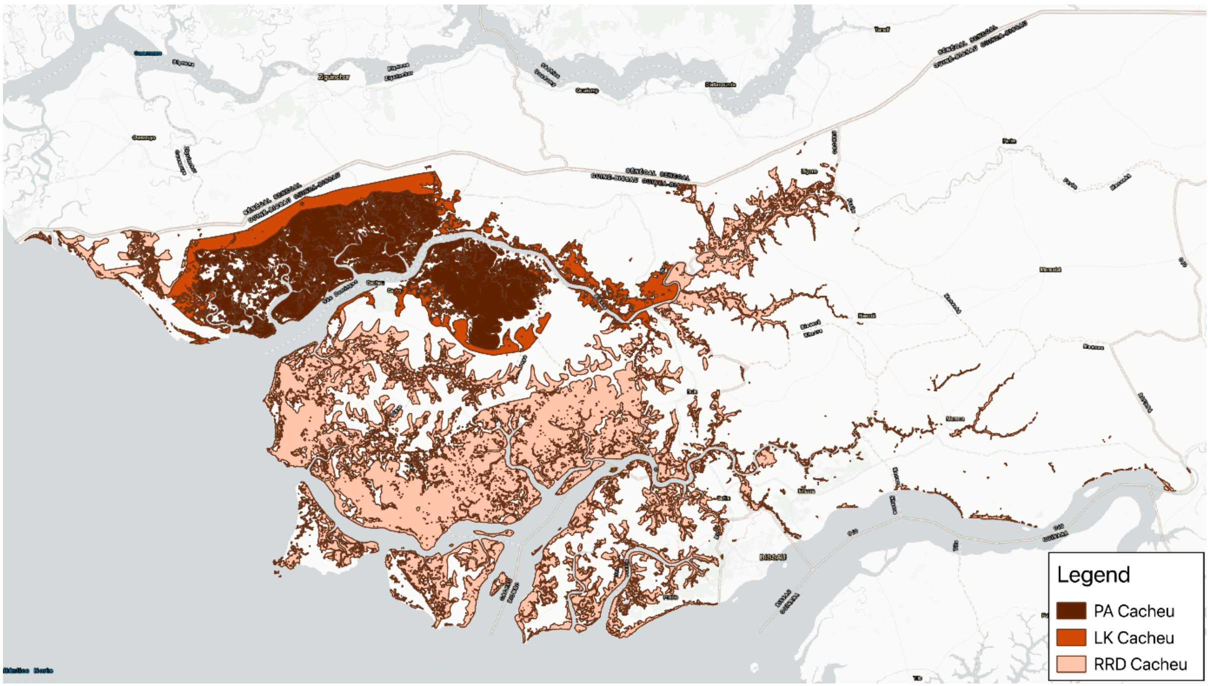


Figure A2: PA, LK, RRD Cantanhez Mangrove Forest National Park (PNC), (Source: Own Illustration)

