Community-Based Mangrove Management in Sucre, Colombia: Stakeholder Perceptions, Land Cover Trends, and Challenges

Ángela M. Barrera-Bello[*,1,2,3], Alexandra Rodríguez-Rodríguez[4], Ana Maria Valencia Palacios[5], Jaime Polanía[6,7], Jose M. Riascos[8], Juan Felipe Blanco-Libreros[5,7], Jean Hugé[1,9,10,11,12], and Farid Dahdouh-Guebas[1,2,7,13]

[1] Systems Ecology and Resource Management Research Unit (SERM), Department of Organism Biology, Université Libre de Bruxelles - ULB, Brussels, Belgium
[2] bDIV: Ecology, Evolution & Genetics, Vrije Universiteit Brussel - VUB, Brussels, Belgium
[3] Department of Forest & Conservation Sciences, Faculty of Forestry, University of British Columbia, Vancouver, Canada
[4] Centre for Nature Positive Solutions, RMIT University, Melbourne, Australia
[5] Institute of Biology, Faculty of Exact and Natural Sciences, Universidad de Antioquia, Medellin, Colombia
[6] Departamento de Ciencias Forestales, Universidad Nacional de Colombia, Medellín, Colombia
[7] Mangrove Specialist Group (MSG), Species Survival Commission (SSC), International Union for the Conservation of Nature (IUCN) c/o Zoological Society of London (ZSL), Regent's Park, NW1 4RY London, UK
[8] Marine Science Institute, Faculty of Exact and Natural Sciences, Universidad de Antioquia, Turbo, Colombia
[9] Department of Environmental Sciences, Open University of the Netherlands, Heerlen, Netherlands
[10] Research Group Zoology, Biodiversity & Toxicology, Centre for Environmental Sciences, Hasselt University, Hasselt, Belgium
[11] Biology Department, Vrije Universiteit Brussel - VUB, Brussels, Belgium
[12] Marine Biology Research Group, Biology Department, Ghent University, Ghent, Belgium
[13] Interfaculty Institute of Social-Ecological Transitions, Université Libre de Bruxelles - ULB, Brussels, Belgium
*Corresponding author; e-mail: angelabarrerabello@gmail.com

Abstract: Mangrove forests support ecosystems, livelihoods, and cultural practices. However, their degradation threatens the utilization of mangroves by human communities, causing economic losses, particularly impacting local livelihoods. Cost-effective, community-led restoration and

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conservation efforts are essential to enhancing the ecological and economic resilience of coastal communities. This study investigated Community-Based Mangrove Management (CBMM) in Sucre, Colombia, where mangroves provide essential goods and services to human communities. We employed a discourse analysis technique (*Q*) and Geographic Information System integration, including analysis of remotely sensed data to identify mangrove cover trends (1986–1993 and 2017–2021). *Q* methodology identified two main discourses: "Optimism in CBMM" and "A call to enhance CBMM," highlighting issues such as lack of administrative skills, economic resources, land tenure, and socio-environmental conflicts. Interviews identified tourism expansion as a major driver of mangrove loss, threatening the ecosystem's ability to provide resources to local communities. The temporal analysis supported these trends, especially in Rincón del Mar, where tourism has increased. This study emphasizes the economic and ecological challenges faced by CBMM members, highlighting the need to integrate Local Ecological Knowledge and community perspectives to guide mangrove conservation policy that emphasizes the benefits of mangrove forests and their non-timber forest products.

Resumen: Los manglares sostienen ecosistemas, medios de vida y prácticas culturales. Sin embargo, su degradación amenaza el uso de los manglares por parte de las comunidades humanas, provocando pérdidas económicas que impactan especialmente los medios de vida locales. Los esfuerzos de restauración y conservación, liderados por las comunidades y de bajo costo, son esenciales para mejorar tanto la resiliencia ecológica como económica de las comunidades costeras. Este estudio investigó la Gestión Comunitaria de Manglares (CBMM, por sus siglas en inglés) en Sucre, Colombia, donde los manglares proporcionan bienes y servicios esenciales a las comunidades humanas. Empleamos la técnica de análisis del discurso (*Q*) e integración de Sistemas de Información Geográfica, incluyendo el análisis de datos de teledetección para identificar tendencias de la cobertura de manglares (1986–1993 y 2017–2021). La metodología *Q* identificó dos discursos principales: 'Optimismo en la CBMM' y 'Un llamado a fortalecer la CBMM,' destacando problemáticas como la falta de habilidades administrativas, recursos económicos, tenencia de la tierra y conflictos socioambientales. Las entrevistas señalaron la expansión del turismo como un factor importante de pérdida de manglares, amenazando la capacidad del ecosistema para proveer recursos a las comunidades locales. El análisis temporal respaldó estas tendencias, especialmente en Rincón del Mar, donde el turismo ha aumentado. Este estudio enfatiza los desafíos económicos y ecológicos que enfrentan los miembros de la CBMM, subrayando la necesidad de integrar el conocimiento ecológico local y las perspectivas comunitarias para guiar una política de conservación de manglares que destaque los beneficios de los manglares y sus productos forestales no maderables.

Keywords: Mangrove forests, Coastal communities, Community-based management, Traditional knowledge, Discourse analysis, Remote sensing

Introduction

Mangroves are coastal ecosystems found in tropical, subtropical, and warm temperate regions (Dahdouh-Guebas et al. 2020). These forests offer socio-cultural services as well as vital ecosystem services like food, construction materials, fuelwood, biodiversity habitat, nutrient cycling, carbon sequestration, fisheries, and flood protection (Dahdouh-Guebas et al. 2021; Friess et al. 2020a; Zu Ermgassen et al. 2021). Despite their recognized value, the effectiveness of conservation efforts varies. In highly biodiverse countries, mangrove loss often exceeds

global averages (0.3–0.6%; Friess et al. 2019, 2020b), with 50% of the world's mangroves at risk of collapse (IUCN 2024). Prioritizing areas to protect mangroves is therefore a priority per se, and research has demonstrated that this is possible while maximizing ecosystem services (Dabalà et al. 2023).

Despite their recognized values and repeated reports of alarming trends (Duke et al. 2007; Friess et al. 2020a; Goldberg et al. 2020), mangrove conservation continues to face significant challenges, particularly in biodiverse regions where deforestation rates are often above global averages (Friess et al. 2019, 2020b). Colombia, with 283,419 ha of mangroves in 2020, has a 0.38% annual loss rate (Murillo-Sandoval et al. 2022). Building on global conservation concerns, Colombia has implemented various restoration strategies since the 1980s, evolving from traditional (top-down) reforestation methods to more community-driven approaches such as community-based ecological mangrove restoration (Brown et al. 2014; Gann et al. 2019; MAP 2020; Rodríguez-Rodríguez et al. 2021). Since the 1990s, Colombia has also developed a national framework for mangrove conservation and restoration (Table ESM 1). However, these policies often lack community follow-up to ensure site-specific feasibility and address stakeholders' needs (Álvarez-León 2003; Rodríguez-Rodríguez 2022). The success of restoration efforts in Colombia varies, with community-based ecological mangrove restoration being notably effective (Rodríguez-Rodríguez et al. 2021). While restoration efforts have made progress, their success remains inconsistent. Some projects have yielded positive results, yet many face challenges related to site selection, methodology, and long-term monitoring (Elster 2000; Rodríguez-Rodríguez et al. 2021). Additionally, many efforts are undocumented and lack proper monitoring (Rodríguez-Rodríguez et al. 2021), with the human dimension of mangrove management, including stakeholder perceptions, community engagement, and socio-economic factors, being the least studied aspect (Castellanos-Galindo et al. 2021).

Despite the challenges, certain initiatives demonstrate the potential for successful community-driven conservation. One notable example is the "Vida Manglar" committee on the Colombian Caribbean coast, which stands as a model grounded in the long history of community involvement in mangrove management in Cispatá Bay (Vida Manglar 2023). Nearby, in Sucre, smaller-scale community-based mangrove restoration initiatives have been underway since the 2000s, although these efforts require more comprehensive documentation (Rodríguez-Rodríguez 2022; Vega-Cabrera et al. 2021). Integrating and documenting these and other community-based mangrove conservation and restoration initiatives in Sucre could improve management, address the needs of their members, and enhance our understanding of Community-Based Mangrove Management (CBMM) in the region.

Colombia's efforts align with broader global trends, where long-term community engagement has been a critical factor in the success of mangrove conservation projects (Rodríguez-Rodríguez et al. 2021; Kairu et al. 2021; Kongkeaw et al. 2019; Wickramasinghe 2017). Key success factors previously reported in other studies are sustained funding, local economic benefits, alignment with local resource use, incorporation of local knowledge, legislative support, and public endorsement (Damastuti et al. 2022). Success is also linked to using diverse species and large-scale efforts (López-Portillo et al. 2017). In contrast, continued mangrove loss occurs in projects lacking a scientific basis for planting strategies (Kodikara et al. 2017).

To better understand the effectiveness of CBMM, including both restoration and conservation efforts within the mangrove social-ecological system (Ostrom and Nagendra 2006), requires an interdisciplinary approach that integrates community perspectives with environmental monitoring techniques. Various methods are available for analyzing the social dimensions of mangrove ecosystems (Hugé et al. 2016, 2023; Kongkeaw et al. 2019; Ostrom, 2009). For example, discourse techniques like *Q* methodology offer insights into stakeholders' views on forest status and trends, aiding policy development (Hugé et al. 2013; Nyangoko et al. 2022). Understanding public and stakeholder perceptions, along with incorporating Local Ecological

Knowledge and community involvement, are crucial indicators of successful mangrove management (Dahdouh-Guebas et al. 2020; Walters et al. 2008). Consequently, this approach has been notably applied in mangrove management research (Arumugam et al. 2021; Dupont et al. 2025; Lhosupasirirat et al. 2023; Nijamdeen et al. 2024; Torres-Guevara et al. 2016).

Complementarily, biophysical assessments of CBMM focus on the mangrove ecosystem status. This involves monitoring various aspects of mangroves, such as survival rates (Kodikara et al. 2017), faunal recruitment (Bosire et al. 2004), forest structure (Bosire et al. 2008), and remote sensing (Otero et al. 2018). Remote sensing enhances ground-based inventories by covering large or inaccessible areas, enabling retrospective assessments (Dahdouh-Guebas et al. 2004; Otero et al. 2018), and being a cost-effective alternative to field techniques (Baloloy et al. 2020). Techniques like the normalized difference vegetation index and mangrove vegetation indexes correct mapping inaccuracies by detecting spectral responses in multispectral data between mangroves and non-mangrove vegetation cover, proving to be useful in recent mapping efforts (Aljahdali et al. 2021; Baloloy et al. 2020). In Colombia, a country-wide 36-year analysis to track mangrove cover change was conducted by integrating the Landsat satellite archive, mangrove vegetation indexes, and the LandTrendr algorithm (Murillo-Sandoval et al. 2022). Similarly, a multi-temporal analysis (2017–2021) for Sucre using Sentinel- 2-derived mangrove vegetation index shape models and ground truth data was recently obtained (Ruiz-Roldán et al. 2023).

Given the identified research gaps in the effectiveness of CBMM in Colombia—particularly in the lack of human dimension consideration—this study seeks to explore CBMM's dynamics further in Sucre, Colombia. The human dimension is critical because it encompasses the perceptions, behaviors, and socio-economic conditions of local stakeholders, which are essential for the long-term success of CBMM. Therefore, this study investigates CBMM dynamics in Sucre, focusing on stakeholder perceptions, land cover trends, and challenges. We integrated discourse analysis and remote sensing data to address two key questions: (1) What are the main discourses among stakeholders on CBMM? and (2) What are the perceived and observable trends in mangrove cover and its drivers?

Methods

Study Area

The study was conducted in Sucre, on the Colombian Caribbean coast (Fig. ESM 1). Sucre's coast, characterized by a dry forest biome, has an annual precipitation of less than 1000 mm/year and temperatures between 27 and 33 °C (Gómez-Cubillos et al. 2015). Sucre has 8924 ha of mangroves (Ruiz-Roldán et al. 2023), which include species from the family Rhizophoraceae, such as *Rhizophora mangle* L., and the family Acanthaceae, represented by *Avicennia germinans* (L.) Stearn. Other common species include *Laguncularia racemosa* (L.) C.F.Gaertn. (family Combretaceae), *Pelliciera* spp. Triana & Planch. (family Tetrameristaceae), and *Conocarpus erectus* L. (family Combretaceae; Rodríguez-Rodríguez, 2022). In this region, *Rhizophora mangle* tends to dominate the outer strips, *Avicennia germinans* the inner basins, and *Conocarpus erectus* the transition zones landwards (Ruiz-Roldán et al. 2023). Along the Gulf of Morrosquillo, mangroves are found in specific narrow physiographic zones, like sandbars and coastal edges (Gómez-Cubillos et al. 2015).

Currently, Sucre has 15 protected areas, including four mangrove-protected areas that cover nearly 8000 hectares. These areas fall under various protection schemes, such as Regional Natural Parks, Regional Integrated Management Districts, Fauna and Flora Sanctuaries, and Civil Society Natural Reserves (RUNAP 2023). Four Sucre locations were selected for *Q* methodology interviews (Fig. ESM 1). The first two, Berrugas and Rincón del Mar (San Onofre municipality), were chosen for their proximity to CBMM projects, listed in detail in Vega-Cabrera et al. (2021). The main restoration areas of these two sites are 5 ha in Berrugas and 6 ha in Rincón del Mar (Rodríguez-Rodríguez 2022). While there are additional restoration sites in these locations, this study focuses on these two. The other two locations, Tolú and Coveñas, are near protected areas (Parque Natural Regional Boca

de Guacamaya and Distrito Regional de Manejo Integrado La Caimanera), with CBMM projects ongoing since the early 2000s. Communities in all locations rely on mangroves for fishing, tourism, and materials like wood and honey. Historically, the drivers of mangrove cover change reported for Sucre include water deficits, hydrological alterations, infrastructure expansion, sedimentation, logging, shrimp farms, agriculture, and tourism (Gómez-Cubillos et al. 2015; Sánchez-Paez et al. 2002).

