Assessment of mangrove ecosystems in Colombia and their potential for emissions reductions and restoration

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Winrock International, December 2017.

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Table of Contents

Document developed by Winrock International. Suggested citation: Bernal B., G. Sidman, T. Pearson. 2017. Assessment of mangrove ecosystems in Colombia and their potential for emissions reductions and restauration. Winrock International. 29 pp.

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Winrock gratefully acknowledges the support of the Government of the Federal Republic of Germany under the International Climate Initiative.

Supported by:

Federal Ministry
for the Environment, Nature Conservation,
Building and Nuclear Safety

based on a decision of the German Bundestag

This project is part of the International Climate Initiative (IKI). The German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) supports this initiative on the basis of a decision adopted by the German Bundestag.

INTRODUCTION

Understanding of the importance of resilient growth and adaptation to environmental change has been increasing in response to the increasing realization that maladapted environments have direct and significant negative effects on human wellbeing. Where once the goal was a sustainable development strategy, it is now a resilient development strategy, where environmental change is acknowledged and an active role must be taken to adapt to it. Many countries, including Colombia, are working towards such a strategy.

This report is a preliminary evaluation of the potential of including mangrove restoration and sustainable mangrove use in Colombia's Nationally Appropriate Mitigation Actions (NAMA) strategy. Mangrove forests are key for coastal resilience in tropical countries; they provide multiple ecosystem services while increasing the ability of coastal communities to adapt to a changing climate. Some of the services provided by mangroves include carbon storage in biomass and soils, support of coastal community livelihoods through coastline protection and the provision of nursery habitat for fish and crustaceans. Colombia has mangrove swamps along its Pacific and Caribbean coasts. These mangroves are degrading quickly due to anthropogenic pressure from urban and agricultural development, causing a decline in the services provided to nearby communities. The largest mangrove forest in Colombia (in the Ciénaga Grande de Santa Marta), for example, has lost 60% of its coverage since the mid-1950's[1], and ten years ago about 21% of Colombia's remaining mangroves were considered degraded[2]. Mangrove restoration and conservation are therefore of key importance for the country.

To this end, we evaluate available information from publications by the Colombian Government and environmental entities as well as peer reviewed publications on site-specific mangrove conditions in Colombia, as a first attempt to assess the current mangrove conditions in the country. We discuss the main drivers that are responsible for mangrove degradation and deforestation, and assess the potential benefits of mangrove restoration in Colombia. The intention of this work is to lay the ground for a more in-depth analysis of site-specific causes of mangrove degradation and loss, and point out the needs of country-specific and up to date mangrove restoration targets. Next steps following on from this report would be an accurate assessment of Colombia's mangrove environmental conditions and opportunities of improvement. Such an assessment would entail site-specific data and on-site impact evaluation, to accurately assess the interaction of hydrological processes, vegetation cover, and ecosystem dynamics with the communities living in and around the mangrove areas.

[1] *Elster 2000.*
[2] *INVEMAR 2004.*

MANAGEMENT OF COASTAL AREAS IN COLOMBIA

Most of the reports describing Colombia's initiatives and legislation on mangrove management and land use were released around the start of the 21st century. In 2002, Colombia released their first countrywide strategy on mangrove restoration and conservation[3]. Also in that year, Colombia developed a national environmental policy, the *Proyecto Colectivo Ambiental*, that sought to improve the country's land use planning and the management and restoration of its natural resources, both inland and coastal. These two initiatives were not the starting point on mangrove awareness in the country; the *Proyecto Colectivo Ambiental* policy emphasized the importance of developing coastal ecosystems management plans under the already published framework *Manejo Integrado de Zonas Costeras* (MIZC), a framework created in the 80's that envisioned a collaboration among scientists, stakeholders, and local and national government entities. A decade after the MIZC was created, INVEMAR (Colombia's Coastal Research Institute) took the lead in keeping MIZC relevant by promoting capacity building and technical support to decision makers on the management and land use planning of coastal zones in Colombia. Aside from the training of professionals, the major accomplishments since then on INVEMAR's coastal management has been the development of a National Network of Coastal Zones, the setup of 35 monitoring stations in coastal areas (19 in the Caribbean and 16 in the Pacific coast)[4], and the mapping of mangrove coverage in collaboration with the national Government in 2007[5]. In parallel to INVEMAR's achievements, the national Government, with the regional natural resource management corporations and the participation of local communities, coordinated the development and implementation of two key initiatives that have been supported with a set of new pieces of legislation to ensure their success:

- *Proyecto Manglares de Colombia* in the decade of the 90's, which assessed national mangrove coverage in 1995 and coverage change, and boosted the restoration of degraded mangrove areas in the next 10 years by listing strategic actions for the conservation and sustainable use of mangroves in Colombia[6].
- *Programa Nacional para el Uso Sostenible, Manejo y Conservación de los Ecosistemas de Manglar* (PNM), in 2002, whose goal was to integrate feedback from stakeholders and local communities into the development and implementation of sustainable mangrove uses.

Additionally, the Government of Colombia releases regularly the National Plan of Forest Development and the National Plan of Forest Restoration; the latest one was published in 2015[7]. These Plans outline the country's strategy

[3] *Uso sostenible, manejo y conservación de los Ecosistemas de manglar en Colombia. 2002. MINAMBIENTE. Santa Fe de Bogotá D.C., Colombia.*
[4] *Álvarez-León. 2003.*
[5] *http://www.invemar.org.co/*
[6] *Sánchez-Páez et al. 2000.*
[7] *Plan Nacional de Restauración: Recuperación Ecológica, Rehabilitación y Recuperación de Áreas Disturbadas. 2015. MINAMBIENTE. Santa Fe de Bogotá D.C., Colombia.*

towards forest resources management, including mangroves, and lists the regulations on mangrove management and land use.

Despite the Colombian Government's interest in preserving its mangrove ecosystems, demonstrated by the development of regulations, initiatives, and management plans to achieve a sustainable use of mangroves and coastal zones, the country recognizes a failure to properly communicate the importance of sustainable mangrove use to local communities living in and around mangrove areas (called *mangleros*), and to monitor compliance with and enforce of mangrove protection regulations[5]. Consequently, despite some restoration initiatives in the country, Colombia estimated in 2004 that 21% of the total mangrove cover was degraded[8]. To reverse this trend, the central Government outlined a series of strategies and programs towards meeting the target of developing a comprehensive and sustainable land use planning and management of Colombia's mangrove ecosystems by 2025 (listed in Annex 2). However, to the date, an accurate country-wide assessment of "mangrove baseline conditions" seems to be lacking.

Defining "mangrove baseline conditions" to which restoration initiatives would be compared is key to assess short and long-term success of mangrove restoration and conservation initiatives. The first steps towards defining this baseline would be (1) perform a review of studies and reports to assess the condition and functionality of coastal ecosystems, to identify opportunities and constraints of restoration and assess the feasibility of coastal restoration projects in the country; (2) identify stakeholders and beneficiaries of the restoration project; and (3) evaluate historical trends on mangrove cover change through historical land cover maps, as well as a thorough assessment of the drivers of mangrove loss and degradation in the country.

[8] *INVEMAR 2004.*

BENEFITS OF CONSERVING COLOMBIA'S COASTAL ECOSYSTEMS

Coastal areas around the world are being degraded or replaced by other land uses through anthropogenic pressure and, to a lesser extent, climatic impacts[9]. The loss of coastal ecosystems such as mangroves entails the loss of the multiple ecosystem services they provide[10]. The provision of these services (see Box 1) makes coastal ecosystems one of the most valued in the planet[11], and their rapid loss accentuates the urgent need to restore them worldwide. Bayraktarov et al.[12] published a synthesis of the cost and feasibility of coastal restoration and determined that mangrove restoration projects around the world are the largest yet the least expensive (on a per area basis) of the coastal and marine ecosystems. Mangroves are a resilient system that, once their environmental requirements are met, spread quickly on the landscape. Given the wide array of services these ecosystems provide, their restoration yields social, economic, and ecological benefits.

Box 1: Main ecosystem services provided by mangroves

- Provision of food and fibers (biodiversity haven)

- Coastal protection and stabilization (storm and erosion abatement)

- Flood mitigation

- Water purification (sediment and nutrient filtering)

- Cultural services (tourism and recreation)

- Mitigation to climate change (GHG removal in biomass and soil)

- Adaptation to climate change (sea level rise and storm events)

Alongi 2008, Hussain & Badola 2008, McLeod et al. 2011, Duarte et al. 2013, Mukherjee et al. 2014, Mitsch & Gosselink 2015.