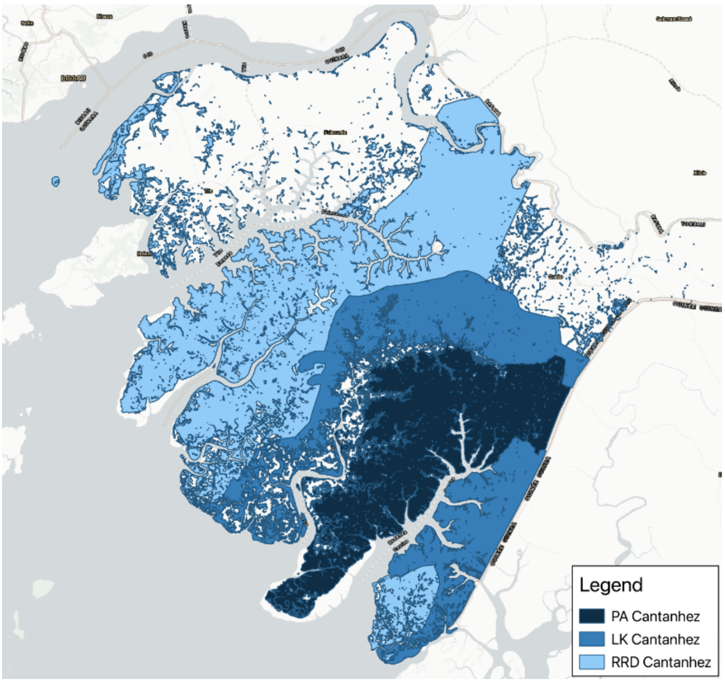

Figure A3: Average Annual Mangrove Coverage PNTC

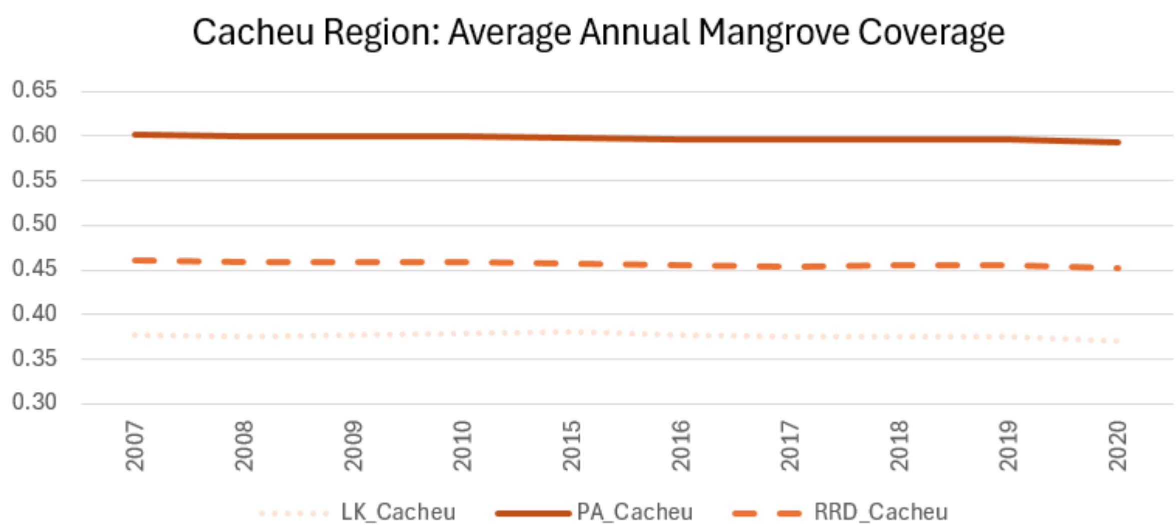


Figure A4: Average Annual Mangrove Coverage PNC

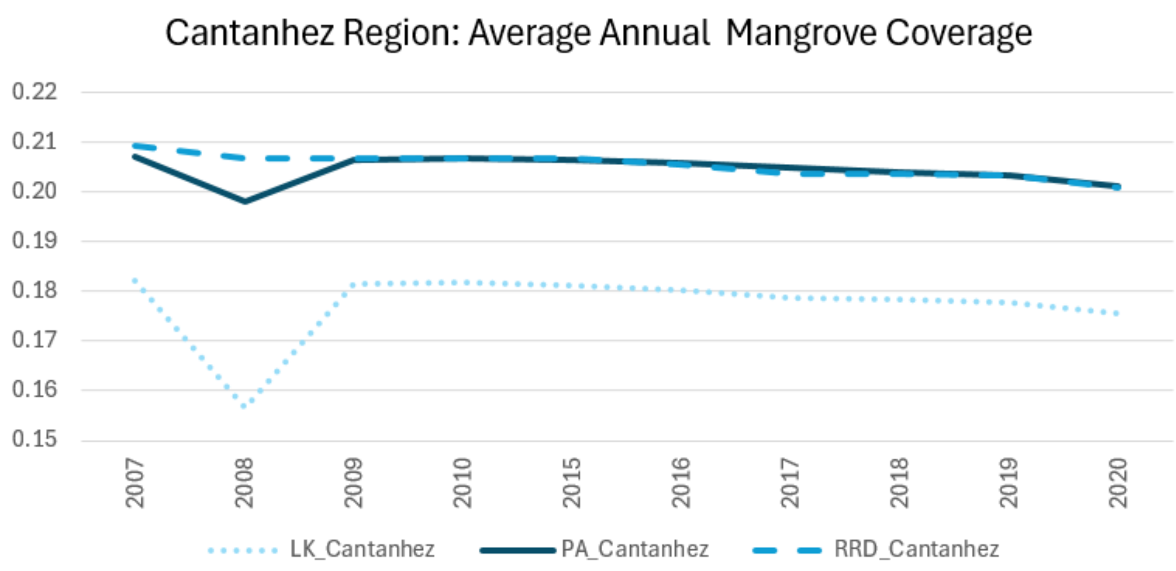

Table A1: Regression Output Mangroves

| VARIABLES | (1)<br>**Mangrove** |
|---|---|
| 2007.treated_year | 0.000492 |
| | (0.00153) |
| 2008.treated_year | 0.000857 |
| | (0.00134) |
| 2009.treated_year | 0.000567 |
| | (0.000661) |
| 2015.treated_year | -0.000454 |
| | (0.000608) |
| 2016.treated_year | 4.42e-05 |
| | (0.00134) |
| 2017.treated_year | 0.000926 |
| | (0.00107) |
| 2018.treated_year | 0.000665 |
| | (0.000688) |
| 2019.treated_year | 0.000466 |
| | (0.000317) |
| 2020.treated_year | 0.00104 |
| | (0.000793) |
| 2008.year | -0.00128** |
| | (0.000341) |
| 2009.year | -0.00102 |
| | (0.000835) |
| 2010.year | -0.000586 |
| | (0.00128) |
| 2015.year | -0.000936 |
| | (0.00161) |
| 2016.year | -0.00287* |
| | (0.00138) |
| 2017.year | -0.00440** |
| | (0.00133) |
| 2018.year | -0.00449*** |
| | (0.000952) |
| 2019.year | -0.00453*** |
| | (0.000991) |
| 2020.year | -0.00727*** |
| | (0.000599) |
| 2.region_id | -0.196*** |
| | (0) |
| 3.region_id | 0.220*** |
| | (0.000480) |
| 4.region_id | -0.172*** |
| | (0.000480) |
| 5.region_id | 0.0805*** |
| | (0) |
| 6.region_id | -0.171*** |
| | (0) |
| Constant | 0.379*** |
| | (0.000872) |
| Observations | 60 |
| R-squared | 1.000 |

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A2: Regression Output Forest