Main Stakeholder Perceptions on CBMM

To investigate the perceptions of key stakeholders involved in CBMM in Sucre, this study employed *Q* methodology. This technique identifies and analyzes discourses considering the values, interests, goals, and ideas of the participants. *Q* is a method in which respondents are asked to rank statements according to their degree of (dis)agreement. The methodology followed the guidelines outlined by Zabala et al. (2018) and Watts and Stenner (2014).

Research Design

First, the *Q* set—defined as the initial set of statements provided to participants for ranking—was created from a comprehensive list of statements (concourse) that reflected diverse viewpoints on CBMM in Sucre (Hugé et al. 2016). The concourse was developed based on research literature and prior interactions with mangrove experts and officials (e.g., emails, meetings, video calls). The *Q* set was formed by 36 statements (Table ESM 2) and translated into Spanish. Participants were identified using a snowball sampling technique, where existing participants helped recruit others. Snowball sampling is commonly used in *Q* methodology (Hugé et al. 2016; Zabala et al. 2018) as it prioritizes participants with relevant viewpoints over random selection (Watts and Stenner 2014). To mitigate recruitment bias from a single network or personal researcher contacts, known limitations of snowball sampling (Parker et al. 2019), participants were identified across different settings and activities. To ensure broad representation of CBMM stakeholders, we considered socioeconomic and sectoral diversity (Table ESM 3). When profiles became redundant, we intentionally selected diverse participants within the snowball sampling process and included others from outside the referral chain to enhance diversity.

Experts were defined as stakeholders directly or indirectly involved in mangrove management for more than 1 year (e.g., local community representatives, non-governmental organization representatives, scientists, officials; Ramsar Convention Secretariat 2010), using the expanded concept of "expert" sensu Burgman et al. (2011).

Data Collection

Interviews for conducting the *Q* methodology took place from July 2023 to August 2023. All interviews were conducted in person and lasted about an hour. The participants ranked statements within the *Q* set (Q sorting) using a scale from -3 to $+3$ to indicate their level of (dis) agreement, importance, or acceptability relative to other statements. The participants completed their rankings using a board that displayed a "near-normal forced" distribution, forming the so-called *Q* grid (Fig. ESM 2). This distribution is termed "near-normal" because most responses fell near the middle of the scale (0), with fewer at the extremes (-3 and $+3$). This helped participants focus their rankings, making it easier to analyze and interpret the results (Watts and Stenner 2014). The ranked statements provided by each participant are referred to as a *Q* sort. Statements in the same rank were considered to have the same score. Explanations of the statements were consistent for all participants, and participants were always asked to confirm whether the statements were clear to them, aiming to minimize researcher bias during *Q* sorting (Zabala et al. 2018). In some cases where limited literacy was present, statements were fully explained verbally. It was decided to include experts with limited literacy due to their extensive experience in CBMM. Additionally, qualitative data, including life experiences, behavior, and willingness to be interviewed, was collected, while participants ranked statements and during post-sorting interviews. This encompassed details such as education level, years of residence in the territory, involvement in community restoration projects, experiences with mangroves, and motivation

for participating in community-based mangrove restoration. In these post-sorting interviews, participants were also asked about their overall perception of mangrove trends (increase or decrease) and the main drivers influencing mangrove cover change. Qualitative information was also gathered during guided walks and canoe trips to community-based mangrove conservation and restoration areas, facilitated by some participants (Figs. ESM 3–6).

Of the 37 interviews conducted, nine were excluded to ensure data integrity, leaving 28 for analysis. Exclusions were based on two criteria: (1) the participant's perceived lack of engagement with the interview (evidenced by expressions of disinterest such as lack of eye contact with the board, repeated comments unrelated to the subject of the interview, repeated lack of understanding of the statements despite continuous explanations given, continuous interruptions generated by agents external to the interview) and (2) the participant's unfamiliarity with the functioning of local CBMM organizations, despite being a member of environmental and/or educational projects in the territory. The remaining *Q* participants' number met the methodological aim of *Q* by prioritizing diversity of perspectives over sample size, ensuring fewer *Q* participants than *Q* statements, with a minimum ratio of nearly 3:1 (Watts and Stenner 2014), a condition our study fulfills with 28 *Q* participants and 36 *Q* statements.

While *Q* methodology is a powerful tool for analyzing subjective viewpoints, it should not be confused with claims of objectivity in a traditional statistical sense (Sneegas 2020). Rather, it is designed to identify patterns in perspectives rather than generalize findings to a larger population.

Data Analysis

The analysis was conducted using the PQMethod software (Schmolck 2014). This software compared and clustered the participants' *Q* sorts into factors within a correlation matrix, with each factor representing a shared perspective among a subset of participants. The matrix calculated Pearson correlation coefficients to group participants based on the similarities in their rankings (i.e., similar *Q* sorts were those ranked in a similar way). The plots and figures illustrating these perspectives were generated using R© (R Core Team 2024).

A conventional multivariate data reduction analysis was applied to the correlation matrix, consisting of two major steps. First, a factor-reduction technique known as centroid factor analysis (*QCENT option in PQMethod*) was applied to condense a broad spectrum of perspectives into the succinct set of factors. Centroid factor analysis was chosen due to its flexibility in examining data (Hugé et al. 2016; Akhtar-Danesh 2016). The centroid factor analysis extracted five factors, based on the number of *Q* sorts suggested by Watts and Stenner (2014), with one factor for every 6–8 *Q* sorts (i.e., 28 *Q* sorts, five factors). Second, factor-rotation techniques, including Varimax and manual rotations (by-hand rotations), were employed to identify the primary or predominant viewpoints within the participant group (Watts and Stenner 2014).

1. Varimax Rotation: The five factors were rotated using Varimax rotation (*QUARIMAX option in PQMethod*), a statistical technique that achieves simplification and a better interpretation of the resulting factor structure by maximizing the correlation coefficients between a *Q* sort and a given factor (Akhtar-Danesh 2016; Zabala et al. 2018). The Varimax rotation removed two factors (factors 3 and 5; Table ESM 4) due to the loss of all their unique significant factor loadings and a marked decrease in their explanatory power (i.e., percentage of variance explained by the factor). Significant factor loadings, defined as *Q* sorts defining factors, were identified by employing a threshold of $p < 0.01$ at the significance level. This threshold was derived using the equation (Eq. 1) outlined in Watts and Stenner (2014):

$$2.58 \times (1 \div \sqrt{\text{Number of items in the Q set}}) = 2.58 \times (1 \div \sqrt{36}) = 0.43 \quad (1)$$

Equation 1. Threshold for identifying significant factor loadings. The number of items in the *Q* set refers to the number of statements in the *Q* set.

2. Manual Rotations: Manual rotations in *Q* methodology (*QROTATE option in PQMethod*) involve adjusting factor positions to refine interpretation while maintaining the relative positions of *Q* sorts determined by initial correlations (i.e., unrotated factor loadings; Watts and Stenner 2014). We visually assessed factors and performed manual rotations. The clustering of *Q* sorts between factors 1 and 3 prompted a 20° rotation, leading to a potential two-factor solution after the significant loadings of factor 3 were lost. A subsequent 35° rotation between the remaining factors retained only factor 1 due to loadings loss, producing a single-factor solution.

Both solutions met the criteria outlined by Watts and Stenner (2014) for a sound solution, including explained variation (35–40%), eigenvalues (EVs) above 1 (Kaser–Guttman), two or more significant factor loadings per factor, Humphrey's rule, the Scree test, and parallel analysis (Fig. ESM 7). EVs, calculated from the sum of squares of factor loadings per *Q* sort, alongside variance, indicate factor strength and explanatory potential (Watts and Stenner 2014).

Finally, the two-factor solution was chosen as it achieved a robust coverage and representation of the dataset that captured the perspectives of the majority of stakeholders while representing diverse stakeholder perspectives within the two factors.

Interpretation

The factors obtained were interpreted as discourses—a collection of viewpoints that reflect both shared and individual perspectives within a group of participants (Lhosupasirirat et al. 2023). To express the correlation between the statements and each discourse, we used standardized factor loadings, known as *Z* score coefficients (Zabala et al. 2018). Higher *Z* score values indicated stronger agreement, while lower values indicated disagreement (Ibid.). The ranked order of *Z* scores helped identify consensus statements, which highlight common perspectives among all participants. Differences in *Z* scores were used to pinpoint contrasting perspectives between factors. Both discourses were labeled to facilitate interpretation. This ranked order of *Z* scores also produced factor arrays, which are representative *Q* sorts for each factor (discourse) identified. These factor arrays maintain the original data distribution and are constructed relative to the size of the *Q* grid, providing a practical way to present stakeholders' perspectives as initially recorded (Watts and Stenner 2014).

In addition to the factor arrays, the two-factor solution was interpreted by analyzing post-sorting interviews, with a focus on single significant *Q* sorts at the $p < 0.01$ level for each factor (i.e., participants defining the factor). These post-sorting interviews provided contextual depth, allowing participants to elaborate on their rankings and clarify their perspectives, further ensuring that factor arrays accurately reflected participant viewpoints rather than imposing predefined categories. For a more comprehensive interpretation, we also included interviews with participants who were not part of the *Q* but had extensive experience in the area and knowledge of the historical changes in mangroves within the region. A summary of the steps of *Q* methodology is shown in Fig. 1.

The research team acknowledges that ethical engagement is a continuous process throughout the research. Beyond obtaining ethics committee approval and informed consent, our ethical commitments included maintaining open communication and ensuring transparency about the objectives and outcomes of the study. As a concrete example of reciprocity and respect for participants' contributions, the research team agreed to produce and share a short video and a translated version of the findings with the participants.

Mangrove Cover Trend Analysis

The trend analysis involved the creation of two multitemporal mosaics of mangrove area to estimate area loss, gain, and net change, using the QGIS version 3.3 (QGIS Development Team 2018).

Data Source

We used mangrove vegetation index Landsat-derived shape layers. This satellite imagery was obtained from the Landsat missions' archive to produce annual mangrove vector layers for the period 1985–2021 (MSS/TM, ETM +, and

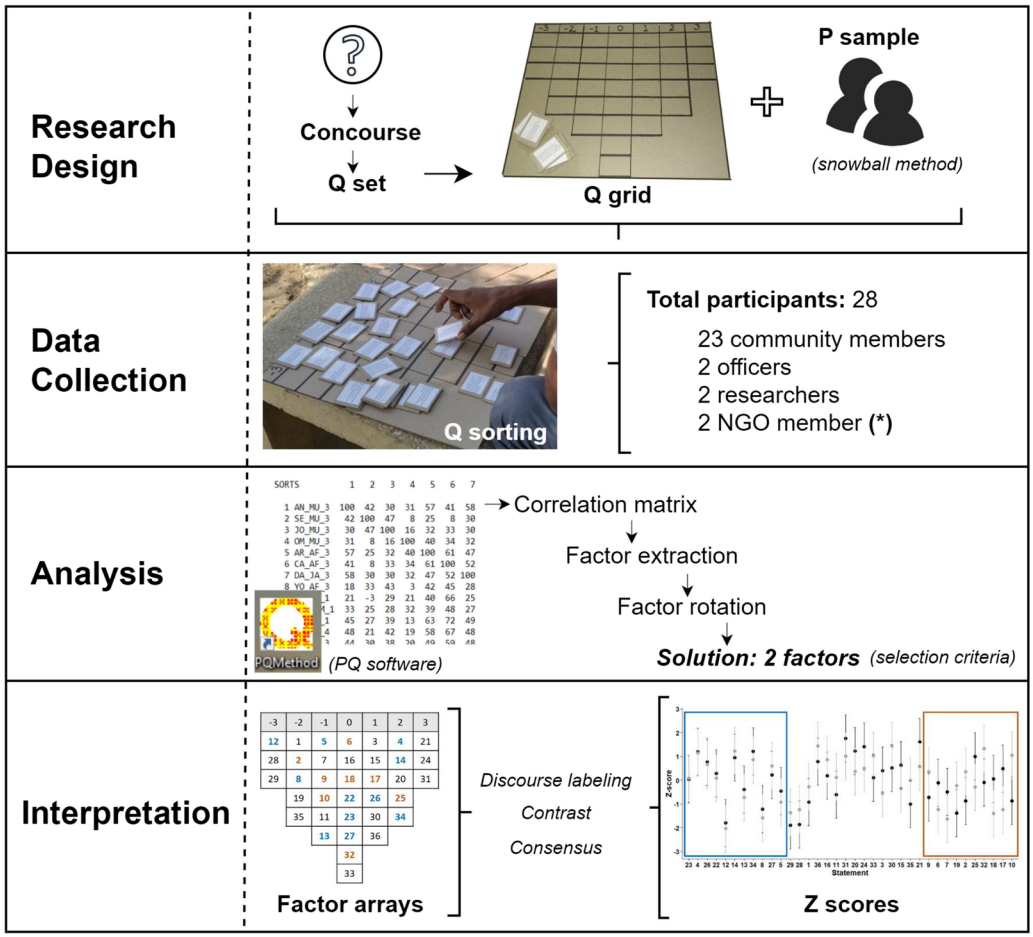

Fig. 1. *Q* methodology flowchart outlining the research stages. The research design includes formulating a research question, constructing a concourse of statements that are subsequently filtered to produce the *Q* set, designing the *Q* grid to establish ranking values, and selecting participants (P sample). The data collection involves interviews where participants rank the *Q* set statements (*Q* sorting), and additional qualitative data is gathered. The analysis is conducted using the PQ software (Schmolck 2014), generating a correlation matrix and calculating factor loadings to identify significant *Q* sorts for each factor. Factor extraction and rotation techniques are applied, leading to an output of selected factors that meet the selection criteria (see Fig. ESM 7). These factors would then become the discourses. Interpretation: Discourses are labeled to facilitate their interpretation and visualized through either factor arrays or a *Z* scores plot to identify distinctive, contrasting (orange), and consensus (blue) statements across different discourses. The methodology followed the guidelines outlined by Zabala et al. (2018) and Watts and Stenner (2014). (*) One non-governmental organization (NGO) member participated as NGO and a researcher

OLI/TIRS sensors; Blanco-Libreros and Valencia-Palacios, unpublished data) using Google Earth Engine (Shapiro, 2024; Yancho et al. 2020). One cloud-free image was selected from each year, and the mangrove vegetation index (Baloloy et al. 2020) was computed using GEE. Landsat images were chosen for their long-term availability and consistent data quality, acknowledging that high cloud cover in tropical regions greatly reduces the number of usable images (Murillo-Sandoval et al. 2022). For this reason, the analysis was conducted on a partial region of Sucre, focusing on the areas of interest (AOIs) including Rincón del Mar, Sanguaré (Reserva

Natural de la Sociedad Civil Sanguaré), and Berrugas rather than all interview sites. The total mangrove area analyzed, covering both historic and more recent extents, was 1044 ha. While this area includes community-based mangrove restoration project sites, they were not differentiated within the analysis considering the scope of this thesis.