Colombia's mangroves are suffering from land use change and degradation, as explained in detail in the following sections of this report. The direct beneficiaries of achieving mangrove conservation through protection and restoration projects would be the communities living in and around mangrove ecosystems. Sustainable management of mangrove ecosystems, however, benefits the entire country indirectly. Specific benefits obtained from ecosystem services are usually difficult to translate into economic gains, a metric that is frequently used to assess the

[9] UNEP 2006. https://www.millenniumassessment.org/en/Articlee27e.html?id=76
[10] Supporting, provisioning, regulating, and cultural services. Botero & Salzwedel. 1999
[11] Costanza et al. 1997, 2014.
[12] Bayraktarov et al. 2016.

justification for a restoration investment[13]. A recent ecosystem services valuation database[14] reviewed over 150 economic valuations of the ecosystem services provided by mangroves around the world, classifying them by ecosystem service (storm protection, food provision, erosion prevention, nursery, etc) and by valuation method (direct market pricing, avoided cost, replacement cost, among others), and obtained that mangroves were worth, on average 1,494 USD ha^{-1} y^{-1}, ranging between <0.1 and <60,000 USD ha^{-1} y^{-1}. **Colombia would benefit from a country-specific ecosystem valuation assessment of its mangrove forests, as it could help identifying restoration hotspots in the country.**

MANGROVE COVER AND LOSS RATE IN COLOMBIA

Colombia's national Government claims that even though their mangroves have been severely degraded by intensive logging, infrastructure development, urban expansion, and pollution, there are still areas in the country where mangroves are valued and sustained[15]. Colombia's mangroves covered about 371,250 ha in 1997, with about three-fourths located in the Pacific coast (~283,000 ha) and one-fourth in the Caribbean coast (~88,250 ha)[16]. By 2014, the total coverage had decreased to 286,804 ha (Table 1), a 23% decrease from the 1997 coverage at a loss rate of 4,967 ha y^{-1} (assuming a constant rate of mangrove loss). The review by Álvarez-León[17] reported an even higher loss rate between 1966 and 1991 of 7,965 ha y^{-1}. The decrease in the mangrove deforestation rate could be due to the conservation initiatives implemented by the Government, even though they have been proved not to be 100% successful[18]. Logging permits for red mangrove forests (*Rhizophora* sp.)[7] are still being issued in the Pacific coast and shrimp ponds development continues along the Caribbean coast. In addition, illegal logging persists as a common practice in the country and especially in the Pacific, including illegal mangrove logging[19]. Despite extensive logging, the Pacific coast still has extensive mangrove strips that go up to 20 km inland[20], whereas the Caribbean coast has only narrow strips of mangrove forests along freshwater tidal creeks and lagoons[21] (Figure 1).

Shrimp pond construction is one of the land uses replacing Colombian mangroves. The shrimp industry is growing in Colombia, particularly in the Caribbean where the local Government issues shrimp ponds certificates (permits) and encourages shrimp exports[22]. Shrimp industry in the Caribbean coast is centered in the States of Bolivar and

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[13] *Barbier 2017.*
[14] *TEED Valuation Database. Van der Ploeg and de Groot. 2010.*
[15] *http://www.minambiente.gov.co/*
[16] *Sánchez-Páez et al. 1997b.*
[17] *Álvarez-León. 2003.*
[18] *Uso sostenible, manejo y conservación de los Ecosistemas de manglar en Colombia. 2002. MINAMBIENTE. Santa Fe de Bogotá D.C., Colombia.*
[19] *Programa BIOREDD+, Producto 6. 2014.*
[20] *Villalba Malaver. 2004.*
[21] *Polania et al. 2015.*
[22] *ICA 2012.*

Sucre, covering about 1,971 ha of coastal land[23] and being responsible of over 95% of the national shrimp production, most of which is sold in the international market[24]. The Pacific coast has 245 ha of active shrimp production, located in Nariño, whose produce is sold within Colombia. The shrimp business is an important driver of mangrove loss because shrimp ponds have typically a lifetime of 3-9 years[25] and thus, for a country to maintain shrimp productivity coastal areas need to keep on being cleared to build new ponds. Other land uses replacing mangrove forests such as urban construction or croplands do not have such a short life expectancy. Old abandoned shrimp ponds, however, have the potential to be restored to their former mangrove land cover.

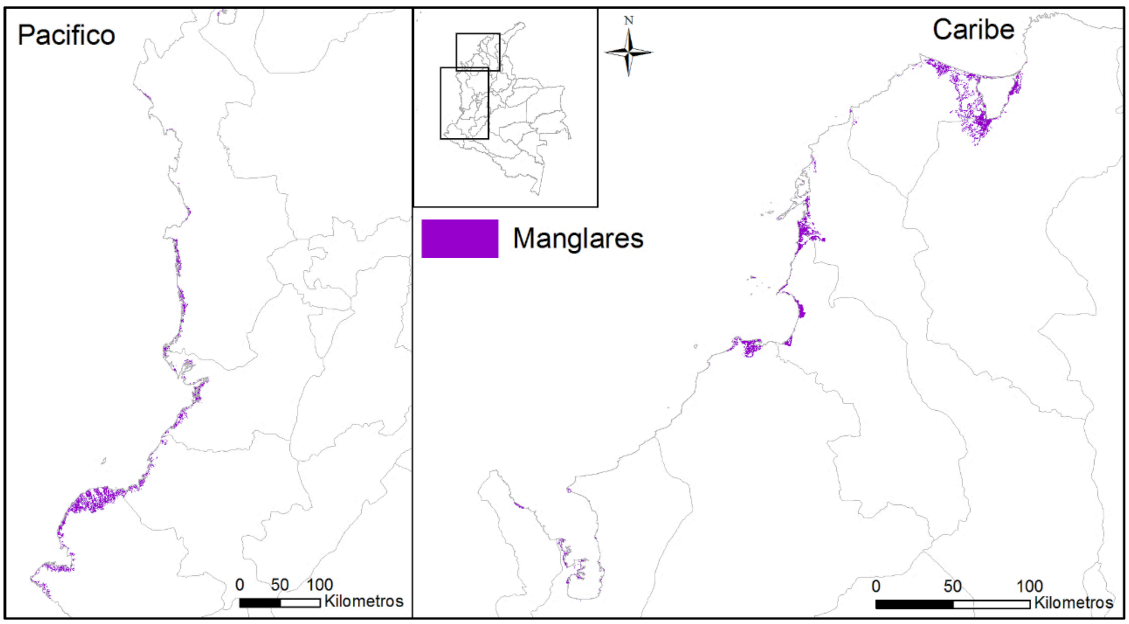

Figure 1. Mangrove distribution in the Pacific (left) and Caribbean coasts (right) of Colombia. Map developed with INVEMAR data (2014)[26].

A review of the drivers of mangrove loss and degradation in Colombia (described in detail by state at the end of this report) shows that mangroves are being lost at a rapid rate in the Caribbean, where land use change for **coastal development (resorts and ports, among others) and economic expansion (shrimp ponds, crops, and plantations) are the leading drivers of mangrove deforestation.** In the Pacific coast, on the other hand, the shrimp ponds are less abundant than in the Caribbean and **mangrove timber logging becomes one of the main drivers of mangrove loss and degradation**. Specific local drivers are described in the following sections of this report.

[23] FAO-INCODER 2011.
[24] PTP 2014.
[25] Kauffman et al. 2017.
[26] http://www.caribbeanmarineatlas.net/maps/6322

Table 1. Latest mangrove zoning in Colombia, according to INVEMAR (2014) and to the central Government[27].

State (*Departamento*)	Total mangrove cover (ha)	Protected mangrove area (ha)	Protected mangrove area (%)
San Andrés y Providencia	208	35	16.8
La Guajira	2,730	166	1.4
Sucre	12,190	0	0.0
Magdalena	38,042	21,106	55.5
Atlántico	237	0	0.0
Bolívar	9,739	2,929	30.1
Córdoba	8,975	0	0.0
Antioquia	5,810	0	0.0
Caribbean Region, Total	**77,938**	**24,236**	**31.3**
Chocó	40,774	33	0.1
Valle del Cauca	32,386	0	0.0
Cauca	23,204	0	0.0
Nariño	113,041	42,771	37.8
Pacific Region, Total	**209,405**	**42,804**	**20.4**
Country, Total	**286,804**	**67,040**	**23.4**

Box 2: Common drivers of mangrove deforestation and degradation

DEFORESTATION DRIVERS:

- Most common land use changes leading the deforestation of mangroves are the creation of aquaculture ponds (shrimp farms), the construction of infrastructure (roads and ports), and urban development of the coast.