| VARIABLES | (1)<br>forest |
|---|---|
| Treated group x year = 2000 | -0.000566 |
| | (0.00284) |
| Treated group x year = 2001 | -9.62e-05 |
| | (0.00397) |
| Treated group x year = 2002 | -0.000426 |
| | (0.00587) |
| Treated group x year = 2003 | 0.000490 |
| | (0.00764) |
| Treated group x year = 2004 | 0.00196 |
| | (0.00684) |
| Treated group x year = 2005 | 0.00126 |
| | (0.00445) |
| Treated group x year = 2006 | 0.000445 |
| | (0.00215) |
| Treated group x year = 2007 | -0.000815 |
| | (0.000761) |
| Treated group x year = 2008 | -0.00179 |
| | (0.00206) |
| Treated group x year = 2009 | 0.000257 |
| | (0.00119) |
| Treated group x year = 2011 | 0.00339 |
| | (0.00330) |
| Treated group x year = 2012 | 0.00463 |
| | (0.00352) |
| Treated group x year = 2013 | 0.00483 |
| | (0.00357) |
| Treated group x year = 2014 | 0.00563 |
| | (0.00337) |
| Treated group x year = 2015 | 0.00563 |
| | (0.00337) |
| Treated group x year = 2016 | 0.00636 |
| | (0.00317) |
| Treated group x year = 2017 | **0.00736*** |
| | (0.00318) |
| Treated group x year = 2018 | **0.00579*** |
| | (0.00254) |
| Treated group x year = 2019 | **0.0101**** |
| | (0.00331) |
| Treated group x year = 2020 | **0.0106**** |
| | (0.00321) |
| 2001.year | 0.000508 |
| | (0.000510) |
| 2002.year | 0.000682 |
| | (0.00153) |
| 2003.year | -3.45e-05 |
| | (0.00291) |
| 2004.year | 0.000653 |
| | (0.00275) |
| 2005.year | -0.000163 |
| | (0.00107) |
| 2006.year | -0.00100 |
| | (0.00163) |
| 2007.year | -0.00274 |
| | (0.00144) |
| 2008.year | -0.00497** |
| | (0.00133) |
| 2009.year | -0.00776*** |
| | (0.00184) |
| 2010.year | -0.00977*** |
| | (0.00185) |
| 2011.year | -0.0184*** |

| | |
|---|---|
| | (0.00257) |
| 2012.year | -0.0199*** |
| | (0.00253) |
| 2013.year | -0.0201*** |
| | (0.00258) |
| 2014.year | -0.0209*** |
| | (0.00257) |
| 2015.year | -0.0209*** |
| | (0.00257) |
| 2016.year | -0.0221*** |
| | (0.00256) |
| 2017.year | -0.0233*** |
| | (0.00231) |
| 2018.year | -0.0255*** |
| | (0.00236) |
| 2019.year | -0.0261*** |
| | (0.00353) |
| 2020.year | -0.0261*** |
| | (0.00353) |
| 2.region_id | 0.103*** |
| | (0) |
| 3.region_id | 0.00366** |
| | (0.00103) |
| 4.region_id | 0.00141 |
| | (0.00103) |
| 5.region_id | -0.0533*** |
| | (0) |
| 6.region_id | 0.114*** |
| | (0) |
| Constant | 0.144*** |
| | (0.00126) |
| | |
| Observations | 126 |
| R-squared | 0.998 |

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A3: Regression Output Cropland