Multitemporal Mosaics

A 35-year comparison was performed between historic shapefiles from 1986 to 1993 and the more recent shapefiles (2017–2021). Each of these intervals was merged (using the "merge vector layers" function) to create a single mosaic. The decision to pool the layers into two periods (1986–1993 and 2017–2021) was made to minimize yearly biases in mangrove area estimates caused by seasonal and tidal variations. This approach focuses on identifying long-term (inter-decadal) trends rather than detailed year-to-year changes, a common practice in regions with limited pre-1990 cartographic data (Baltezar et al. 2023). Areas below 15 m of elevation were considered using the digital elevation model derived from the Shuttle Radar Topography Mission, as the highest altitude found in the area on Google Earth Pro was 15 m, consistent with similar studies (Ibid.). We employed the "Raster Calculator" to filter these areas and then used the "Clip Raster by Mask Layer" function to clip the digital elevation model with the mosaics. To address geometry errors during clipping, we first used the "Fix Geometries" tool to correct self-intersecting polygons, duplicate nodes, and overlapping rings on the mosaics, ensuring smooth processing (QGIS Development Team 2018). Additionally, the current layer (2017–2021) was visually inspected to ensure areas known to not have mangrove were accurately represented. In cases where discrepancies were found, corrections were made to the layer.

Mangrove Area Estimation

For estimating mangrove area loss, gain, and net change, a difference layer was generated between the two mosaics using the "Difference" function. This allowed the identification of areas of loss and gain. Areas present in the current layer but not in the difference layer were classified as areas of mangrove gain. Conversely, areas present in the difference layer but not in the current layer were classified as areas of mangrove loss. Subsequently, using the "Intersection" tool, the AOIs, as well as the partial region of Sucre containing them, were analyzed separately. Finally, using the "Field Calculator" function, the areas were quantified. This allowed for the calculation of mangrove loss, gain, and net change areas to identify trends in mangrove cover.

Accuracy Assessment

A confusion matrix was designed for the accuracy assessment. This matrix was generated by visually inspecting 200 random points over the predicted mangrove area (mosaic 2017–2021) and comparing them with reference mangrove areas (Google Earth Pro 2021; Ruiz-Roldán et al. 2023). This comparison produced values for true positives (TP), false positives (FP), false negatives (FN), and true negatives (TN). Based on these confusion matrix values, the following accuracy metrics were calculated: overall accuracy, producer's accuracy (recall or sensitivity), user's accuracy (precision), and F1 score. Standard equations and definitions can be found in Table ESM 5 and are based on Lunetta and Lyon (2004) and Nicolau et al. (2023). A summary outline of the steps of this methodology is shown in Figure ESM 8.

Results

Main Stakeholder Perceptions on CBMM

The majority of participants (23 out of 28) were community leaders involved in CBMM, either directly or indirectly. They were engaged in various informal jobs related to fishing, ecotourism (both mangrove and non-mangrove-related), boat driving, and handicraft making, among others. The remaining participants included officers, non-governmental organization members, and researchers. Participants came from the four interview sites, but the numbers varied by site. Three of the 28 participants were women. Although this gender disparity was not anticipated nor intended, as it might appear to introduce a bias into the discourse analysis, it is ultimately an outcome of

the analysis as it reflects the existing structure of CBMM in the region and represents the main stakeholders' perceptions of CBMM in Sucre, Colombia.

The two-factor solution explained 46% of the total variance, surpassing the minimum acceptable threshold of 35–40%, as detailed in Figure ESM 7. Out of the 28 participants who completed the *Q* sorts, 21 (75%) exhibited significant loading on one of the two factors (*Q* sorts defining factor), with 16 loading onto Factors 1 and 5 onto Factor 2 (Table 1). However, due to the inter-factor correlation of 57% and the smaller number of *Q* sorts defining Factor 2, Factor 2 was treated as an alternative version of the broader discourse represented by Factor 1.

Discourse 1: "Optimism in CBMM"

Adherents of discourse 1, including community leaders and a non-governmental organization member (Table ESM 3), maintain a positive view of the management trajectory of CBMM despite facing challenges in decision-making dynamics (S1, with S referring to "Statement" from the *Q*-methodology survey; see Table ESM 2 for the full list of statements). For example, participant 14 mentioned ease in managing despite conflicts in decision-making (Q1, with *Q* referring to "Quote"; see Table ESM 6 for the full list of quotes). Their motivation to continue with CBMM stems from mangrove ecosystem services (S20, S21, S24) and the income generated by its activities, as expressed by participant 26 (Q2). From Q2 and other post-sorting interviews, we identified community practices and cultural relationships around mangroves, including fishing traditions, which foster a sense of purpose, belonging, and spiritual connections. Additionally, interviews with elders highlighted how mangroves once served as spaces for childhood recreation, a role that both younger and older CBMM stakeholders perceive as diminishing. Overall, these cultural dimensions contribute to the strong local identity associated with CBMM and may help sustain community engagement. However, despite these deep-rooted connections, challenges remain in the formalization of local associations and access to essential information for CBMM.

Table 1. Two-factor solution derived from 28 participants (Q sorts)

Q sort	Sector	Factor 1	Factor 2
1	CML	**0.5653 *X**	0.2396
2	CML	**0.5188 *X**	− 0.101
3	CML	**0.4775 *X**	0.1352
4	CML	0.2689	0.0431
5	CML	**0.6910 *X**	0.3562
6	CML	0.506 *	0.5958 *
7	CML	**0.5309 *X**	0.2408
8	CML	**0.6922 *X**	0.0585
9	CML	0.286	**0.4982 *X**
10	CML	0.2877	**0.4802 *X**
11	CML	0.4214	**0.7614 *X**
12	O	0.4502 *	0.481 *
13	CL	0.4999 *	0.5179 *
14	CML	**0.5951 *X**	0.3059
15	CML	**0.4561 *X**	0.2785
16	CML	0.565 *	0.6551 *
17	CML	0.4866 *	0.6026 *
18	CML	**0.5655 *X**	0.349
19	O	0.0082	**0.7757 *X**
20	CML	**0.5503 *X**	0.2599
21	CML	**0.6372 *X**	0.3498
22	CML	**0.6691 *X**	0.0493
23	NGO	**0.5939 *X**	0.4161
24	CML	**0.5210 *X**	0.3424
25	CML	**0.6826 *X**	0.3072
26	CML	**0.4398 *X**	0.4113
27	R	0.1006	**0.6935 *X**
28	R, NGO	0.6061 *	0.4363 *
Q sorts defining factor		16	5
EV		7.43	5.29
% expl. Var		27	19
Average rel. coef		0.800	0.800
Composite reliability		0.985	0.952
SE of factor *Z* scores		0.124	0.218

Table 1. (continued)

The sector column depicts participants' relation to Community-Based Mangrove Management (CBMM) in Sucre, Colombia. Asterisks (*) denote significant loadings on one or both factors, indicating a significant correlation (above 0.43; for calculation details, see the "Data Analysis" section in "Methods"). Values in bold marked with an asterisk (*) followed by "X" indicate a Q sort exhibiting a significant loading on only one of the two factors (i.e., Q sort defining the factor). *EV* (eigenvalues) and *% expl. Var.* (% explained variation) quantify the data variance accounted for by each factor. The *Average Rel. Coef.* (average relative coefficient) indicates the mean correlation between statements and the extracted factors. *Composite reliability* assesses the consistency of the factors identified from participants' Q sorts. The *SE (Standard Error) of Factor Z Scores* quantifies the uncertainty associated with the factor scores derived from participants'Q sorts

Abbreviations: *CML* CBMM leader, *CL* community leader, NGO, non-governmental organization member, *O* Official, *R* researcher

Although the lack of formalization of local associations is not perceived as a difficulty according to the *Q* analysis (S9), most interviewees verbally expressed that the lack of formalization hinders CBMM, as noted by participant 24 (Q3). They also find it challenging to access information on the expansion or decline of mangrove forests in Sucre (S2), but they acknowledge that such information exists (Q4). Overall, they expressed confidence in the project's continuity and see it as a role model for community-based work in the country (S25, Q5).

Discourse 2: "A Call to Enhance CBMM"

Adherents of discourse 2 include community leaders, an officer, and a researcher (Table ESM 3) who perceive CBMM as lacking progress due to poor administrative (S10), planning (S18), and communication skills (S6). For example, participants 19 and 27 highlighted these limitations (Q6–Q7).

They also acknowledge the existence of national policies supporting CBMM (S7) but perceive a gap between policy and practice (Q8). Participants 21 and 22 added their frustrations with the lack of support from governmental entities (Q9–Q10). There is also a need to improve scientific research (S32) and related technologies to help monitor mangroves, as emphasized by participant 25 (Q11). On the other hand, participant 5 emphasized the importance of ancestral knowledge (S33) for CBMM over sometimes scientific concepts (Q12). These participants recognized the need to strengthen partnerships (S30) with public and private entities (Q13) and to collaborate among local CBMM organizations to overcome current conflicts (Q14). Partnerships with Vida Manglar (in Tolú and Coveñas towns), VIVACT non-governmental organization (in Rincón del Mar), and Dos Aguas hotel (in Rincón del Mar) were perceived positively. These entities acted as intermediaries among government institutions, NGOs, and community leaders and provided funding for specific activities. However, some community members remain cautious due to past negative experiences with external partners.

In general, participants in discourse 2 have a less favorable view of the project's management effectiveness, believing these issues contribute to public disinterest in their mangrove restoration projects (S17, Q15). Therefore, they emphasized the importance of community involvement (S36) to advance community-based mangrove restoration (Q16).

Consensus Statements

Shared perspectives between discourses 1 and 2 emphasize the importance of monitoring (S4) after planting (Q17–Q18). Both discourses agreed on the lack of fixed income (S12), as expressed by participant 17 (Q19). The majority supports the idea that CBMM should be economically sustainable (S26), with perceptions ranging from seeing CBMM as a business (Q20) to a voluntary exercise (Q21), and a clear recognition that project members sometimes have different goals or reasons for participating in CBMM (S5, Q22). Both discourses shared concerns about insufficient economic resources for project continuation (S8), with participant 12 emphasizing the need for project formulation to secure resources (Q23). Added to this, both discourses identified a lack of technical training (S13), compensated sometimes by empirical knowledge, with participant 27 noting the self-taught empirical training among community leaders (Q24). They also underlined the importance of organizing events to share lessons learned (S14) and exchange knowledge and experiences (Q25).

Another consensus point was the advocacy for greater involvement of women in projects (S34).

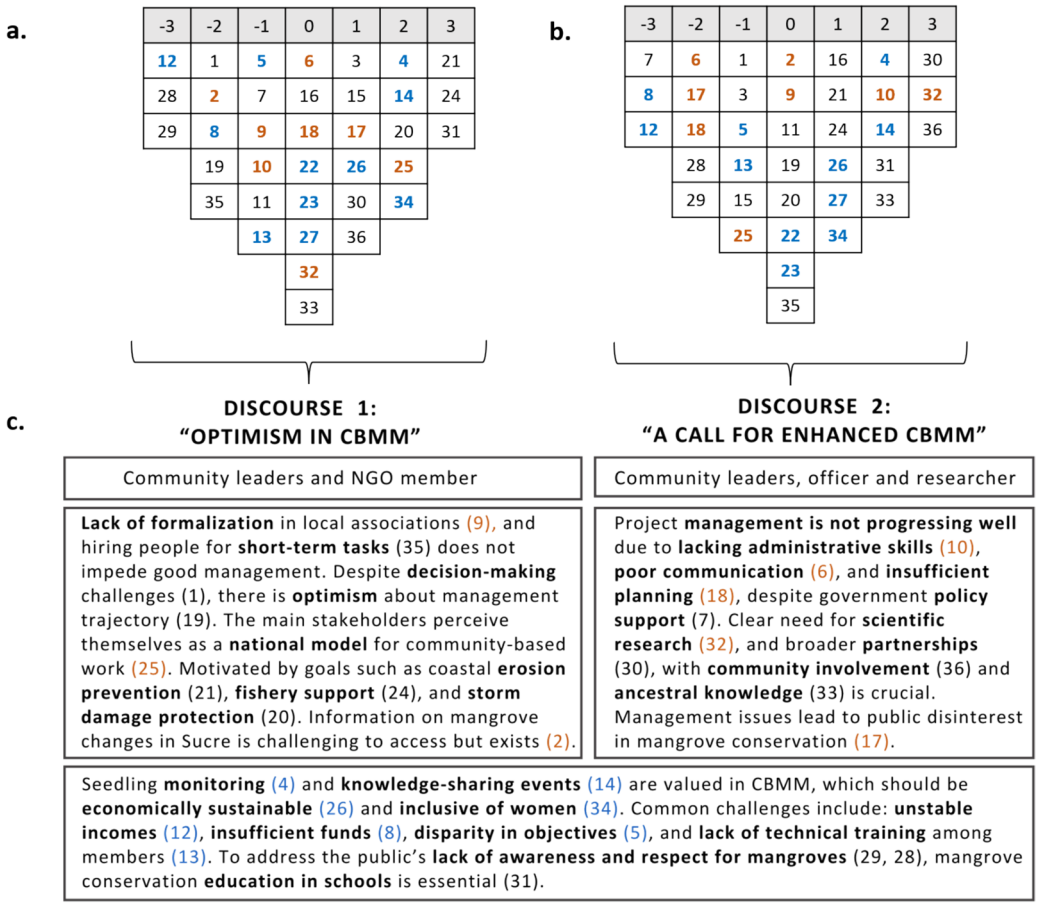

Fig. 2. Discourse construction from factor arrays. Representative *Q* sortings (factor arrays) for factors 1 (**a**) and 2 (**b**) result in the construction of discourses 1 and 2 (**c**). Each number represents a statement (refer to Table ESM 2), with numbers highlighted in blue indicating consensus statements (not statistically significant at $P > 0.05$), while numbers in orange represent contrasting statements, determined by applying a threshold for significant *Z*-score differences ($|Z| > 1.08$) based on relevant statements identified during post-sorting interviews. Numbers in black do not indicate consensus or notable contrasting statements among participants; instead, they represent intermediate key aspects of each discourse

Participants 11 and 10 highlighted how women's involvement improves public perception of mangroves (Q26) and their tenacity during work (Q27), respectively. In general, both discourses strongly coincided with the need to improve mangrove education in schools (S31) to overcome the current lack of public awareness (S28, S29), as described by participants 11 and 16 (Q28–Q29). A summary of the main highlights of both discourses is found in Fig. 2, and an alternative visualization based on *Z*-scores is found in Figure ESM 9.