- Indirectly, hydrological alterations (water diversions) and dredging of the peat soil can lead to mangrove disappearance, when the alteration is severe.

DEGRADATION DRIVERS:

- Hydrological alterations are the leading cause of mangrove degradation. This entails the restriction of water flow in the tidal channels, either from the salt water or from the freshwater source. Mangroves are brackish ecosystems and as such thrive in salinities of 3 (oligohaline) to 30 ppt (saline), with different species adapted to different salinity gradients. Eliminating the freshwater input can lead to the desiccation of the mangrove system and to the overconcentration of salts that create hypersaline conditions, resulting in mangrove death.

- Fuelwood extraction is common in rural coastal communities, leading to ecosystem overharvest and deterioration.

- Eutrophication can result in the long term in mangrove degradation, due to an increase in the shoot:root ratio of the trees and thus, becoming more vulnerable to storm events.

Cardona y Botero 1998, Elster et al 1999, Lovelock et al. 2009, Sathe et al. 2013, Kauffman et al. 2014, Lang'at et al. 2014, Mitsch & Gosselink 2015, Thomas et al. 2017.

[27] *http://www.minambiente.gov.co/*

Figure 2 shows a collection of aerial images of the Colombian coastline where degradation and deforestation drivers (described in Box 2) have been identified, ranging from plantations to aquaculture ponds to eutrophication plumes polluting the mangrove waters.

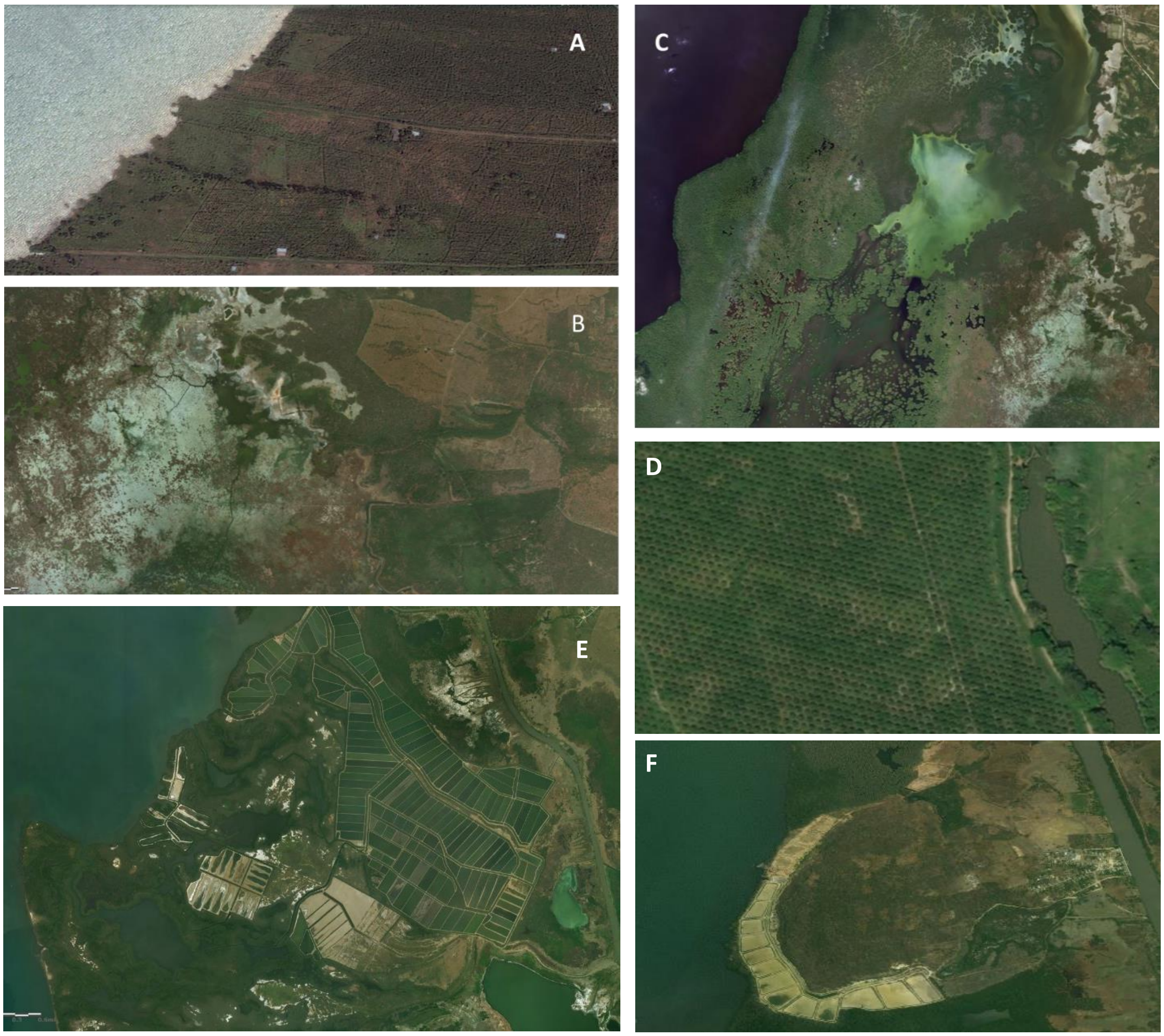

Figure 2. Aerial images of current and former mangrove ecosystems in the coastal regions in Colombia with reported mangrove loss and degradation due to known drivers (according to the information in INVEMAR 2004, MINAMBIENTE 2012, and publications cited in the following sections and in the reference list). **A.** Palm plantations in the coast of Antioquia. **B.** Banana plantations by the desiccating Ciénaga de Santa Marta (Magdalena). **C.** Eutrophication plumes in Ciénaga de Santa Marta. **D.** Zoom-in of plantations by the Ciénaga de Santa Marta. **E, F.** Aquaculture ponds in Bolívar.

To date, **there is no clear assessment of the extent of mangrove degradation in Colombia.** The country would benefit from an accurate evaluation of mangrove degradation and an estimation of the extent of degraded mangrove land. **Such an assessment would help Colombia in targeting restoration in specific coastal areas, in evaluating**

the impact of degradation drivers, and prioritizing restoration interventions in the country. As a preliminary step towards this direction, we have overlapped the forest cover map (forest being over 30% of canopy closure)[28] with the mangrove forest map developed by INVEMAR[29] to estimate the proportion of mangroves in Colombia that did not fall under the 'forest' category and thus, would be considered shrub-scrub mangroves. Mangrove shrubs are common in subtropical areas, but are also frequently found in stressed tropical systems (e.g. high salinities). In consequence, mature scrub-shrub mangroves are smaller than mangrove trees – IPCC classifies mangroves under the tree category when they are 5 m tall or higher, and under the shrub-scrub category when they are below 5 m tall[30]. The shrub mangroves in Colombia can therefore be assumed to be stressed, and could serve as a proxy for mangrove degradation in the country. This statement, however, would need to be verified with current ground data and ecosystem conditions assessment. Our analysis reveals that the mangrove areas in the coastal municipalities in Colombia present mangrove shrub communities covering between 4% and 98% of the municipalities total mangrove area (Table 2). **An on-site evaluation of mangrove environmental conditions in these municipalities would confirm if the mangrove shrubs in Colombia could fall onto the mangrove forest category, if degradation drivers in each municipality are identified and the ecosystem is restored.**

Table 2. Analysis of forest area (canopy closure greater than 30%) and mangrove area, to estimate the amount of mangrove cover that is forest and non-forest in Colombia. Non-forest mangroves are assumed to be shrub-scrub mangroves.