| VARIABLES | (1)<br>Cropland, including LK | (2)<br>Cropland, excluding LK |
|---|---|---|
| **Treated*year** | | |
| Treated group x year = 2000 | 0.00459 | 0.00341 |
| | (0.00363) | (0.00436) |
| Treated group x year = 2001 | 0.00312 | 0.00341 |
| | (0.00441) | (0.00543) |
| Treated group x year = 2002 | 0.00189 | 0.00240 |
| | (0.00670) | (0.00593) |
| Treated group x year = 2003 | 0.000953 | 0.00253 |
| | (0.00877) | (0.00750) |
| Treated group x year = 2004 | -0.00151 | 0.000700 |
| | (0.00895) | (0.00807) |
| Treated group x year = 2005 | -0.000994 | 0.000108 |
| | (0.00616) | (0.00628) |
| Treated group x year = 2006 | -8.62e-05 | 0.00104 |
| | (0.00352) | (0.00348) |
| Treated group x year = 2007 | 0.00137 | 0.00220 |
| | (0.00189) | (0.00123) |
| Treated group x year = 2008 | 0.00252 | 0.00329 |
| | (0.00289) | (0.00230) |
| Treated group x year = 2009 | -0.00106 | 0.000762 |
| | (0.00158) | (0.00149) |
| Treated group x year = 2011 | -0.00519 | -0.00692 |
| | (0.00391) | (0.00426) |
| Treated group x year = 2012 | -0.00484 | -0.00846 |
| | (0.00668) | (0.00738) |
| Treated group x year = 2013 | -0.00644 | -0.00973 |
| | (0.00667) | (0.00754) |
| Treated group x year = 2014 | -0.00795 | -0.0117 |
| | (0.00691) | (0.00754) |
| Treated group x year = 2015 | -0.00795 | -0.0117 |
| | (0.00691) | (0.00754) |
| Treated group x year = 2016 | -0.00827 | -0.0124 |
| | (0.00695) | (0.00755) |
| Treated group x year = 2017 | -0.0102 | -0.0146 |
| | (0.00686) | (0.00729) |
| Treated group x year = 2018 | -0.00846 | **-0.0166*****|
| | (0.00636) | (0.00339) |
| Treated group x year = 2019 | -0.00863 | **-0.0201****|
| | (0.00860) | (0.00511) |
| Treated group x year = 2020 | -0.00825 | **-0.0201*****|
| | (0.00864) | (0.00424) |
| 2001.year | -0.00166 | -0.00313** |
| | (0.00131) | (0.00103) |
| 2002.year | -0.00176 | -0.00345* |
| | (0.00273) | (0.00137) |
| 2003.year | -0.000987 | -0.00375 |
| | (0.00433) | (0.00296) |
| 2004.year | -0.00202 | -0.00541 |
| | (0.00422) | (0.00289) |
| 2005.year | -0.000952 | -0.00323 |
| | (0.00213) | (0.00292) |
| 2006.year | -0.000472 | -0.00278 |
| | (0.00207) | (0.00295) |
| 2007.year | 0.00151 | -0.000495 |
| | (0.00187) | (0.00258) |
| 2008.year | 0.00439** | 0.00244 |
| | (0.00157) | (0.00191) |
| 2009.year | 0.00922** | 0.00621** |
| | (0.00268) | (0.00193) |
| 2010.year | 0.0125*** | 0.0113** |

| | | |
|---|---|---|
| | (0.00275) | (0.00338) |
| 2011.year | 0.0269*** | 0.0274*** |
| | (0.00240) | (0.00537) |
| 2012.year | 0.0298*** | 0.0323*** |
| | (0.00316) | (0.00611) |
| 2013.year | 0.0316*** | 0.0337*** |
| | (0.00319) | (0.00657) |
| 2014.year | 0.0334*** | 0.0360*** |
| | (0.00306) | (0.00523) |
| 2015.year | 0.0334*** | 0.0360*** |
| | (0.00306) | (0.00523) |
| 2016.year | 0.0361*** | 0.0391*** |
| | (0.00340) | (0.00543) |
| 2017.year | 0.0392*** | 0.0424*** |
| | (0.00338) | (0.00572) |
| 2018.year | 0.0447*** | 0.0517*** |
| | (0.00516) | (0.00374) |
| 2019.year | 0.0469*** | 0.0572*** |
| | (0.00789) | (0.000663) |
| 2020.year | 0.0475*** | 0.0582*** |
| | (0.00807) | (5.23e-05) |
| 2.region_id | 0.0829*** | 0.0904*** |
| | (0) | (0) |
| 3.region_id | -0.172*** | -0.170*** |
| | (0.00239) | (0.000193) |
| 4.region_id | 0.147*** | 0.148*** |
| | (0.00239) | (0.000193) |
| 5.region_id | -0.00276*** | -0.00350*** |
| | (0) | (0.000300) |
| 6.region_id | -0.00491*** | -0.00565*** |
| | (0) | (0.000300) |
| Constant | 0.314*** | 0.314*** |
| | (0.00155) | (0.00338) |
| Observations | 126 | 86 |
| R-squared | 0.998 | 0.999 |