Additional Remarks

Although not explicitly addressed in the *Q* methodology, several additional aspects emerged repeatedly in the post-sorting interviews. Participants frequently mentioned issues such as mangrove land reclamation, the presence of large foreign landowners, violence, corruption, and the lack of employment opportunities and access to basic services for the surrounding communities. They perceived most of these issues as interconnected.

Mangrove land reclamation, understood as the anthropogenic process of creating new land by converting mangrove areas (Numbere 2020), was described by participants as involving both locals and foreign landowners (Q30–Q31). The risks of violence faced by CBMM leaders, due to their proximity to foreign landowners, were emphasized by participant 5 (Q32). The impact of drug trafficking on CBMM efforts was noted by participant 11 (Q33). Moreover, local government corruption leading to mangrove conversion by the tourism sector was described as a factor causing distrust of the public sector among CBMM leaders (Q34). Participant 25 added that officials often prioritize cutting costs and making money at the community's expense (Q35). Added to this, concerns about the lack of employment and its effects on the community were expressed (Q36).

The lack of access to basic services was a frequently mentioned issue in these towns, specifically, the absence of sanitation services in Berrugas (Q37; Fig. ESM 4) and the lack of a garbage collection system—which led to mangrove swamp contamination (Q38)—and further conversion of mangrove forests in Rincón del Mar (Q39; Fig. ESM 3).

Mangrove Cover Trend Analysis

Perceptions

All respondents unanimously perceived an overall decrease in mangrove cover in Sucre (i.e., a net change in mangrove area). More than half of the participants ($n = 28$) identified urban expansion, selective harvesting, and tourism expansion as the main drivers of mangrove loss in Sucre (Fig. 3). Urban expansion was a recurrent perceived driver in all Areas of Interest (AOIs), while tourism expansion and selective cutting-down were particularly noted in Berrugas, Coveñas, and Rincón del Mar (Fig. ESM 10). In these areas, participants and field observations indicated that mangroves are being cleared for populated centers, hotel infrastructure, and tourist centers. This information was also supported by the net mangrove loss reported in the temporal analysis for Rincón del Mar and Berrugas AOIs. This was observed even in restoration sites where mangrove planting was initiated in the 2000s, like in Berrugas (Fig. ESM 4). Field visits to recent restoration sites, such as Punta Seca in Rincón del Mar AOI, showed vacation houses adjacent to restoration areas, leading to conflicts between these house owners and CBMM members.

Finally, mangrove restoration and hydrological rehabilitation were mentioned as factors increasing mangrove cover. Most participants who viewed these techniques positively for mangrove cover were stakeholders directly involved in CBMM, except for one official. These stakeholders were from the four AOIs where the interviews were conducted.

Additional land tenure conflicts were identified between Sanguaré and Rincón del Mar AOI. Interviews revealed that the residential complex Balsillas in Rincón del Mar AOI has owned a mangrove area since the 1980s. Following a resolution prohibiting land ownership in mangrove areas during the 1900s, Balsillas placed these areas under a private protection scheme. This ownership has been a source of ongoing conflict. Interviewees described ongoing conflicts between Balsillas, the community of Rincón del Mar, Sanguaré, and nearby vacation house owners, with persistent accusations regarding the alleged occupation of mangrove areas by Rincón del Mar residents and vacation house owners, both within and outside Balsillas and Sanguaré mangrove areas.

Temporal Analysis

The temporal analysis of a subset of Sucre's coastal area (Rincón del Mar AOI, Sanguaré, and Berrugas AOI) revealed a mangrove loss trend over the 35-year period of analysis (Fig. 4; Table 2). The historical extent of 913.1 ha was reduced to 837.9 ha. There was a loss of 206.5 ha and a gain of 131.3 ha. The net change was − 8.2%, with Rincón del Mar AOI experiencing the greatest loss (− 18.7%). Conversely, Sanguaré showed a net gain of 4.8%. The overall accuracy of this analysis was acceptable at 80.6% (Table ESM 5).

Discussion

Main Stakeholder Perceptions on CBMM

Continuum and Representation of Perspectives

Rather than viewing "Optimism in CBMM" and "A call to enhance CBMM" as polarized

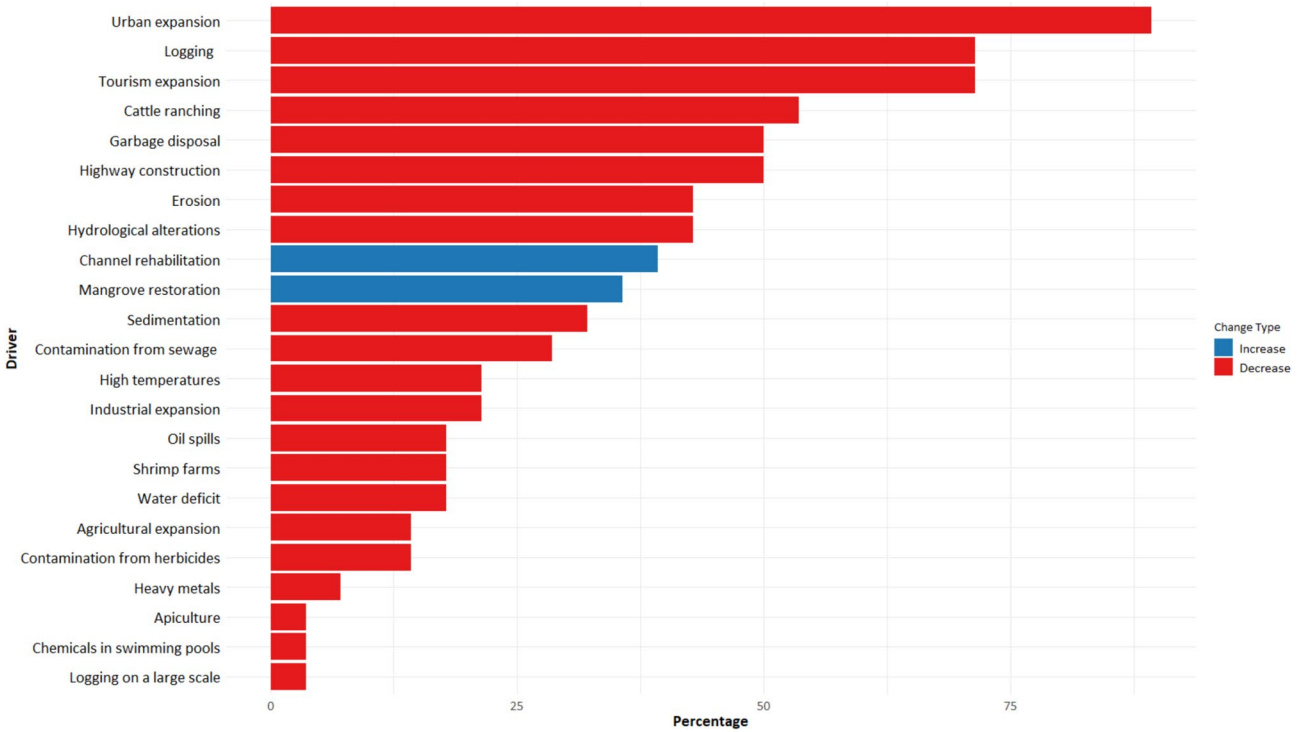

Fig. 3. Perceived drivers of mangrove cover change in Sucre, Colombia. The graph shows the percentage of *Q* methodology participants ($n = 28$) who identified each factor as a driver of mangrove cover change (increase or decrease) during post-sorting interviews. Urban expansion was specifically explained to participants as domestic urban expansion to distinguish it from tourism expansion. Although channel rehabilitation is part of mangrove restoration, it was asked about separately in this questionnaire to distinguish its specific perception from broader mangrove restoration efforts

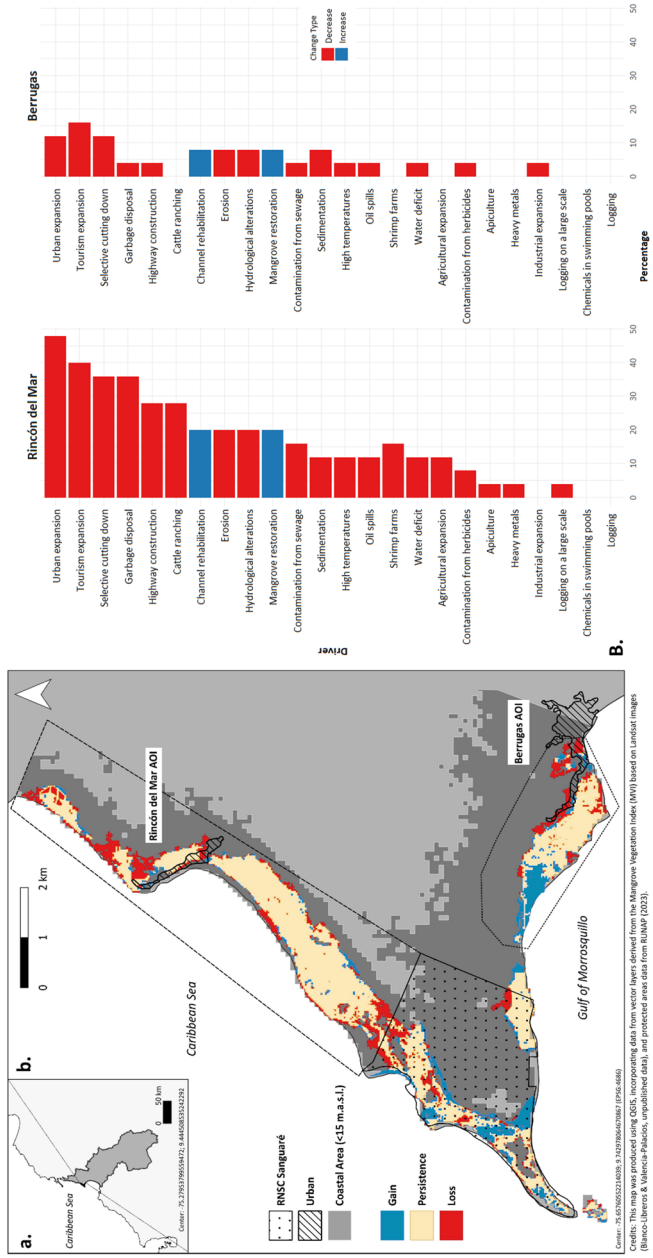

Fig. 4. **A** Map of mangrove cover change in Sucre, Colombia. (a) The Central Caribbean region of Colombia. (b) Classification difference map between the 1986–1993 Sucre mangrove baseline and the 2017–2021 mangrove extent. Blue, beige, and red areas represent where mangroves have been gained, maintained, and lost, respectively. Dashed areas represent urban zones corresponding to Rincón del Mar and Berrugas, which overlap with the areas analyzed (AOIs). The Balsillas mangrove area, part of the residential complex Balsillas, is located within the Rincón del Mar AOI, south of the Rincon del Mar urban area, and extends to the border with Reserva Natural de la Sociedad Civil (RNSC) Sanguaré. **B** Perceived drivers of mangrove cover change in Rincón del Mar and Berrugas. The bar charts display the percentage of participants ($n = 25$) who work exclusively within these AOIs and identified key drivers of mangrove change (increase or decrease) during post-sorting interviews. Urban expansion was specifically explained separately from tourism expansion to distinguish domestic from tourism-related growth. Selective cutting down is also referred in the text as selective harvesting. Sample sizes: Rincón del Mar ($n = 12$) and Berrugas ($n = 4$)

Table 2. Mangrove area changes in a subset of Sucre coastal area from 1986–1993 to 2017–2021

Area	1986–1993 (ha)	2017–2021 (ha)	Mangrove loss (ha)	Mangrove loss (%)	Mangrove gain (ha)	Mangrove gain (%)	Net change in mangrove area (ha)	Net change in mangrove area (%)	Annualized net change in mangrove area (%)
Rincón del Mar AOI	488.0	397.0	108.0	22.1	17.0	3.5	− 91.0	− 18.7	− 0.53
RNSC Sanguaré	224.7	235.5	49.7	22.1	60.5	26.9	+ 10.8	+ 4.8	+ 0.14
Berrugas AOI	176.3	175.3	45.4	25.8	44.4	25.2	− 1.0	− 0.6	− 0.02
Study area*	913.1	837.9	206.5	22.6	131.3	14.4	− 75.2	− 8.2	− 0.24

The annualized net change in mangrove area (%) represents the net change in mangrove area (%) over the 35-year period analyzed (1986–2021), calculated as an annual rate. *The study area row corresponds to the total area quantified in the map on Fig. 4, which includes but is not limited to the sum of Rincón del Mar AOI, Reserva Natural de la Sociedad Civil (RNSC) Sanguaré, and Berrugas AOI

discourses of CBMM, these different views in Sucre can be better understood as a continuum. In this context, a continuum means that these perspectives are not completely opposed but rather overlap in some areas. The high interrelation between discourses, reflected in post-sorting interview comments, supports this idea of pluralism in viewpoints. Importantly, some participants did not load significantly onto a single discourse, demonstrating perspectives that integrated both optimism and critique. These individuals often acknowledged both the strengths of CBMM efforts and the need for improvement, reflecting a more nuanced perspective. This diversity of views within CBMM suggests that management should account for integrative perspectives. These blended viewpoints may also reflect emerging or minority discourses that, while outside dominant narratives, offer valuable insights into CBMM dynamics. This continuum of perspectives in forest management has been identified previously regarding mangrove forest management (Hugé et al. 2016). However, the assemblage of perspectives into specific discourses, undoubtedly facilitated the identification of priority elements considering the multifaceted nature of the perspectives on CBMM (Ibid.).