State (*Departamento*)	Coastal Municipality	Forest area (ha)	Mangrove area (ha)	Mangrove area that is forest (ha)	Mangrove area that is shrub (ha)	% of mangroves that are shrub
Antioquia	Arboletes	26,825	3.82	1.53	2.29	60.0
Antioquia	Necoclí	75,632	402.32	328.41	73.91	18.4
Antioquia	San Juan de Urabá	17,727	20.41	12.6	7.81	38.3
Antioquia	Turbo	234,622	5,383.51	4644.72	738.79	13.7
Atlántico	Barranquilla	17,719	19,699.32	9945.18	9,754.14	49.5
Atlántico	Juan de Acosta	6,470	33.24	4.59	28.65	86.2
Atlántico	Luruaco	10,480	74.77	54.72	20.05	26.8
Atlántico	Puerto Colombia	1,147,751	234.25	72.54	161.71	69.0
Atlántico	Piojó	7,342	165.84	82.44	83.40	50.3
Atlántico	Tubará	8,475	29.38	4.41	24.97	85.0
Bolívar	Cartagena de Indias	20,620	6,144.31	3174.12	2,970.19	48.3
Bolívar	Arjona	13,665	3,389.17	1867.14	1,522.03	44.9
Bolívar	María la Baja	19,564	0.61	0.36	0.25	41.2
Bolívar	Santa Catalina	6,415	205.13	11.43	193.70	94.4
Cauca	Guapí	209,278	8,768.62	7988.85	779.77	8.9

[28] *Global Forest Change 2000-2015, UMD. In: Hansen et al. 2013.*
[29] *http://www.caribbeanmarineatlas.net/maps/6322*
[30] *2003 IPCC Good Practice Guidance for Land Use, Land Use Change and Forestry.*

State (*Departamento*)	Coastal Municipality	Forest area (ha)	Mangrove area (ha)	Mangrove area that is forest (ha)	Mangrove area that is shrub (ha)	% of mangroves that are shrub
Cauca	López de Micay	237,910	7,530.09	6848.91	681.18	9.0
Cauca	Timbiquí	167,655	6,905.42	6357.42	548.00	7.9
Chocó	Acandí	68,542	698.70	626.13	72.57	10.4
Chocó	Bajo Baudó	408,620	25,096.29	23029.65	2,066.64	8.2
Chocó	Bahía Solano	99,960	1,255.58	1128.6	126.98	10.1
Chocó	Juradó	135,783	2,019.52	1836.99	182.53	9.0
Chocó	Nuquí	70,125	3,009.33	2772.72	236.61	7.9
Chocó	Unguía	85,709	1.96	1.89	0.07	3.7
Córdoba	Los Córdobas	12,956	3.39	0.72	2.67	78.8
Córdoba	Moñitos	12,604	251.39	107.82	143.57	57.1
Córdoba	Puerto Escondido	13,723	20.75	15.66	5.09	24.5
Córdoba	San Antero	8,321	3,357.15	2758.86	598.29	17.8
Córdoba	San Bernardo del Viento	9,866	5,342.80	4100.22	1,242.58	23.3
Guajira	Manaure	31,552	139.13	4.59	134.54	96.7
Guajira	Riohacha	361,823	420.86	199.44	221.42	52.6
Guajira	Uribia	7,824	1,636.60	29.34	1,607.26	98.2
Magdalena	Aracataca	123,740	1,325.66	1223.73	101.93	7.7
Magdalena	Ciénaga	133,235	3,984.40	2222.82	1,761.58	44.2
Magdalena	Pivijay	63,769	204.30	133.29	71.01	34.8
Magdalena	Pueblo Viejo	16,225	5,065.12	3819.96	1,245.16	24.6
Magdalena	Remolino	12,614	7,349.06	5178.33	2,170.73	29.5
Magdalena	Santa Marta	183,621	113.34	80.28	33.06	29.2
Nariño	El Charco	132,494	16,181.98	12661.47	3,520.51	21.8
Nariño	Francisco Pizarro	62,245	12,335.15	11102.4	1,232.75	10.0
Nariño	La Tola	33,798	5,512.32	4333.59	1,178.73	21.4
Nariño	Mosquera	49,260	24,404.04	20119.41	4,284.63	17.6
Nariño	Olaya Herrera	90,422	8,290.56	6175.08	2,115.48	25.5
Nariño	Roberto Payán	106,653	37.19	34.74	2.45	6.6
Nariño	Santa Bárbara	162,727	21,709.07	18525.06	3,184.01	14.7
Nariño	Tumaco	233,185	24,570.48	21889.35	2,681.13	10.9
San Andrés y Providencia	Providencia	7,683	59.92	36.27	23.65	39.5
San Andrés y Providencia	San Andrés	1,825	148.19	124.11	24.08	16.2
Sucre	San Antonio de Palmito	5,136	54.71	35.55	19.16	35.0
Sucre	San Onofre	43,861	7,914.98	5261.85	2,653.13	33.5
Sucre	Tolú	8,417	4,220.49	2817.27	1,403.22	33.2
Valle del Cauca	Buenaventura	615,900	32,386.21	29804.13	2,582.08	8.0

MANGROVE DEGRADATION DUE TO FUELWOOD COLLECTION

One of the drivers of mangrove degradation in Colombia is the extraction of mangrove biomass for fuelwood and charcoal, especially in the Caribbean coast[31]. The selective biomass harvest for fuelwood and charcoal is causing forest degradation when the forest biomass is removed at a rate that exceeds the capacity of the forest to grow (thereby considered non-renewable biomass - NRB). Population is therefore driving the fuelwood demand and, in coastal communities in and around a mangrove forest, their fuelwood is supplied from the nearby upland and mangrove forests. To evaluate the pressure that Colombia's fuelwood demand has on mangrove resources in the coastal communities with mangrove cover, a spatial analysis[32] of fuelwood demand and supply potential using the *Woodfuel Integrated Supply/Demand Overview Mapping* (WISDOM) model was used. For this analysis, only the fuelwood demand that was satisfied by non-land use change forest by-products was considered[33]. NRB already accounts for the available biomass of mangrove forests, but likely does not consider shrub biomass.

To assess the pressure that fuelwood demand has on Colombia's mangrove ecosystems, we

- **(A)** evaluated the location of the most densely-populated coastal municipalities and overlapped it with the mangrove cover map (Figure 3); and
- **(B)** calculated the average biomass carbon pool of mangrove shrubs from a review of published worldwide mangrove carbon stocks[33], and assessed if mangrove shrubs in the area can meet the local NRB need (see list of references and the detailed data in Annex 1).

The overlapping of population density and mangrove cover maps indicate that the coastal Colombian regions that could be exerting more pressure on their mangroves ecosystems would be the coast of Valle del Cauca and southern Nariño, in the Pacific, and the coasts of Sucre, Cordoba, Bolívar, and Magdalena in the Caribbean. Additionally, the estimate of the biomass carbon (C) pool contained in the shrub mangrove ecosystems revealed the coastal communities in the country could meet the local NRB demand through mangrove shrub biomass. Given the available country information, we do not know where Colombian coastal communities obtain their fuelwood biomass (i.e. whether it is from upland forests or from mangrove forests), but we know that these communities demand more fuelwood biomass than what would be available under a sustainable biomass extraction, which means that forests (mangrove and/or upland forests) are being degraded for fuelwood extraction (see NRB for Colombia's coastal communities in Annex 1). Shrub mangrove biomass, however, is not accounted for in WISDOM and can be used to meet the fuelwood demand as well. Our analysis reveals that almost all coastal communities in Colombia can meet

[31] *Uso sostenible, manejo y conservación de los Ecosistemas de manglar en Colombia. 2002. MINAMBIENTE. Santa Fe de Bogotá D.C., Colombia.*
[32] *Drigo. 2014.*
[33] *https://infoflr.org/what-flr/global-emissions-and-removals-databases*

their NRB demand with the locally available shrub mangrove biomass, except for San Antonio de Palmito in San Andrés, Arboletes in Antioquia, Maria la Baja in Bolívar, Unguía and Los Córdobas in Choco, and Roberto Payán in Nariño. These 6 communities we estimate are exerting an unsustainable amount of pressure on their mangroves (shrubs and trees) through fuelwood extraction, and thus will be degrading the ecosystem; degradation would and could be averted through fuelwood demands being met by other sources such as upland forests or purchasing wood from commercial sources. Of course, on a more local scale there are likely to be localities outside the six identified where concentrated extraction is unsustainable even where it can be argued that the broader region has sufficient resources.