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A4: Regression Output Population

| VARIABLES | (1)<br>pop_count |
|---|---|
| **Treated*year** | |
| Treated group x year = 2000 | 0.0260* |
| | (0.0118) |
| Treated group x year = 2001 | 0.0254** |
| | (0.00854) |
| Treated group x year = 2002 | 0.0217* |
| | (0.00856) |
| Treated group x year = 2003 | 0.0197** |
| | (0.00705) |
| Treated group x year = 2004 | 0.0131* |
| | (0.00581) |
| Treated group x year = 2005 | 0.0106 |
| | (0.00755) |
| Treated group x year = 2006 | 0.00812 |
| | (0.00663) |
| Treated group x year = 2007 | 0.00754 |
| | (0.00502) |
| Treated group x year = 2008 | 0.00488 |
| | (0.00519) |
| Treated group x year = 2009 | 0.00327 |
| | (0.00393) |
| Treated group x year = 2011 | -0.00345 |
| | (0.00198) |
| Treated group x year = 2012 | -0.00447 |
| | (0.00361) |
| Treated group x year = 2013 | -0.00521 |
| | (0.00795) |
| Treated group x year = 2014 | -0.0104 |
| | (0.00742) |
| Treated group x year = 2015 | -0.0134 |
| | (0.0104) |
| Treated group x year = 2016 | -0.0111 |
| | (0.00855) |
| Treated group x year = 2017 | -0.0172* |
| | (0.00777) |
| Treated group x year = 2018 | -0.0199* |
| | (0.00953) |
| Treated group x year = 2019 | -0.0209* |
| | (0.00984) |
| Treated group x year = 2020 | -0.0275* |
| | (0.0125) |
| 2001.year | -0.00356 |
| | (0.00416) |
| 2002.year | 0.00122 |
| | (0.00310) |
| 2003.year | 0.00299 |
| | (0.00392) |
| 2004.year | 0.0107*** |
| | (0.00101) |
| 2005.year | 0.0149*** |
| | (0.00138) |
| 2006.year | 0.0226*** |
| | (0.00346) |
| 2007.year | 0.0251*** |
| | (0.00173) |
| 2008.year | 0.0337*** |
| | (0.00583) |
| 2009.year | 0.0364*** |
| | (0.00424) |
| 2010.year | 0.0404*** |
| | (0.00543) |
| 2011.year | 0.0464*** |
| | (0.00687) |

| | |
|---|---|
| 2012.year | 0.0537*** |
| | (0.00858) |
| 2013.year | 0.0527*** |
| | (0.0113) |
| 2014.year | 0.0649*** |
| | (0.0122) |
| 2015.year | 0.0748*** |
| | (0.0155) |
| 2016.year | 0.0692*** |
| | (0.00856) |
| 2017.year | 0.0794*** |
| | (0.0101) |
| 2018.year | 0.0882*** |
| | (0.0134) |
| 2019.year | 0.0915*** |
| | (0.0139) |
| 2020.year | 0.100*** |
| | (0.0151) |
| 2.region_id | -0.0903*** |
| | (0) |
| 3.region_id | -0.166*** |
| | (0.00139) |
| 4.region_id | -0.160*** |
| | (0.00139) |
| 5.region_id | 0.0650*** |
| | (0) |
| 6.region_id | -0.115*** |
| | (0) |
| Constant | 0.309*** |
| | (0.00611) |
| | |
| Observations | 126 |
| R-squared | 0.992 |

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The following figures are provided for illustrative purposes. They do not directly relate to the findings of this report.

Graphic A1: Mangroves in the PNTC

Graphic A2: Rice Fields in the PNTC

Graphic A3: Abandoned rice field in the PNTC

Graphic A4: Sustainable Oyster cultivation

Graphic A5: Group picture with Bolola Community members

Graphic A6: Interview with the Fishing Association

Graphic A7: Group picture with Elalabe Community members

Graphic A8: Picture with Didier Monteiro

Graphic A9: Group picture with the BELAB Team