The distribution of discourses by stakeholder sector (community leaders, non-governmental organizations, officials, researchers) revealed that "Optimism in CBMM" discourse was primarily represented by community leaders, the direct stakeholders, while "A call to enhance CBMM" discourse included both community leaders and participants from official and academic institutions. This pattern suggests that community leaders tended to express a more optimistic perspective, whereas officials and researchers were more critical. Similarly, Hugé et al. (2016) found that stakeholders configuring the "business as usual" discourse, like "Optimism in CBMM," are often directly involved in environmental management. However, rather than reflecting a bias, this dual representation provides valuable firsthand insights into the challenges faced by CBMM in Sucre, and the opportunity for self-criticism, a key strength of *Q* methodology. Understanding these dynamics and challenges identified is crucial to strengthening mangrove community-led conservation efforts in Sucre.

Key Internal Challenges in CBMM

Among the various internal challenges facing CBMM, limitations in management skills, funding, and governance structures emerge as critical barriers to long-term success.

1. Management skills are a significant challenge. Sucre CBMM leaders face poverty and violence, which may hinder quality education and skill development (McLaughlin and Sheridan 2016). Therefore, capacity building through education and training is crucial for advancing community forestry in the Global South, including CBMM in Sucre (Schweizer et al. 2021).
2. Funding availability is another major challenge. Perspectives range from viewing CBMM as voluntary community work to considering it a profitable activity, highlighting the need for consensus. It is recognized that generating financial incentives for community members is crucial for effective forest management involving restoration (Mansourian et al. 2022). Additionally, mangrove governance should consider the socio-cultural, economic, environmental, and climatic realities of local communities (Dahdouh-Guebas et al. 2022). In Sucre, low socio-economic adaptive capacity (Vega-Cabrera et al. 2021), high levels of unmet basic needs (DANE, 2018), and high unemployment rates likely impact community engagement in CBMM (Sathiyamoorthy and Sakurai 2024). Limited funding not only affects daily operations but also hampers long-term commitments to mangrove conservation, particularly in areas requiring ongoing hydrological rehabilitation and post-restoration monitoring, both of which are essential for effective mangrove restoration (Lewis 2005). Together, these issues underscore the need for CBMM initiatives to secure access to sustained socio-economic benefits.

Key External Challenges in CBMM: Structural and Systemic Issues

Both discourses highlighted key structural factors within the government that influence CBMM and exacerbate its internal challenges. These challenges emphasize the need for transformational change, which involves improving governance, education, access to basic services, employment opportunities, and eliminating corruption (Arts et al. 2024). Participants directly linked these factors to CBMM's progress.

1. Funding issues also stem from public contracting processes, with participants citing community conflicts related to the bidding process. Participants identified several interconnected issues: (1) The lack of administrative skills, such as project proposal writing, causes community organizations to struggle for government resources. (2) Not all community organizations that receive funds have the necessary skills and training in CBMM, which can lead to failure. (3) Recent government efforts aim to address these issues by providing technical, legal, and financial assistance for selected projects (MinInterior 2023). However, despite these aids, systemic corruption and bureaucratic barriers in contracting processes continue to pose significant challenges for CBMM funding in Sucre (Transparencia por Colombia 2022).
2. Violence as a challenge for CBMM. Participants described the beginning of violence in the 1980s with FARC guerrilla groups and the escalation of violence with the rise of paramilitary groups. These groups murdered and forcibly displaced residents of San Onofre, including Rincón del Mar and Berrugas (Centro Nacional de Memoria Histórica 2024), between 1997 and 2005. This led to unequal land distribution, continuing even after the paramilitary demobilized (Grajales 2011). Thus, the acquisition of land by new landowners, both international and national, continues to cause CBMM members to fear accessing adjacent mangrove areas.
3. Although national and international regulations prohibit commercial extractive activities or granting rights over mangrove areas (Gobierno de Colombia 2022; Ramsar Convention Secretariat 2010), CBMM stakeholders are often unaware of them and/or perceive weak law enforcement. However, even with strict law enforcement, without poverty alleviation strategies and alternative livelihood options, these measures may not solve ongoing land tenure conflicts (Damastuti et al. 2022; Debrot et al. 2020). In Sucre, such conflicts are likely to persist without shared access rules, clear government regulations on community stewardship, effective enforcement, poverty alleviation, and dispute resolution mechanisms (Eufemia et al. 2020; Walters et al. 2008).

Strengthening policy frameworks and improving institutional coordination could help bridge these gaps and enhance CBMM effectiveness.

Our results illustrate how internal challenges in CBMM interact with broader structural barriers, including limitations in existing public policies. Although Colombian policies, such as the National Program for the Sustainable Use, Management and Conservation of Mangrove Ecosystems, Resolución 1263 de 2018, and Ley 2243 de 2022, aim to support mangrove protection and conservation (Table ESM 1), their inconsistent implementation has led to stakeholder mistrust. This is reflected in discourse 2, where adherents strongly perceived CBMM as needing improvement due to the gap between policy intentions and enforcement. Taken together, these challenges underscore the need for a holistic approach to CBMM, one that secures long-term financial support while integrating socio-economic realities into mangrove conservation planning.

Key Opportunities in CBMM

While CBMM faces various challenges, several key opportunities identified could strengthen effectiveness and long-term sustainability. Some of the most significant factors are the role of partnerships, Local Ecological Knowledge, and gender inclusion, which can enhance community capacity and resource management.

1. Partnerships were identified as crucial for CBMM. It is known that the participation by intermediaries, or "horizontal synergies," strengthens community leaders' skills for mangrove management and restoration (Jusoff and Taha 2009; Murcia et al. 2016). However, it remains to be assessed how current partner organizations specifically impact CBMM in Sucre. For example, CBMM project members in Tolú, currently engaged with Vida Manglar, expressed an overall favorable perception of CBMM, suggesting that this partnership may be contributing to more effective management frameworks. Specific activities within this collaboration include training on mangrove ecology, compensation for CBMM members conducting guided tours and fieldwork, and continuous support through regular meetings and follow-ups. Care should be taken so that partnerships promote effective CBMM without undermining community leadership or focusing solely on resource and unemployment issues over mangrove ecosystem management.
2. Local Ecological Knowledge as a Valuable Asset. The motivation of community leaders to participate in CBMM, rooted in their Local Ecological Knowledge and strong sense of belonging, demonstrates the high social-ecological adaptive capacity within these communities, as also supported by Vega-Cabrera et al. (2021). This knowledge is particularly critical given the dependence of local livelihoods on mangroves for fishing, ecotourism, and other informal economic activities. Strengthening synergies between Science-based Ecological Knowledge and Local Ecological Knowledge could also improve CBMM in Sucre, by strengthening capacity building and knowledge generation though mutual learning (Ruiz-Mallén and Corbera 2013). By integrating these insights into management practices, communities can better address socio-economic and ecological challenges, such as ensuring sustainable resource use and safeguarding the livelihoods that depend on healthy mangrove ecosystems. Incorporating this synergy into management skills acquisition could be particularly beneficial, as it has been shown to empower community members, fostering greater acceptance and ownership of projects (IDB 2018; Marquez and Olavides 2024).
3. Role of Women and Education. Increasing the involvement of women in CBMM presents a significant opportunity to improve public perception of mangroves and address the challenges of awareness and misinformation about mangrove conservation (Dahdouh-Guebas et al. 2020). Although women's participation in CBMM in Sucre is currently low, possibly due to traditional male associations with mangrove activities in the Caribbean (such as fishing, honey extraction, and wood harvesting), this trend is not unique across all mangrove SES. On Colombia's Pacific coast, women are more involved in mangrove-related activities (Sánchez-Páez et al. 2002), as has also been observed in mangrove harvesting in Cameroon (Feka et al. 2011) and Kenya (Ndarathi et al. 2020). By increasing women's participation in Sucre CBMM and enhancing mangrove

education, there is strong potential to boost public awareness and support for mangrove conservation (Wickramasinghe 2017), central challenges identified by participants. In this regard, Maya and Ramos (2006) observed that in Colombia's Pacific coast, women's groups have played a key role in driving conservation efforts, particularly through social cohesion and internal agreements that enhance compliance with conservation strategies, often without the need for external enforcement. While this does not diminish the role of men in CBMM, it highlights the potential benefits of fostering more inclusive participation in mangrove conservation initiatives. Therefore, future studies could further examine this gender gap and its implications for mangrove conservation efforts in Colombia's Caribbean coast.

Mangrove Cover and Drivers

While identifying challenges and opportunities from stakeholder perspectives is crucial for improving CBMM, understanding broader environmental trends is equally essential. Examining mangrove cover change offers valuable insights into the pressures these ecosystems face and the effectiveness of conservation efforts. The data revealed significant shifts in mangrove extent and was consistent with previous reports, with an annualized net loss of 0.24%, slightly lower than Colombia's 0.38% rate (Murillo-Sandoval et al. 2022). However, Rincón del Mar AOI had a higher annualized net loss of 0.53%. This rate exceeds the national average of 0.38%, some regional rates (Friess et al. 2019), and the global average of less than 0.4% (Friess et al. 2020b). The significant loss of mangroves in the Rincón del Mar AOI, which has experienced a perceived increase in tourism (Fig. 4), is consistent with urban and tourism expansion as major drivers at regional, national (CVS and INVEMAR, 2010; Gómez-Cubillos et al. 2015; Sánchez-Paez et al. 2002), and global levels (Goldberg et al. 2020). While global reports highlight land conversion to agriculture and aquaculture as a major driver of mangrove change (Goldberg et al. 2020), this was less prevalent in the studied sites, with urban expansion being more commonly mentioned by participants. Selective harvesting was also perceived as a significant driver of mangrove loss, likely due to its close association with the other two drivers, urban (domestic) and tourism expansion.

In addition to selective harvesting, land reclamation has been frequently cited as a major driver of mangrove degradation, despite legal protections aimed at preventing such practices in Colombia (Gobierno de Colombia 2022). This phenomenon is well-documented (CVS and INVEMAR 2010), and its impact is known (Numbere 2020). Furthermore, mangrove land reclamation exemplifies ocean grabbing, a broader phenomenon in which shifts in the control and allocation of ocean territories undermine coastal livelihoods at multiple scales (Bennett et al. 2015). Globally, ocean grabbing through mangrove land reclamation has intensified land tenure conflicts, jurisdictional disputes, and weak enforcement mechanisms, hindering conservation efforts (Bosire et al. 2008; Van Lavieren et al. 2012; Jusoff and Taha 2009). In Sucre, this process has exacerbated conflicts between locals and foreigners, directly threatening mangrove conservation and community-based management.

Despite the losses, nearly 92% of the mangrove cover persisted, with a 14.4% increase helping to offset a 22.6% loss. Private protected areas, such as Sanguaré and Balsillas, showed visual trends of persistence and gain, reinforcing their role as strong conservation tools (Leal and Spalding 2022), likely contributing to the overall mangrove cover persistence. This is however not a global trend and protected areas on private lands have been shown to be at risk elsewhere (Heck et al. 2024). Notably, participants unanimously perceived mangrove loss, likely because most were community leaders from AOIs without net mangrove gain. The only sites with a positive balance, Sanguaré and Balsillas, were outside the interviewed areas, highlighting a spatial disconnect between net mangrove cover gains and community-led efforts. This also underscores unresolved land tenure conflicts between public and private mangrove areas, emphasizing the need for clearer tenure rights and stronger mangrove protection. In this context, CBMM organizations in Sucre face significant challenges in restoring and conserving mangroves in unprotected areas, particularly against the pressures of hotel and domestic development, the main drivers of mangrove loss in Sucre.

While these findings highlight the resilience of mangrove ecosystems in some areas, further investigation is needed to understand the historical and socio-political factors influencing these trends. Future studies could assess the impact of historical events on mangrove cover change, namely, the expansion of urban expansion during the post-conflict period in Sucre (Centro Memoria Histórica 2024). This violence, particularly forced displacement by paramilitaries in the 2000s, may have exacerbated urban expansion, as noted by participants and reported in other forests in Colombia (Murillo-Sandoval et al. 2022; Forensic Architecture and The Commission for Truth and Reconciliation 2021).