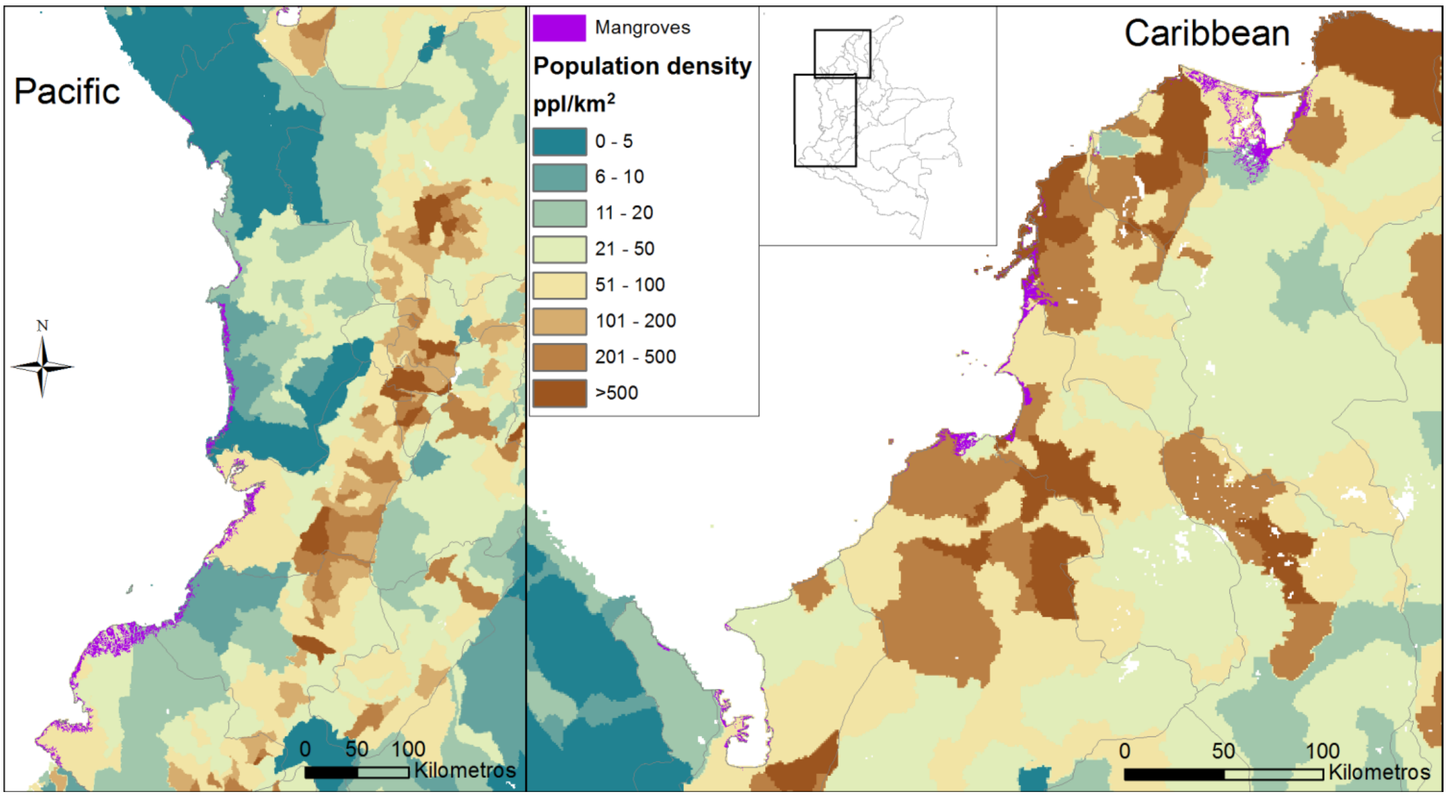

Figure 3. Location of mangrove coverage (purple) in the Caribbean and Pacific coasts of Colombia. The States (*Departamentos*) are colored according to the population density of their municipalities (people per km^2).

POTENTIAL EMISSIONS REMOVAL WITH MANGROVE RESTORATION

To the date, there is no specific information available on Colombia's mangrove restoration targets. Several peer-reviewed publications and Government reports evaluate the success of mangrove restoration in some areas of the country (see the following sections on Caribbean and Pacific mangrove current status and the list of bibliographical references used). Mangroves are included in the latest National Restoration Plan[34], without specifying explicit restoration locations, target areas (size) of restoration, or even a current extension of degraded mangroves in the country. Therefore, it **seems that an evaluation of priority restoration targets is lacking in Colombia, as well as a restoration feasibility plan that would allow identifying benefits of restoring specific mangrove areas in the country.**

There are some sources of information that could help Colombia to set a restoration target. For example, INVEMAR developed a coastal erosion map[35] that shows the coastal areas where erosion is occurring. This map could be used to identify priority areas for coastal restoration. More ground data would be necessary to assess the proportion of mangrove area being affected by this coastal erosion phenomenon, and determine if eroding areas can actually support mangrove growth to aid in decreasing the coastal erosion process. Additionally, the zonation of protected mangrove areas (Table 1) would suggest that, under a land management that ensures that protected areas are not degraded in the country, the mangrove areas that can potentially be degraded in Colombia and thus potentially restored would be those that are not protected with the current legislation. Furthermore, the coverage of mangroves that do not fall under the forest category could also indicate potential areas that are under environmental stress and could potentially be restored (Table 2). Lastly, the coastal land covered by shrimp and aquaculture ponds will be unfit for its current land use once the ponds surpass their life expectancy, and will likely be abandoned[36], thereby becoming coastal land suitable for mangrove restoration. In Table 3 we show the area of each coastal State in Colombia that could potentially be a restoration target. This estimate, however, should be verified with actual on-site data, when it becomes available. According to this assumption, if shrub mangroves are indeed degraded mangroves in Colombia and are located only in non-protected areas, more than half of the unprotected mangroves in the Caribbean coast would be degraded, while only about one-sixth in the Pacific coast. Table 3 also shows the area of active shrimp pond infrastructure[37] that will be appropriate for restoration once the ponds are no longer in use.

[34] *Plan Nacional de Restauración: Recuperación Ecológica, Rehabilitación y Recuperación de Áreas Disturbadas. 2015. MINAMBIENTE. Santa Fe de Bogotá D.C., Colombia.*
[35] *http://gis.invemar.org.co/erosioncostera/*
[36] *Kauffman et al. 2017.*
[37] *FAO-INCODER 2011.*

Table 3. Potential areas in Colombia per State that could be degraded and thus could be suitable for restoration, either because they are not protected, because they do not fall under the 'forest' cover classification, or because they have active shrimp ponds that will be suitable for restoration once they are obsolete.

State (*Departamento*)	Unprotected mangrove area (ha)	Shrub mangrove area (ha)	Shrimp pond infrastructure (ha)[38]
San Andrés y Providencia	173	48	No data
La Guajira	2,197	4,076	100
Sucre	12,024	1,963	793
Magdalena	16,936	5,383	No data
Atlántico	237	10,073	163
Bolívar	6,810	4,686	1,532
Córdoba	8,975	1,992	405
Antioquia	5,810	823	No data
Caribbean Region, Total	**53,162**	**29,044**	**2,993**
Chocó	40,741	2,685	No data
Valle del Cauca	32,386	2,582	No data
Cauca	23,204	2,009	No data
Nariño	70,270	18,200	1,545
Pacific Region, Total	**166,601**	**25,476**	**1,545**
Country, Total	**219,764**	**54,520**	**4,538**

Mangrove restoration can be motivated by an interest in recovering the ecosystem services they provide (main ones listed in Box 1), which can be translated to economic metrics through ecosystem services valuation as described earlier in this report. **Mangrove restoration can also be an important component of the country's climate change mitigation strategies.** Colombia is working on potentially including mangrove restoration in their Forestry NAMA, as a tool to remove emissions through mangrove biomass growth.

Our review of published world-wide mangrove C stocks[39] was used to develop growth curves for mangrove forests. These C stocks correspond to aboveground biomass, and their growth is defined following the Chapman-Richards model[40]:

$$AGB = MAX * [1 - EXP(-k * y)]^{1/(1-m)}$$

where *AGB* is the C contained in aboveground biomass (t C ha^{-1}), *MAX* is the asymptote of the sigmoid growth curve, reflecting the maximum attainable biomass, *EXP* is the exponential function of the curve, k and m are unitless growth coefficients, and y is the number of years. The curves are shown in Figures 4A and 4B, and the parameters of the model are detailed in Table 4.

[38] *FAO-INCODER 2011.*
[39] *https://infoflr.org/what-flr/global-emissions-and-removals-databases*
[40] *Pienaar and Turnbull. 1973.*

Table 4. Parameters developed for the Chapman-Richards biomass growth curves for mangrove ecosystems in Colombia.