Recommendations for CBMM

To strengthen community-led mangrove management practices, it is advisable to enhance capacity building through knowledge sharing, education, and training on administrative skills such as project proposal writing and financial literacy. This approach can help ensure sustained funding availability for CBMM project continuity. Additionally, to improve mangrove conservation and restoration strategies, it is essential to strengthen the integration of Local Ecological Knowledge with Scientific Ecological Knowledge (cf. Grimm et al. 2024). Bridging the knowledge of community members and academia can enhance CBMM effectiveness while emphasizing the cultural and economic significance of mangroves, particularly their role in providing non-timber forest products.

Another key consideration is the promotion of women's involvement through financial and educational programs, as well as their active participation in mangrove-related activities. This can help address the current gender gap while expanding the use of ethnobotanical resources, such as medicinal plants and sustainable harvesting practices. Integrating ethnobotanical knowledge, customs and local practices into these initiatives can strengthen the community's connection to mangroves and enhance their long-term stewardship of these vital ecosystems.

Finally, addressing structural and systemic challenges through policy to improve education, access to basic services, employment opportunities, and corruption surveillance is crucial. Strengthening policy frameworks and improving institutional coordination could help bridge governance gaps, ensuring clearer regulations on community stewardship and more effective enforcement. Successful CBMM models in Mexico and Sri Lanka demonstrate how policies that integrate local communities and their livelihoods enhance mangrove conservation (IDB 2018; Wickramasinghe 2017). Applying similar approaches in Sucre could align conservation strategies with poverty alleviation, reduce land tenure conflicts, and foster more sustainable CBMM efforts.

Conclusions

This study analyzed Community-Based Mangrove Management (CBMM) in Sucre, Colombia, identifying key stakeholder perceptions and assessing land cover trends. CBMM refers to mangrove conservation and restoration practices involving active participation and decision-making by local communities. Two primary discourses emerged from the analysis, highlighting the main advances and ongoing challenges faced by CBMM initiatives in the region.

Positive aspects identified in CBMM in Sucre include existing partnerships, human capital, and the integration of Local Ecological Knowledge into management practices. These strengths are critical for fostering resilience and supporting collective action aimed at conserving mangroves, which are essential ecosystems providing ecological, economic, and cultural benefits, especially to coastal communities. However, significant internal and external challenges persist. Internally, issues such as limited administrative capacity and a lack of sustainable, long-term funding hinder effective management and continuity. Externally, structural challenges include insufficient governmental support, unresolved land tenure conflicts, ongoing mangrove habitat loss, and socio-environmental tensions linked to urbanization and tourism pressures, particularly evident in areas like Rincón del Mar. These challenges underscore the urgent need for reinforcing traditional management practices and ensuring their sustainability.

A clear relationship was found between stakeholders' perceptions of CBMM effectiveness and actual mangrove cover trends. Stakeholders identified urban and tourism expansion as major drivers of mangrove loss, consistent

with higher loss rates in areas like Rincón del Mar. These findings underscore the need for comprehensive management strategies that address socio-economic pressures. By aligning stakeholder perceptions with land cover data, this study highlights the importance of integrating local knowledge into mangrove management practices.

The findings of this study contribute to broader discussions on CBMM at both national and global levels, highlighting common challenges such as securing long-term funding, developing conflict resolution mechanisms, increasing public support, integrating ecosystem management approaches, strengthening political commitments, ensuring effective law enforcement, and enhancing stakeholder partnerships. Furthermore, the study reaffirms the value of ethnobotanical and cultural perspectives in guiding sustainable mangrove management, stressing the importance of these ecosystems not only for biodiversity conservation but also for preserving cultural identities and local livelihoods.

Given the dynamic socio-environmental context, periodic evaluations of stakeholder perceptions are crucial for effective and adaptive CBMM strategies. This research thus offers valuable insights for policymakers and practitioners aiming to support sustainable mangrove management practices that are inclusive, culturally relevant, and ecologically effective.

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Author Contributions

Ángela M. Barrera-Bello: Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing. Alexandra Rodríguez-Rodríguez: Conceptualization, writing – review & editing, Supervision. Ana Valencia Palacios: Formal analysis, Resources. Jaime Polanía: Conceptualization, Writing – review & editing, Supervision. Jose M. Riascos: Conceptualization, Writing – review & editing, Supervision. Juan Felipe Blanco-Libreros: Conceptualization, Methodology, Formal analysis, Resources, Validation, Writing – review & editing, Supervision. Jean Hugé: Conceptualization, Methodology, Validation, Writing – review & editing, Supervision. Farid Dahdouh-Guebas: Conceptualisation, Methodology, Validation, Writing – review & editing, Supervision, Project administration, Funding acquisition.

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Data Availability

Data from this study are available upon reasonable request from the corresponding author.

Declarations

Ethics Approval The research was approved by the Board of the Tropimundo Erasmus Mundus Joint Masters Degree in Tropical Biodiversity and Ecosystems, following the guidelines of the Ethics Committee of the Vrije Universiteit Brussel University, whereby respect for the cultural norms and practices of the participants is mandated, as well as the use of a signed informed consent form. All interviews were recorded and transcribed for analysis following the explicit consent of the participants. The objectives of the study were clearly explained to the participants prior to their engagement.

Competing interests The authors declare no competing interests.

References

Akhtar-Danesh, N. 2016. An overview of the statistical techniques in Q methodology: Is there a better way of doing Q analysis? Operant Subjectivity: The International Journal of Q Methodology 38/3–4(2016): 1–8. https://doi.org/10.15133/j.os.2016.007

Aljahdali, M. O., S. Munawar, and W. R. Khan. 2021. Monitoring mangrove forest degradation and regeneration: Landsat time series analysis of moisture and vegetation indices at Rabigh Lagoon, Red Sea. Forests 12(1): 52. https://doi.org/10.3390/f12010052

Álvarez-León, R. 2003. Los manglares de Colombia y la recuperación de sus áreas degradadas: Revisión bibliográfica y nuevas experiencias. Madera y Bosques 9(1): 3–25. https://www.redalyc.org/articulo.oa?id=61790101

Arts, B., M. Brockhaus, L. Giessen, and C. McDermott. 2024. The performance of global forest governance: Three contrasting perspectives. Forest Policy and Economics 161: 103165. https://doi.org/10.1016/j.forpol.2024.103165

Arumugam, M., R. Niyomugabo, F. Dahdouh-Guebas, and J. Hugé. 2021. The perceptions of stakeholders on current management of mangroves in the Sine-Saloum Delta, Senegal. Estuarine, Coastal and Shelf Science 248: 107160. https://doi.org/10.1016/j.ecss.2020.107160

Baloloy, A., A. Blanco, R. Ana, and K. Nadaoka. 2020. Development and application of a new mangrove vegetation index (MVI) for rapid and accurate mangrove mapping. ISPRS Journal of Photogrammetry and Remote Sensing 166: 95–117. https://doi.org/10.1016/j.isprsjprs.2020.06.001

Baltezar, P., P. J. Murillo-Sandoval, K. C. Cavanaugh, C. Doughty, D. Lagomasino, T. Tieng, M. Simard, and T. Fatoyinbo. 2023. A regional map of mangrove extent for Myanmar, Thailand, and Cambodia shows losses of 44% by 1996. Frontiers in Marine Science 10: 1127720. https://doi.org/10.3389/fmars.2023.1127720

Bennett, N. J., H. Govan, and T. Satterfield. 2015. Ocean grabbing. Marine Policy 57: 61–68. https://doi.org/10.1016/j.marpol.2015.03.026

Bosire, J. O., F. Dahdouh-Guebas, J. G. Kairo, S. Cannicci, and N. Koedam. 2004. Spatial variations in macrobenthic fauna recolonisation in a tropical mangrove bay. Biodiversity & Conservation 13: 1059–1074. https://doi.org/10.1023/B:BIOC.0000018149.88212.2d

Bosire, J. O., F. Dahdouh-Guebas, M. Walton, B. I. Crona, R. R. Lewis, C. Field, J. G. Kairo, and N. Koedam. 2008. Functionality of restored mangroves: A review. Aquatic Botany 89(2): 251–259. https://doi.org/10.1016/j.aquabot.2008.03.010

Brown, B., R. Fadillah, Y. Nurdin, I. Soulsby, and R. Ahmad. 2014. Case Study: Community Based Ecological Mangrove Rehabilitation (CBEMR) in Indonesia. SAPIENS 7: 53–64. https://journals.openedition.org/sapiens/1589 (17 February 2025).

Burgman, M., A. Carr, L. Godden, R. Gregory, M. McBride, L. Flander, and L. Maguire. 2011. Redefining expertise and improving ecological judgment. Conservation Letters 4(2): 81–87. https://doi.org/10.1111/j.1755-263X.2011.00165.x

Castellanos-Galindo, G. A., L. C. Kluger, M. A. Camargo, J. Cantera, J. E. M. Pineda, J. F. Blanco-Libreros, and M. Wolff. 2021. Mangrove research in Colombia: Temporal trends, geographical coverage, and research gaps. Estuarine, Coastal and Shelf Science 248: 106799. https://doi.org/10.1016/j.ecss.2020.106799

Cattell, R. B. 1966. The Scree Test for the number of factors. Multivariate Behavioral Research 1(2): 245–276. https://doi.org/10.1207/s15327906mbr0102_10

Centro Nacional de Memoria Histórica. 2024. No existe el olvido (documentary series). https://www.youtube.com/watch?v=Ivh1wWT6GJcandlist=PLAaTPARKqv4XPBnvx7eHCRjJGpdF2csyi (27 March 2025).

CVS and INVEMAR (Corporación Autónoma Regional de los valles del Sinú y del San Jorge and Institute for Marine and Coastal Research). 2010. Plan integral de manejo del Distrito de Manejo Integrado (DMI) bahía de Cispatá - La Balsa - Tinajones y sectores aledaños del delta estuarino del río Sinú, departamento de Córdoba (Serie de Publicaciones Especiales No. 18). Santa Marta: Institute for Marine and Coastal Research.

Dabalà, A., F. Dahdouh-Guebas, D. C. Dunn, J. D. Everett, C. E. Lovelock, J. O. Hanson, K. C. V. Buenafe, S. Neubert, and A. J. Richardson. 2023. Priority areas to protect mangroves and maximise ecosystem services. Nature Communications 14: 5863. https://doi.org/10.1038/s41467-023-41333-3

Dahdouh-Guebas, F., I. Van Pottelbergh, J. G. Kairo, S. Cannicci, and N. Koedam. 2004. Human-impacted mangroves in Gazi (Kenya): Predicting future vegetation based on retrospective remote sensing, social surveys, and tree distribution. Marine Ecology Progress Series 272: 77–92. https://doi.org/10.3354/meps272077

Dahdouh-Guebas, F., G. N. Ajonina, A. A. Amir, D. A. Andradi-Brown, I. Aziz, T. Balke, E. B. Barbier, S. Cannicci, S. M. Cragg, M. Cunha-Lignon, D. J. Curnick, C. M. Duarte, N. C. Duke, C. Endsor, S. Fratini, I. C. Feller, F. Fromard, J. Hugé, M. Huxham, J. G. Kairo, T. Kajita, K. Kathiresan, N. Koedam, S. Y. Lee, H.-J. Lin, J. R. Mackenzie, M. M. Mangora, C. Marchand, T. Meziane, T. E. Minchinton, N. Pettorelli, J. Polanía, G. Polgar, M. Poti, J. Primavera, A. Quarto, S. M. Rog, B. Satyanarayana, Y. Schaeffer-Novelli, M. Spalding, T. Van der Stocken, D. Wodehouse, J. W. H. Yong, M. Zimmer, and D. A. Friess. 2020. Public perceptions of mangrove forests matter for their conservation. Frontiers in Marine Science 7: 603651. https://doi.org/10.3389/fmars.2020.603651

Dahdouh-Guebas, F., J. Hugé, G. M. O. Abuchahla, S. Cannicci, L. P. Jayatissa, J. G. Kairo, S. Kodikara Arachchilage, N. Koedam, T. W. G. F. M. Nijamdeen, N. Mukherjee, M. Poti, N. Prabakaran, H. A. Ratsimbazafy, B. Satyanarayana, M. Thavanayagam, K. Vande Velde, and D. Wodehouse. 2021. Reconciling nature, people, and policy in the mangrove social-ecological system through the adaptive cycle heuristic. Estuarine, Coastal and Shelf Science 248: 106942. https://doi.org/10.1016/j.ecss.2020.106942

Dahdouh-Guebas, F., D. A. Friess, C. E. Lovelock, R. M. Connolly, I. C. Feller, K. Rogers, and S. Cannicci. 2022. Cross-cutting research themes for future mangrove forest research. Nature Plants 8(10): 1131–1135. https://doi.org/10.1038/s41477-022-01245-4

Damastuti, E., R. de Groot, A. O. Debrot, and M. J. Silvius. 2022. Effectiveness of community-based mangrove management for biodiversity conservation: A case study from Central Java, Indonesia. Trees, Forests and People 7: 100202. https://doi.org/10.1016/j.tfp.2022.100202

DANE (Departamento Administrativo Nacional de Estadística). 2018. Necesidades Básicas Insatisfechas – NBI (Servicios Públicos, Sucre), Censo Nacional de Población y Vivienda 2018. https://geoportal.dane.gov.co/geovisores/sociedad/cnpv-2018/ (27 March 2025).