Mangrove type	R^2	Growth curve parameters			
		MAX	k	m	1/(1-m)
Tree	0.56	158	0.073	0.55	2.222
Shrub-scrub	0.53	37	0.111	0.71	3.448

The uncertainty associated to the biomass growth is calculated with a 95% confidence interval, using the following equation:

$$IC = TINV * \sigma_{res} * \sqrt{\left(\frac{1}{n}\right) + [(y - y_a)^2 / \sum y_{res}]}$$

where, IC is the half-width of the 95% confidence Interval of the AGB (t C ha^{-1}), $TINV$ is the inverse of the t-Student distribution of the Chapman-Richards curve with a p-value of 0.05, σ_{res} is the standard deviation of the residuals of the Chapman-Richards curve, n is the number of data points that produced the curve, y is the number of years, y_a is the average of the years that were used to develop the Chapman-Richards curve, $\sum y_{res}$ is the sum of the residuals of the years in the curve. These parameters are detailed in Table 5.

Table 5. Parameters developed for the 95% confidence intervals of the Chapman-Richards biomass growth curves for mangrove ecosystems in Colombia.

Mangrove type	Parameters of the confidence Interval of the model.				
	TINV	σ_{res}	a_p	$\sum a_{res}$	n
Tree	2.01	54.24	17	18,202.50	50
Shrub-scrub	2.16	6.60	15	1,169.08	13

The analysis indicates that mangrove restoration in Colombia can potentially remove CO_2e, through aboveground mangrove biomass growth, at a rate of 16.1 ± 2.9 t CO_2e ha^{-1} y^{-1}, and 4.4 ± 0.7 t CO_2e ha^{-1} y^{-1} during the first 20 years of restoration of mangrove trees and shrubs, respectively. After the first 20 years since planting, the emission removal rates would be 7.4 ± 1.9 t CO_2e ha^{-1} y^{-1} for mangrove trees and 1.4 ± 1.3 t CO_2e ha^{-1} y^{-1} for mangrove shrubs over the next 30 years, assuming a constant rate of growth. These removal rates can be applied to mangrove restoration areas to estimate the total CO_2e removals with mangrove restoration. The NAMA Tool developed by Winrock International for Colombia's Ministry of Environment and Sustainable Development (MADS) uses this logic

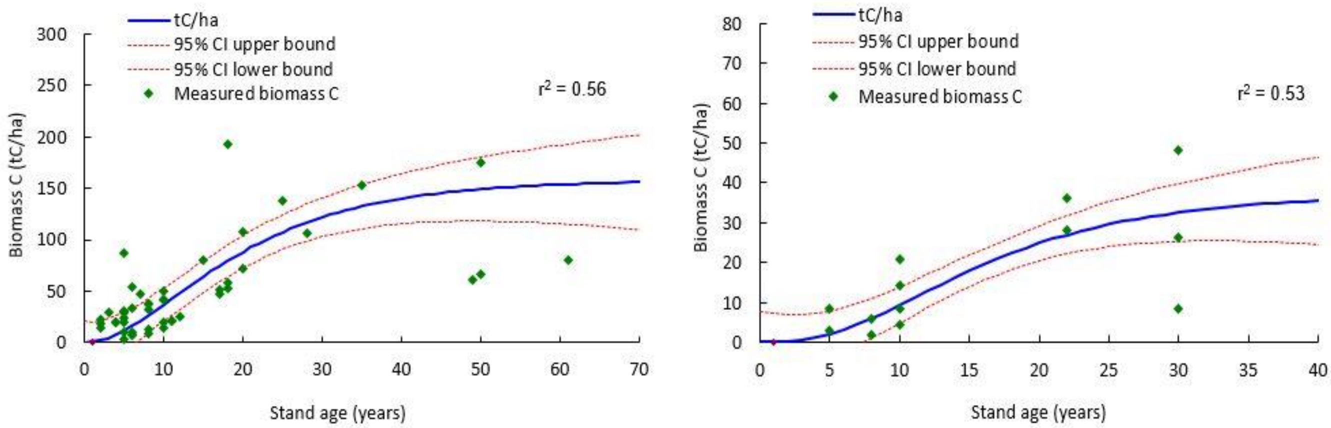

Figure 4. A. Biomass-C growth curve of mangrove trees; and **B.** biomass-C growth curve of mangrove shrub-scrub.

to support stakeholder decision making, as part of Colombia's Forestry NAMA initiative. As an example of how these removal rates could be applied to a mangrove restoration area, Table 6 shows the result of multiplying the described aboveground mangrove tree biomass growth to the areas potentially suitable for mangrove restoration (from Table 3), if all those areas were able to achieve a successful restoration and grow healthy mangrove trees. Such a suitability must ultimately be determined on-site with current ground-data in a restoration feasibility assessment.

Table 6. Average CO_2e removal rates (t CO_2e y^{-1}) that Colombia could potentially achieve if all the unprotected mangrove areas, shrub mangrove areas, and shrimp pond areas estimated above were fitted for mangrove restoration and were able to grow healthy mangrove trees once the restoration is implemented.

State (*Departamento*)	Average potential CO_2e removal rate, years 0-20 since of restoration			Average potential CO_2e removal rate, years 20-50 since of restoration		
	Unprotected mangroves	Shrub mangroves	Shrimp ponds	Unprotected mangroves	Shrub mangroves	Shrimp ponds
San Andrés y Providencia	2,785	773	No data	1,280	355	No data
La Guajira	35,372	65,624	1,610	16,258	30,162	740
Sucre	193,586	31,604	12,767	88,978	14,526	5,868
Magdalena	272,670	86,666	No data	125,326	39,834	No data
Atlántico	3,816	162,175	2,624	1,754	74,540	1,206
Bolívar	109,641	75,445	24,665	50,394	34,676	11,337
Córdoba	144,498	32,071	6,521	66,415	14,741	2,997
Antioquia	93,541	13,250	No data	42,994	6,090	No data
Caribbean Region	**855,908**	**467,608**	**48,187**	**393,399**	**214,926**	**22,148**
Chocó	655,930	43,229	No data	301,483	19,869	No data
Valle del Cauca	521,415	41,570	No data	239,656	19,107	No data
Cauca	373,584	32,345	No data	171,710	14,867	No data
Nariño	1,131,347	293,020	24,875	519,998	134,680	11,433
Pacific Region	**2,682,276**	**410,164**	**24,875**	**1,232,847**	**188,522**	**11,433**
Country, Total	**3,538,200**	**877,772**	**73,062**	**1,626,254**	**403,448**	**33,581**

CURRENT STATE OF MANGROVES IN THE CARIBBEAN REGION

The Caribbean region has a total mangrove forest area of 77,938 ha[41], of which about one-third is protected[42] (Table 1). Magdalena is the state with the highest mangrove cover in this coast. This region has four main estuaries, developed by the river Magdalena and the river Sinú, that have 59 coastal lagoons where mangroves grow[43]. One of these lagoons is the Ciénaga Grande de Santa Marta, the largest in the country. The most common mangrove species in the Caribbean coast of Colombia are *Avicennia germinans* and *Rhizophora mangle*, followed by *Laguncularia racemosa, Conocarpus erecta* and *Pelliciera rhizophorae*[44]. Coastal communities in the Caribbean have traditionally used the natural resources that grow and inhabit the mangrove ecosystems, such as fishing, recollection, biomass extraction, tourism, etc. Mangrove biomass has traditionally been used in this region to build canoes and utensils, or as fuelwood and charcoal, given its high calorific content and low ash production[45,46].

The information on the conditions of the mangroves in this coastal region and the drivers impacting the ecosystem in each Caribbean State has been compiled from reports from INVEMAR[47] and the central Government[48,49], and from the numerous research publications listed in the references list.

Drivers of mangrove loss, degradation, and expansion in the Caribbean region

La Guiajira: Mangroves in this State have had little anthropogenic pressure, but they are impacted by increasing drought desiccating freshwater supply channels, resulting in hyper salinization of the soil and the surviving water ponds and in the death of vegetation and aquatic animals. Mangroves in the upper region of the State have also suffered from pests that caused in the die-off of the species *Avicenia germinans*.