Debrot, A. O., A. Veldhuizen, S. W. K. van den Burg, C. J. Klapwijk, M. N. Islam, M. I. Alam, M. N. Ahsan, M. U. Ahmed, S. R. Hasan, R. Fadilah, Y. R. Noor, R. Pribadi, S. Rejeki, E. Damastuti, E. Koopmanschap, S. Reinhard, C. Terwisscha van Scheltinga, C. Verburg, and M. Poelman. 2020. Non-timber forest product livelihood-focused interventions in support of mangrove restoration: A call to action. Forests 11(11): 1224. https://doi.org/10.3390/f11111224

Duke, N. C., J.-O. Meynecke, S. Dittmann, A. M. Ellison, K. Anger, U. Berger, S. Cannicci, K. Diele, K. C. Ewel, C. D. Field, N. Koedam, S. Y. Lee, C. Marchand, I. Nordhaus, and F. Dahdouh-Guebas. 2007. A world without mangroves? Science 317: 41–42. https://doi.org/10.1126/science.317.5834.41b

Dupont, R., K. Diallo, S. Georis, D. Kungula Makoso, A. C. Ximenes, B. Satyanarayana, Y. Tarelkin, K. Diouf Goudiaby, J. Hugé, J. Polanía, and F. Dahdouh-Guebas. 2025. Species-poor mangrove forests also provide rich ecosystem goods and services. Economic Botany XX(X): xx–xx (in press). https://doi.org/10.1007/s12231-024-09628-8

Elster, C. 2000. Reasons for reforestation success and failure with three mangrove species in Colombia. Forest Ecology Management 131: 201–214. https://doi.org/10.1016/S0378-1127(99)00214-5

Eufemia, L., M. Bonatti, S. Sieber, B. Schröter, and M. A. Lana. 2020. Mechanisms of weak governance in grasslands and wetlands of South America. Sustainability 12(17): 7214. https://doi.org/10.3390/su12177214

FAO, SER and IUCN CEM (Food and Agriculture Organization, Society for Ecological Restoration and IUCN Commission on Ecosystem Management). 2023. Standards of practice to guide ecosystem restoration: A contribution to the United Nations decade on ecosystem restoration: Summary report. Rome: FAO.https://openknowledge.fao.org/items/fb87513e-cd4d-42dd-a78d-48fd29afd4ca (27 March 2025).

Feka, N. Z., M. G. Manzano, and F. Dahdouh-Guebas. 2011. The effects of different gender harvesting practices on mangrove ecology and conservation in Cameroon. International Journal of Biodiversity Science, Ecosystem Services & Management 7(2): 108–121. https://doi.org/10.1080/21513732.2011.606429

Forensic Architecture and the Commission for Truth and Reconciliation. 2021. Dispossession and the memory of the Earth: Land dispossession in Nueva Colonia. https://forensic-architecture.org/investigation/land-dispossession-in-nueva-colonia (27 March 2025).

Friess, D. A., K. Rogers, C. E. Lovelock, K. W. Krauss, S. E. Hamilton, S. Y. Lee, R. Lucas, J. Primavera, A. Rajkaran, and S. Shi. 2019. The state of the world's mangrove forests: Past, present, and future. Annual Review of Environment and Resources 44: 89–115. https://doi.org/10.1146/annurev-environ-101718-033302

Friess, D. A., E. S. Yando, G. M. O. Abuchahla, J. B. Adams, S. Cannicci, S. W. J. Canty, K. C. Cavanaugh, R. M. Connolly, N. Cormier, F. Dahdouh-Guebas, K. Diele, I. C. Feller, S. Fratini, T. C. Jennerjahn, S. Y. Lee, D. E. Ogurcak, X. Ouyang, K. Rogers, J. K. Rowntree, S. Sharma, T. M. Sloey, and A. K. S. Wee. 2020a. Mangroves give cause for conservation optimism, for now. Current Biology 30(4): R153–R154. https://doi.org/10.1016/j.cub.2019.12.054

Friess, D. A., E. S. Yando, J. B. Alemu, L. W. Wong, S. D. Soto, and N. Bhatia. 2020b. Ecosystem services and disservices of mangrove forests and salt marshes. Oceanography and Marine Biology 58: 107–142. https://doi.org/10.1201/9780429351495-3

Gann, G. D., T. McDonald, B. Walder, J. Aronson, C. R. Nelson, J. Jonson, J. G. Hallett, C. Eisenberg, M. R. Guariguata, J. Liu, F. Hua, C. Echeverría, E. Gonzales, N. Shaw, K. Decleer, and K. Dixon. 2019. International principles and standards for the practice of ecological restoration. Second edition. Restoration Ecology 27(S1): S1–S46. https://doi.org/10.1111/rec.13035

Gobierno de Colombia. 2010. Plan Nacional de Desarrollo 2010–2014: VI Sostenibilidad ambiental y prevención del riesgo. https://colaboracion.dnp.gov.co/CDT/PND/7C.%20Cap%C3%ADtulo%20VI.pdf (27 March 2025).

Gobierno de Colombia. 2014. Plan Nacional de Desarrollo 2014–2018: Tomo II. https://colaboracion.dnp.gov.co/CDT/PND/PND%202014-2018%20Tomo%202%20internet.pdf (27 March 2025).

Gobierno de Colombia. 2021. LEY 2169 DE 2021 (Diciembre 22). https://www.suin-juriscol.gov.co/viewDocument.asp?id=30043747 (27 March 2025).

Gobierno de Colombia. 2022. LEY 2243 DE 2022 (Julio 8). https://www.anla.gov.co/07rediseureka2024/normativa/leyes/ley-2243-de-2022-protege-los-ecosistemas-de-manglar (27 March 2025).

Goldberg, L., D. Lagomasino, N. Thomas, and T. Fatoyinbo. 2020. Global declines in human-driven mangrove loss. Global Change Biology 26(10): 5844–5855. https://doi.org/10.1111/gcb.15275

Gómez-Cubillos, C., L. Licero, A. Perdomo, D. Rodríguez, D. Romero, D. Ballesteros, A. Gómez-López, L. Melo, M. Chasqui, D. Ocampo, J. Alonso, C. García, M. Peña, C. Bastidas, and C. Ricaurte. 2015. Portafolio Áreas de arrecifes de coral, pastos marinos, playas de arena y manglares con potencial de restauración en Colombia. Serie de Publicaciones Generales 79. Santa Marta: Institute for Marine and Coastal Research. https://www.minambiente.gov.co/documento-entidad/portafolio-de-arrecifes-de-coral-pastos-marinos-playas-de-arena-y-manglares-con-potencial-de-restauracion-en-colombia/ (27 March 2025).

Google Earth Pro. 2021. Google Earth Pro (Version 7.3.4). https://www.google.com/earth/. (22 April 2025).

Grajales, J. 2011. The rifle and the title: Paramilitary violence, land grab and land control in Colombia. Journal of Peasant Studies 38(4): 771–792. https://doi.org/10.1080/03066150.2011.607701

Grimm, K., M. Spalding, M. Leal, K. Kincaid, L. Aigrette, P. Amoah-Quiminee, L. Amoras, D. Amouine, F. Areki, W. Arends, J. M. Argueta, C. A. Arrieta-Giron, A. S. Astra, G. N. Atuga, M. Barillo, S. B. Anariba, M. Botelho, A. S. Cabanban, E. Caceros, D. Caicedo, A. Calzada, S. Canty, S. Cardenas, G. R. Carrera Patiño, J. Castro-Gomez, F. Caucau, A. Celestin, V. Chagas, J. Chulim, J. C. Cuadro, F. Dahdouh-Guebas, Z. M. da Silva, A. Daza, A. Dawud, G. Díaz, M. C. Diazgranados, A. Dubano, C. Durán, R. Espinosa, K. Evangelista, J. Ferreira, M. Fouqueray, A. E. Fraiz-Toma, J. R. Garcia Moraes, J. C. Gomes da Silva, W. Gomez, M. González, M. Govindarajan, D. Iha, P. Jacobo, J. E. Jaén, G. Jaofary, N. Jiménez, S. C. Juma, Kuswantoro, S. Lusiana, Y. Y. Madarriaga, R. Magalingam, A. Mahamudu, U. Malani, N. Malate, M. Marrufo, P. Martin, B. M. L. Martins, H. Mendoza, L. Michie, Y. Mona, A. Moreira, H. Morrissette, M. Mueller, L. D. Murage, M. Naikasowalu, S. Narayana, N. Ndule, M. Ngozi, D. Oeiras, M. Olendo, P. Ortega, D. Pinto, H. Prasetio, A. Quarto, L. R. Quintanilla Guerra, H. Rabemanantsoa, C. Rakotomahazo, A. Ralifo, J. Ravelonjatovo, Z. Ricord de Mendoza, A. Robaigau, O. Rocha, A. E. Rosado, M. Sairi, S. Saleda, K. Sathya, P. Sierra, O. Sierra Rozo, Y. Simanca, L. Sirikwa, S. Somo, W. Sutherland, J. R. Tavares da Silva, L. Thom, V. Tinalevu, P. C. J. Torres, V. Tsilibaris, N. Van Hien, T. Van Lai, D. Van Tao, B. Vedharajan, C. Villamil Echeverri, D. Wodehouse, T. Worthington, S. Yennego, W. Yuniati, and M. Zimmer. 2024. Including Local Ecological Knowledge (LEK) in mangrove conservation & restoration: A best-practice guide for practitioners and researchers. Washington D.C., USA: Global Mangrove Alliance. https://doi.org/10.5479/10088/118227

Heck, N., L. Goldberg, D. A. Andradi-Brown, A. Campbell, S. Narayan, G. N. Ahmadia, and D. Lagomasino. 2024. Global drivers of mangrove loss in protected areas. Conservation Biology 38(6): e14293. https://doi.org/10.1111/cobi.14293

Hugé, J., T. Waas, F. Dahdouh-Guebas, N. Koedam, and T. Block. 2013. A discourse-analytical perspective on sustainability assessment: Interpreting sustainable development in practice. Sustainability Science 8: 187–198. https://doi.org/10.1007/s11625-012-0184-2

Hugé, J., K. Vande Velde, F. Benitez-Capistros, J. H. Japay, B. Satyanarayana, M. N. Ishak, M. Quispe-Zuniga, B. H. Mohd Lokman, I. Sulong, N. Koedam, and F. Dahdouh-Guebas. 2016. Mapping discourses using Q methodology in Matang Mangrove Forest, Malaysia. Journal of Environmental Management 183(3): 988–997. https://doi.org/10.1016/j.jenvman.2016.09.046

Hugé, J., B. Satyanarayana, N. Mukherjee, V. Otero, K. Vande Velde, and F. Dahdouh-Guebas. 2023. Mapping research gaps for sustainable forest management based on the nominal group technique. Environment, Development and Sustainability 25(9): 10101–10121. https://doi.org/10.1007/s10668-022-02478-1

IDB (Inter-American Development Bank). 2018. Mexico: Integrating stakeholders in mangrove assessments and management planning: A model based on collaborative planning in Veracruz, Mexico. www.natureserve.org/sites/default/files/mangrove_replicable_model_final_me_t1313.pdf?utm (27 March 2025).

IUCN (International Union for Conservation of Nature). 2024. Red list of mangrove ecosystems. https://www.iucn.org/resources/conservation-tool/iucn-red-list-ecosystems/red-list-mangrove-ecosystems (27 March 2025).

Jusoff, K., and D. D. H. Taha. 2009. Managing sustainable mangrove forests in peninsular Malaysia. Journal of Sustainable Development 1(1): 88–96. https://doi.org/10.5539/jsd.v1n1p88

Kairu, A., K. Kotut, R. Mbeche, and J. Kairo. 2021. Participatory forestry improves mangrove forest management in Kenya. International Forestry Review 23(1): 41–54. https://doi.org/10.1505/146554821832140385

Kodikara, K. A. S., N. Mukherjee, L. P. Jayatissa, F. Dahdouh-Guebas, and N. Koedam. 2017. Have mangrove restoration projects worked? An in-depth study in Sri Lanka. Restoration Ecology 25(5): 705–716. https://doi.org/10.1111/rec.12492

Kongkeaw, C., J. Kittitornkool, P. Vandergeest, and K. Kittiwatanawong. 2019. Explaining success in community-based mangrove management: Four coastal communities along the Andaman Sea, Thailand. Ocean & Coastal Management 178: 104822. https://doi.org/10.1016/j.ocecoaman.2019.104822

Leal, M., and M. Spalding. 2022. The state of the world's mangroves 2022. Global mangrove alliance. https://www.wetlands.org/publication/the-state-of-the-worlds-mangroves-2022/ (27 March 2025).

Lewis, R. 2005. Ecological engineering for successful management and restoration of mangrove forests. Ecological Engineering 24: 403–418. https://doi.org/10.1016/j.ecoleng.2004.10.003

Lhosupasirirat, P., F. Dahdouh-Guebas, J. Hugé, D. Wodehouse, and J. Enright. 2023. Stakeholder perceptions on community-based ecological mangrove restoration (CBEMR): A case study in Thailand. Restoration Ecology 31(5): e13894. https://doi.org/10.1111/rec.13894

López-Portillo, J., R. R. Lewis, P. Saenger, A. Rovai, N. Koedam, F. Dahdouh-Guebas, C. Agraz-Hernández, and V. H. Rivera-Monroy. 2017. Mangrove forest restoration and rehabilitation. In: Mangrove ecosystems: A global biogeographic perspective: Structure, function, and services, eds. V. H. Rivera-Monroy, S. Y. Lee, E. Kristensen, and R. R. Twilley, 301–345. Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-62206-4_10

Lunetta, R., and J. Lyon. 2004. Remote sensing and GIS accuracy assessment. Boca Raton: CRC Press. https://doi.org/10.1201/9780203497586

Mansourian, S., H. Kleymann, V. Passardi, S. Winter, M. A. A. Derkyi, A. Diederichsen, M. Gabay, P. Pacheco, D. Vallauri, and C. A. Kull. 2022. Governments commit to forest restoration, but what does it take to restore forests? Environmental Conservation 49(4): 206–214. https://doi.org/10.1017/S0376892922000340

MAP (Mangrove Action Project). 2020. Community-based ecological mangrove restoration (CBEMR). https://mangroveactionproject.org/wp-content/uploads/2024/06/CBEMR-article-in-FAO-Nature-Faune-en-article.pdf (27 March 2025).