Magdalena: The most significant impacts to the mangrove ecosystems in this State are located in the delta estuary of the river Magdalena, particularly in the Ciénaga Grande de Santa Marta and the Isla de Salamanca, due to the diversion, diking, and drainage of freshwater courses for construction of infrastructure (roads) and agricultural

[41] *http://www.caribbeanmarineatlas.net/maps/6322*
[42] *http://www.minambiente.gov.co/*
[43] *INVEMAR 2004.*
[44] *Álvarez-León 2003.*
[45] *Sathe et al. 2013.*
[46] *Sánchez-Páez et al. 1997b.*
[47] *INVEMAR 2004*
[48] *Plan Nacional de Restauración: Recuperación Ecológica, Rehabilitación y Recuperación de Áreas Disturbadas. 2012. MINAMBIENTE. Santa Fe de Bogotá D.C., Colombia.*
[49] *Uso sostenible, manejo y conservación de los Ecosistemas de manglar en Colombia. 2002. MINAMBIENTE. Santa Fe de Bogotá D.C., Colombia.*

purposes (e.g. banana plantations)[50,51]. These actions have led to the hyper salinization (reportedly up to 10 times the ocean's salinity) of the ecosystem[52]. This area has also suffered from the increased sedimentation consequence of the deforestation in key watersheds of the State (rivers Sevilla and Fundación)[53]. In consequence, it was estimated that up to 95% of the mangrove trees in the Ciénaga Grande de Santa Marta and the Isla de Salamanca since the 1950s had died in a single event[54]. In 1995–2001, the Government worked on the restoration of the ecosystem under a project with IDB and GTZ funds that reopened and cleared freshwater inlets to restore the hydrology of the ecosystem. The area thereby recovered part of its original mangrove cover and density in the Ciénaga. Further restoration activities and planting of mangroves were implemented in 2004, but seedlings presented high rates of mortality[55], likely because of the persistence of the drivers of mangrove degradation in the area (hyper salinization and altered hydrology)[56]. Additional drivers of mangrove degradation in this area are the extraction of biomass for fuelwood and charcoal production. The Ciénaga Grande de Santa Marta is the largest extent of mangrove forests in the country and one of the most studied in the last two decades.

Atlántico: In this State, high pollution and eutrophication levels have been the main drivers of mangrove degradation, particularly in the Ciénaga de Mallorquín, Ciénaga de Balboa, and Ciénaga del Rincón, due to the discharge of waste and contaminated waters and sediments on the river Magdalena, accumulating on the mangrove ecosystem. Additionally, industrial activities in the area have also been diverting water channels and altering the hydrology of the ecosystem.

Bolívar: Sedimentation blocked the freshwater tidal channels and restricting their flow in large sections of the Bolívar coast, where numerous large size mangroves have been found standing dead. These sediments come mainly from the Canal del Dique. Additionally, the Bahía de Cartagena and the Ciénaga de la Virgen experiences high pollution levels from industry and aquatic traffic, decreasing mangrove productivity in the area. Numerous development of infrastructures around Cartagena have incurred in the clearing of some mangrove areas to construct roads and resorts, and in the modification of waterways that led to the desiccation and hyper salinization of the remaining mangrove areas. In the region of Canal del Dique and in Bahía de Barbacoas there is additional degradation due to the biomass extraction by local communities for fuelwood, and numerous mangrove deforestation areas where the mangrove forest has been replaced by industrial shrimp ponds, which polluted the surrounding areas with their unmanaged wastewater from the shrimp production process.

[50] *Botero and Salzwedel. 1999.*
[51] *Cardona and Botero. 1998.*
[52] *Elster et al. 1999.*
[53] *Sánchez-Páez et al. 2000.*
[54] *Polania et al. 2015.*
[55] *Salas-Leiva et al. 2009.*
[56] *Elster 2000.*

Sucre: The delta of the Canal del Dique and the Ciénaga La Caimanera receive a substantial amount of the sediments that this waterway carries, in addition to those carried from the deforested hills on the west bordering with Córdoba. Additionally, the mangroves in the Golfo de Morrosquillo were severely impacted by the cutting down of the trees and filling of the wetland to convert it to other land uses and create roads[57]. Standing mangroves in the Golfo de Morrosquillo and the Ciénaga La Caimanera have been suffering from significant degradation as well due to these hydrological alterations, leading to hypersaline conditions and to the overharvesting of their biomass for fuelwood. Overall, much of the mangrove areas in Sucre have been replaced by pastures for livestock, crops, and salt flats.

Córdoba: In the Delta Antiguo del Río Sinú, mangrove expansion due to salt water intrusion in former rice paddies. The intrusion of salt water is reported to be consequence of the hydrological alteration of the freshwater flow from the main river feeding the delta. On the other hand, this delta has been negatively affected by the development of shrimp ponds, and the net result on mangrove cover is unclear. Punta Bolívar and the Bahía de Cispatá are frequently experiencing mangrove damages due to strong wind currents in the area. Industrial salt flats in the area have modified the hydrology of the tidal channels, despite the State's regulation. The Bahía de Cispatá is a mangrove ecosystem highly valued by the local communities, and the Government claims that these communities are aware of the need to preserve it for their own subsistence.

Antioquia: The mangroves in the Golfo de Urabá suffer from pollution from communities' trash and from wastewaters originated in the banana plantations and in the port on Bahía Colombia. There is also an important illegal mangrove biomass extraction for charcoal production in Turbo and Necoclí. The mangroves in the Golfo de Urabá have also been impacted since 1997 by a parasite mollusk (*Neoteredo reynei*) that has killed many mangrove individuals, mature and successional.

Chocó (Urabá chocoano): Mangroves in the tidal creeks of Capurganá have been cleared for the construction of resorts and for the establishment of coconut plantations, leaving a few isolated individuals.

San Andrés y Providencia: Mangroves in these islands are mainly impacted by the pollution of their waters due to fuel combustion, grey waters, and garbage dumped by the coastal communities. They have also been deforested for development purposes and, to a lesser extent, due to the expansion of the shrimp industry.

[57] *Urueta et al. 2010.*

CURRENT STATE OF MANGROVES IN THE PACIFIC REGION

The Pacific region has a total mangrove forest area of 209,405 ha[58], of which about one-fifth is protected[59] (Table 1). More than half of the mangrove forest cover in this coast is concentrated in the State of Nariño. The most extended species are the red mangroves (*Rhizophora* sp.); *Avicenia germinans* and *Pelliciera rhizophorae* are also abundant[60]. Communities in the Pacific coast have also been traditionally using the natural resources offered by the mangrove forests, extracting wood to build houses and canoes, collecting fuelwood for fuel and charcoal for their daily needs, fishing and catching sea food inhabiting the ecosystem, etc. The shrimp industry, once strong in this coast and leading mangrove loss, has decreased substantially due to the inefficiency of the shrimp ponds in this area, whose larvae had to be imported and had frequent diseases, and whose products had a highly variable price shrimp market.

The information on the conditions of the mangroves in this coastal region and the drivers impacting the ecosystem in each Pacific State has been compiled from reports from INVEMAR[61] and the central Government[62,63], and from the numerous research publications listed in the references list.

Drivers of mangrove loss, degradation, and expansion in the Pacific region

Chocó: Mangroves in this State have been impacted by the extraction of biomass (logging) for diverse marketable wood products, because of the wood quality of mangroves growing in this coast (*Rhizophora* sp. and *P. rhizophorae*).

Valle del Cauca: The development of the Bahía de Buenaventura has incurred in severe impacts on the surrounding mangrove ecosystems, due to then expansion of its urban area and maritime port. This entailed deforestation, land filling, hydrological alterations, and contamination with fuels, urban and industrial wastewaters, and trash. The Southern region of the State has also been affected by the diversion of freshwater ways to supply urban areas and by the conversion of mangroves to coconut plantations. The conversion of mangrove forests to coconut plantations has been frequent in this State, and has led to an accelerated coastal erosion. The local Government has restricted mangrove biomass extraction in the State, but local communities still collect mangrove wood at a small scale for their community use.

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58 http://www.caribbeanmarineatlas.net/maps/6322
59 http://www.minambiente.gov.co/
60 Álvarez-León. 2003.
61 INVEMAR 2004
62 Plan Nacional de Restauración: Recuperación Ecológica, Rehabilitación y Recuperación de Áreas Disturbadas. 2012. MINAMBIENTE. Santa Fe de Bogotá D.C., Colombia.
63 Uso sostenible, manejo y conservación de los Ecosistemas de manglar en Colombia. 2002. MINAMBIENTE. Santa Fe de Bogotá D.C., Colombia.

Valle del Cauca has high deforestation in their watersheds, and the sediments produced by the increasing erosion accumulate in the estuaries along the coastline[64], forming small islands that get colonized by herbaceous vegetation and mangrove propagules. These islands are semi-permanent, and are gaining stability as vegetation colonizes them. Mangroves are also extending upwards into the tidal creeks, likely due to an increase in the tidal frame.