Marquez, G., and R. Olavides. 2024. Integrating science-based and local ecological knowledge: A case study of mangrove restoration and rehabilitation projects in the Philippines. Disasters 48(S1): e12630. https://doi.org/10.1111/disa.12630

Maya, D., and P. Ramos. 2006. El rol del género en el manglar: Heterogeneidad tecnológica e instituciones locales. Cuadernos de Desarrollo Rural (56): 53–81. https://revistas.javeriana.edu.co/index.php/desarrolloRural/article/view/1236/728 (27 March 2025).

McLaughlin, K., and M. Sheridan. 2016. Beyond cumulative risk: A dimensional approach to childhood adversity. Current Directions in Psychological Science 25(4): 239–245. https://doi.org/10.1177/0963721416655883

MINAMBIENTE (Ministerio de Ambiente y Desarrollo Sostenible de Colombia). 1995. Resolución 1602 del 21 de diciembre de 1995. https://archivo.minambiente.gov.co/images/BosquesBiodiversidadyServiciosEcosistemicos/pdf/Manglares/080811_res_1602_1995.pdf (27 March 2025).

MINAMBIENTE (Ministerio de Ambiente y Desarrollo Sostenible de Colombia). 1996. Resolución 020 del 9 de enero de 1996. https://archivo.minambiente.gov.co/images/BosquesBiodiversidadyServiciosEcosistemicos/pdf/Normativa/Resoluciones/res_0020_090196.pdf (27 March 2025).

MINAMBIENTE (Ministerio de Ambiente y Desarrollo Sostenible de Colombia). 2014a. Anexo 4: Guía de restauración de ecosistemas de manglar en Colombia (GREM). https://www.minambiente.gov.co/wp-content/uploads/2021/10/Anexo-4.-Guia-de-restauracion-de-ecosistemas-de-manglar-en-Colombia.pdf (27 March 2025).

MINAMBIENTE (Ministerio de Ambiente y Desarrollo Sostenible de Colombia). 2014b. Anexo 5: Lineamientos nacionales para el monitoreo del manglar en Colombia. https://www.minambiente.gov.co/wp-content/uploads/2021/10/Anexo-5.-Lineamientos-nacionales-para-el-monitoreo-del-manglar-en-Colombia.pdf (27 March 2025).

MINAMBIENTE (Ministerio de Ambiente y Desarrollo Sostenible de Colombia). 2015. Plan Nacional de Restauración: Restauración ecológica, rehabilitación y recuperación de áreas disturbadas. https://archivo.minambiente.gov.co/images/BosquesBiodiversidadyServiciosEcosistemicos/pdf/plan_nacional_restauracion/PLAN_NACIONAL_DE_RESTAURACI%C3%93N_2.pdf (27 March 2025).

MINAMBIENTE (Ministerio de Ambiente y Desarrollo Sostenible de Colombia). 2018. Resolución 1263 de 2018. https://www.minambiente.gov.co/documento-entidad/resolucion-1263-de-2018/ (27 March 2025).

MinInterior (Ministerio del Interior de Colombia). 2023. Banco de proyectos para las comunidades. https://www.mininterior.gov.co/banco-de-Proyectos-para-las-comunidades/ (27 March 2025).

Murcia, C., M. R. Guariguata, Á. Andrade, G. I. Andrade, J. Aronson, E. M. Escobar, A. Etter, F. H. Moreno, W. Ramírez, and E. Montes. 2016. Challenges and prospects for scaling-up ecological restoration to meet international commitments: Colombia as a case study. Conservation Letters 9(3): 213–220. https://doi.org/10.1111/conl.12199

Murillo-Sandoval, P., T. Fatoyinbo, and M. Simard. 2022. Mangroves cover change trajectories 1984–2020: The gradual decrease of mangroves in Colombia. Frontiers in Marine Science 9: 1277. https://doi.org/10.3389/fmars.2022.892946

Ndarathi, J., C. Munga, J. Hugé, and F. Dahdouh-Guebas. 2020. A socio-ecological system perspective on trade interactions within artisanal fisheries in coastal Kenya. Western Indian Ocean Journal of Marine Science 19(2): 29–43. https://doi.org/10.4314/wiojms.v19i2.3

Nicolau, A. P., K. Dyson, D. Saah, and N. Clinton. 2023. Accuracy assessment: Quantifying classification quality. In: Cloud-based remote sensing with Google Earth Engine: Fundamentals and applications, eds. J. A. Cardille, M. A. Crowley, D. Saah, and N. E. Clinton, 135–145. Cham: Springer International Publishing. https://doi.org/10.1007/978-3-031-26588-4_7

Nijamdeen, T. W. G. F. M., H. A. Ratsimbazafy, K. A. S. Kodikara, T. W. G. F. A. Nijamdeen, T. Thajudeen, S. Peruzzo, M. Govender, F. Dahdouh-Guebas, and J. Hugé. 2024. Delineating expert mangrove stakeholder perceptions and attitudes towards mangrove management in Sri Lanka using Q methodology. Environmental Science & Policy 151: 103632. https://doi.org/10.1016/j.envsci.2023.103632

Numbere, A. 2020. The impact of landscape reclamation on mangrove forest and coastal areas in the Niger Delta, Nigeria. In: Landscape reclamation: Rising from whats's left, eds. L. Loures, 53–70. London: IntechOpen. https://doi.org/10.5772/intechopen.82053

Nyangoko, B. P., H. Berg, M. M. Mangora, M. S. Shalli, and M. Gullström. 2022. Local perceptions of changes in mangrove ecosystem services and their implications for livelihoods and management in the Rufiji Delta, Tanzania. Ocean & Coastal Management 219: 106065. https://doi.org/10.1016/j.ocecoaman.2022.106065

Ostrom, E. 2009. A general framework for analyzing sustainability of social-ecological systems. Science 325(5939): 419–422. https://doi.org/10.1126/science.1172133

Ostrom, E., and H. Nagendra. 2006. Insights on linking forests, trees, and people from the air, on the ground, and in the laboratory. Proceedings of the national Academy of sciences 103(51): 19224–19231. https://doi.org/10.1073/pnas.0607962103

Otero, V., R. Van De Kerchove, B. Satyanarayana, C. Martínez-Espinosa, M. A. Bin Fisol, M. R. Bin Ibrahim, I. Sulong, H. Mohd-Lokman, R. Lucas, and F. Dahdouh-Guebas. 2018. Managing mangrove forests from the sky: Forest inventory using field data and Unmanned Aerial Vehicle (UAV) imagery in the Matang Mangrove Forest Reserve, peninsular Malaysia. Forest Ecology and Management 411: 35–45. https://doi.org/10.1016/j.foreco.2017.12.049

Parker, C., S. Scott, and A. Geddes. 2019. Snowball Sampling. In: Sage research methods foundations, eds. P. Atkinson, S. Delamont, A. Cernat, J. W. Sakshaug, and R. A. Williams, 1–13. London: SAGE Publications Ltd. https://doi.org/10.4135/9781526421036831710

QGIS Development Team. 2018. QGIS Geographic Information System. Open Source Geospatial Foundation Project. http://qgis.osgeo.org (27 March 2025).

R Core Team. 2024. R: A language and environment for statistical computing. R foundation for statistical computing, Vienna, Austria. https://www.R-project.org/ (27 March 2025).

Ramsar Convention Secretariat. 2010. Wise use of wetlands: Concepts and approaches for the wise use of wetlands. Ramsar handbooks for the wise use of wetlands. Gland: ramsar convention secretariat. https://www.ramsar.org/sites/default/files/documents/library/hbk4-01.pdf (27 March 2025).

Rodríguez-Rodríguez, J., J. Mancera-Pineda, and H. Tavera. 2021. Mangrove restoration in Colombia: Trends and lessons learned. Forest Ecology and Management 496: 119414. https://doi.org/10.1016/j.foreco.2021.119414

Rodríguez-Rodríguez, A. 2022. La restauración de los manglares en Colombia: Técnicas, saberes y experiencias (Serie de Publicaciones Generales No. 123). Santa Marta: Institute for Marine and Coastal Research. https://n2t.net/ark:/81239/m9jx3r (20 March 2025).

Ruiz-Mallén, I., and E. Corbera. 2013. Community-based conservation and traditional ecological knowledge: Implications for social-ecological resilience. Ecology and Society 18(4): 72. https://doi.org/10.5751/ES-05867-180412

Ruiz-Roldán, J. J., J. F. Blanco-Libreros, and S. R. López-Rodríguez. 2023. Mapeo de manglares utilizando cómputo en la nube y un índice espectral específico para apoyar acciones de manejo: Un caso del Caribe Colombiano semiárido. Ecosistemas 32(3): 2599–2599. https://doi.org/10.7818/ECOS.2599

RUNAP (Registro único Nacional de Áreas Protegidas). 2023. Departamento Sucre. https://runap.parquesnacionales.gov.co/departamento/936 (24 March 2025).

Sánchez-Paez, H., G. Ulloa, and G. Páez. 2002. Uso sostenible, manejo y conservación de los ecosistemas de manglar en Colombia. Colombia: Dirección General de Ecosistemas. http://par-manglares.net/images/docs/publicaciones/colombia/PNM-2002.pdf (24 March 2025).

Sathiyamoorthy, S., and T. Sakurai. 2024. Effectiveness of community participation in Mangrove restoration: The evidence from northern Sri Lanka. Environmental Economics and Policy Studies 26: 759–779. https://doi.org/10.1007/s10018-024-00397-1

Schmolck, P. 2014. PQ method software, Version November 2014. http://schmolck.userweb.mwn.de/qmethod/ (24 March 2025).

Schweizer, D., M. van Kuijk, and J. Ghazoul. 2021. Perceptions from non-governmental actors on forest and landscape restoration, challenges, and strategies for successful implementation across Asia, Africa, and Latin America. Journal of Environmental Management 286: 112251. https://doi.org/10.1016/j.jenvman.2021.112251

Shapiro, A. 2024. Mangroves. In: Cloud-based remote sensing with Google Earth Engine, eds. J. A. Cardille, M. A. Crowley, D. Saah, and N. E. Clinton, 1023–1043. Cham: Springer International Publishing. https://doi.org/10.1007/978-3-031-26588-4_47

Sneegas, G. 2020. Making the case for critical Q methodology. The Professional Geographer 72(1): 78–87. https://doi.org/10.1080/00330124.2019.1598271

Torres-Guevara, L. E. T., A. Schlüter, and M. C. Lopez. 2016. Collective action in a tropical estuarine lagoon: Adapting Ostrom's SES framework to Ciénaga Grande de Santa Marta, Colombia. International Journal of the Commons 10(1): 334–362. https://doi.org/10.18352/ijc.623

Transparencia por Colombia. 2022. Radiografía de la corrupción en Colombia 2016–2022. https://transparenciacolombia.org.co/analisis-radiografia-corrupcion-2016-2022/ (24 March 2025).

Ulloa-Delgado, G., and W. Gil-Torres. 2001. Caracterización, diagnóstico y zonificación de los manglares en el Departamento de Sucre. Sucre: CARSUCRE.

Van Lavieren, H., M. Spalding, D.M. Alongi, M. Kainuma, M. Clüsener-Godt, and Z. Adeel. 2012. Policy brief: Securing the future of mangroves. Hamilton, Ontario: United Nations University.

Vega-Cabrera, A. M., A. P. Zamora-Bornachera, and A. D. Enriquez-Fernández. 2021. Las comunidades costeras: Protagonistas en la restauración de manglares en Colombia. Programa de Fortalecimiento de la restauración de manglares en Colombia: Técnicas, saberes y experiencias. MinAmbiente – INVEMAR (Serie de publicaciones generales No. 119). Santa Marta: Institute for Marine and Coastal Research. https://n2t.net/ark:/81239/m9nm5b (27 March 2025).

Vida Manglar. 2023. Proyecto. https://www.vidamanglar.co/#proyecto (27 March 2025).

Walters, B. B., P. Rönnbäck, J. M. Kovacs, B. Crona, S. A. Hussain, R. Badola, J. H. Primavera, E. Barbier, and F. Dahdouh-Guebas. 2008. Ethnobiology, socio-economics, and management of mangrove forests: A review. Aquatic Botany 89(2): 220–236. https://doi.org/10.1016/j.aquabot.2008.02.009

Watts, S., and P. Stenner. 2014. Doing Q methodological research theory, method and interpretation. London: SAGE. https://doi.org/10.4135/9781446251911

Wickramasinghe, D. 2017. Regreening the coast: Community-based mangrove conservation and restoration in Sri Lanka. In: Participatory mangrove management in a changing climate: Disaster risk reduction, eds. R. DasGupta, and R. Shaw, 161–171. Tokyo: Springer. https://doi.org/10.1007/978-4-431-56481-2_10

Yancho, J. M. M., T. G. Jones, S. R. Gandhi, C. Ferster, A. Lin, and L. Glass. 2020. The Google Earth Engine mangrove mapping methodology (GEEMMM). Remote Sensing 12(22): 3758. https://doi.org/10.3390/rs12223758

Zabala, A., C. Sandbrook, and N. Mukherjee. 2018. When and how to use Q methodology to understand perspectives in conservation research. Conservation Biology 32(5): 1185–1194. https://doi.org/10.1111/cobi.13123

Zu Ermgassen, P. S. E., N. Mukherjee, T. A. Worthington, A. Acosta, A. R. da Rocha Araujo, C. M. Beitl, G. A. Castellanos-Galindo, C. Parrett, M. Cunha-Lignon, F. Dahdouh-Guebas, P. G. Dwyer, J. R. Gair, A. F. Johnson, B. Kuguru, A. S. Lobo, N. Loneragan, K. Longley-Wood, J. Tomasino Mendonça, J.-O. Meynecke, R. N. Mandal, C. N. Munga, B. Gonzalez Reguero, P. Rönnbäck, J. Thorley, M. Wolff, and M. Spalding. 2021. Fishers who rely on mangroves: Modelling and mapping the global intensity of mangrove-associated fisheries. Estuarine, Coastal and Shelf Science 248: 107159. https://doi.org/10.1016/j.ecss.2020.107159