Cauca: The drivers of mangrove loss and degradation in this State are similar to those described for Valle del Cauca, such as fuelwood extraction, logging, charcoal production, and replacement of mangrove forests by coconut plantations. This state also presents mangrove loss due to the development of shrimp ponds. The phenomenon of mangrove expansion upon the creation of semi-permanent sedimentary islands is also frequent in Cauca.

Nariño: The greatest historical impact on the mangroves in this State are located in the watersheds of the river Patía and the river Sanquianga. These watersheds have been significantly altered by major water diversions and channelization to allow a quicker and easier extraction of logged trees from the upland forest than the traditional terrestrial log extraction route. In the Ensenada de Tumaco, the impacts on mangrove ecosystems are related to an increased development of urban areas, tourism, commercial and industrial activity, port traffic, and shrimp ponds development, resulting in high levels of pollution and eutrophication from the urban and industrial wastewaters and sediments.

[64] *Uso sostenible, manejo y conservación de los Ecosistemas de manglar en Colombia. 2002. MINAMBIENTE. Santa Fe de Bogotá D.C., Colombia.*

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ANNEX 1: FUELWOOD NON-RENEWABLE BIOMASS

Non-renewable biomass C (NRB) was calculated using WISDOM [1], fuelwood emissions were calculated from NRB [2], mangrove shrub area was obtained from crossing mangrove data [3] with forest cover data [4], and the mangrove biomass C tons were calculated multiplying the mangrove areas by the global mangrove shrub-scrub pool average of 16.43 tons C ha^{-1} [2].

State (*Departamento*)	Municipality	A) Non-renewable biomass-C (tons)	B) Mangrove shrub area (ha)	C) Mangrove shrub biomass-C pool (tons)	Mangrove shrub can satisfy NRB? (i.e. A≤C) y/n
Antioquia	Arboletes	143.22	2.29	37.63	n
Antioquia	Necoclí	201.39	73.91	1,214.03	y
Antioquia	San Juan de Urabá	103.42	7.81	128.24	y
Antioquia	Turbo	566.07	738.79	12,135.46	y
Atlántico	Barranquilla	15,260.83	9,754.14	160,223.06	y
Atlántico	Juan de Acosta	122.27	28.65	470.55	y
Atlántico	Luruaco	234.16	20.05	329.43	y
Atlántico	Puerto Colombia	503.10	161.71	2,656.19	y
Atlántico	Piojó	110.74	83.40	1,369.89	y
Atlántico	Tubará	116.30	24.97	410.18	y
Bolívar	Cartagena de Indias	4,689.98	2,970.19	48,788.83	y
Bolívar	Arjona	292.27	1,522.03	25,001.16	y
Bolívar	María la Baja	245.20	0.25	4.15	n
Bolívar	Santa Catalina	307.87	193.70	3,181.79	y
Cauca	Guapí	0.01	779.77	12,808.63	y
Cauca	López de Micay	0.01	681.18	11,189.23	y
Cauca	Timbiquí	0.01	548.00	9,001.53	y
Chocó	Acandí	70.44	72.57	1,192.00	y
Chocó	Bajo Baudó	172.23	2,066.64	33,946.95	y
Chocó	Bahía Solano	60.93	126.98	2,085.75	y
Chocó	Juradó	35.02	182.53	2,998.26	y
Chocó	Nuquí	40.59	236.61	3,886.59	y
Chocó	Unguía	89.94	0.07	1.20	n
Córdoba	Los Córdobas	0.00	2.67	43.90	n
Córdoba	Moñitos	0.01	143.57	2,358.23	y

Córdoba	Puerto Escondido	0.01	5.09	83.64	y
Córdoba	San Antero	0.01	598.29	9,827.65	y
Córdoba	San Bernardo del Viento	0.01	1,242.58	20,410.79	y
Guajira	Manaure	34.64	134.54	2,210.04	y
Guajira	Riohacha	139.97	221.42	3,637.04	y
Guajira	Uribia	74.70	1,607.26	26,401.14	y
Magdalena	Aracataca	206.24	101.93	1,674.33	y
Magdalena	Ciénaga	594.51	1,761.58	28,935.96	y
Magdalena	Pivijay	208.55	71.01	1,166.34	y
Magdalena	Pueblo Viejo	51.26	1,245.16	20,453.17	y
Magdalena	Remolino	61.10	2,170.73	35,656.82	y
Magdalena	Santa Marta (Dist. Esp.)	1,268.38	33.06	543.01	y
Nariño	El Charco	38.91	3,520.51	57,828.46	y
Nariño	Francisco Pizarro	23.96	1,232.75	20,249.38	y
Nariño	La Tola	14.74	1,178.73	19,361.96	y
Nariño	Mosquera	22.57	4,284.63	70,379.99	y
Nariño	Olaya Herrera	47.86	2,115.48	34,749.14	y
Nariño	Roberto Payán	28.61	2.45	40.20	n
Nariño	Santa Bárbara	24.21	3,184.01	52,300.96	y
Nariño	Tumaco	270.12	2,681.13	44,040.63	y
San Andrés y Providencia	Providencia	81.13	23.65	388.55	y
San Andrés y Providencia	San Andrés	961.87	24.08	395.55	y
Sucre	San Antonio de Palmito	5.24	19.16	314.67	n
Sucre	San Onofre	17.13	2,653.13	43,580.64	y
Sucre	Tolú	11.15	1,403.22	23,049.59	y
Valle del Cauca	Buenaventura	2,985.85	2,582.08	42,413.60	y

References of Annex 1

[1] Drigo, R. 2014. “Elaboration of the pan-tropical analysis of NRB harvesting (Tier 1 data, version 01 April 2014).” Produced by the Yale-UNAM GACC Project: Geospatial Analysis and Modeling of Non-Renewable Biomass: WISDOM and Beyond for Global Alliance for Clean Cookstoves.

[2] Global Emissions and Removals FLR dataset: https://infoflr.org/what-flr/global-emissions-and-removals-databases.

[3] INVEMAR dataset: http://www.caribbeanmarineatlas.net/maps/6322.

[4] Hansen M.C., P.V. Potapov, R. Moore, M. Hancher, S.A. Turubanova, A. Tyukavina, D. Thau, S.V. Stehman, S.J. Goetz, T.R. Loveland, A. Kommareddy, A. Egorov, L. Chini, C.O. Justice, J.R.G. Townshend. 2013. High-Resolution Global Maps of 21st-Century Forest Cover Change. Science 342 (6160): 850-853.

ANNEX 2: COLOMBIA'S MANGROVE SUSTAINABILITY TARGET

The central Government is working towards meeting the target of developing a comprehensive and sustainable land use planning and management of Colombia's mangrove ecosystems by 2025. To accomplish this task, the country has outlined the following ambitious strategies and programs[65]:

1. Delineation of mangrove areas and zoning of their land use management in every coastal state.
2. Formulation and implementation of mangrove land use planning for their conservation and sustainable use.
3. Support the creation and management of protected areas in mangrove ecosystems, and collaborate with local communities to establish new areas under protection.
4. Foster scientific research on mangrove ecosystems to improve decision making related to mangrove land use and management.
5. Foster interaction with local communities and citizens, for a better general understanding of the importance of preserving mangrove ecosystems and their sustainable use, and for better mangrove land use planning that integrates the knowledge and needs of the local communities.
6. Restoration and afforestation of degraded and deforested mangrove areas, identified by local communities, government entities, research agencies, and other stakeholders.
7. Development of pilot projects that encourage mangrove conservation while benefiting local communities.
8. Update and implementation of regulation and legislation on mangrove use along with adoption of mechanisms for dissemination.
9. Establishment of an information system that efficiently conveys the information regarding mangroves in a region, to disseminate knowledge and facilitate mangrove conservation and sustainable use.
10. Strengthening of institutions (e.g. Corporaciones Autonómicas Regionales) with competencies on mangrove areas, to ensure their capabilities to meet the requirements of a successful mangrove management.
11. Monitorization of nationwide actions on mangrove conservation and sustainable use.
12. Promotion of international collaboration and technical and financial support among Latin American countries, oriented to the conservation and sustainable use of mangroves.

To the date, there is no specific information available on Colombia's mangrove restoration area goal, or on the expected achievement of emissions removal though mangrove restoration.

[65] *Uso sostenible, manejo y conservación de los Ecosistemas de manglar en Colombia. 2002. MINAMBIENTE. Santa Fe de Bogotá D.C., Colombia.*