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REVIEW

Urban mangroves

Los manglares urbanos

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ABSTRACT

"Urban Mangroves" is a research article whose main objective was to identify key findings regarding the ecological, social, and environmental dynamics of urban mangroves in the context of global change. It explores the ecology, conservation challenges, and socioeconomic value of mangroves that persist in urban and coastal environments, particularly in Mexico. The study focuses on how these ecosystems, despite human pressure and climate change, continue to provide vital services such as coastal protection, water filtration, and biodiversity support. The research also addresses major threats such as habitat fragmentation and land-use conflicts, proposing restoration strategies and highlighting the potential of ecotourism and environmental education as conservation tools. Finally, it emphasizes the importance of public policy and community participation for the sustainable management of these valuable wetlands.

Keywords: Coastal Mangrove; Ecology; Ecosystems; Sustainable.

RESUMEN

"Los Manglares Urbanos" es un artículo de investigación cuyo objetivo principal fue identificar una serie de hallazgos clave sobre la dinámica ecológica, social y ambiental de los manglares urbanos en el contexto del cambio global. Explora la ecología, los desafíos de conservación y el valor socioeconómico de los manglares que persisten en entornos urbanos y costeros, especialmente en México. Se enfoca en cómo estos ecosistemas, a pesar de la presión humana y el cambio climático, continúan ofreciendo servicios vitales como protección costera, filtración de agua y soporte a la biodiversidad. El estudio también aborda las amenazas clave, como la fragmentación del hábitat y los conflictos por el uso del suelo, proponiendo estrategias de restauración y destacando el potencial del ecoturismo y la educación ambiental como herramientas de conservación. Finalmente, se subraya la importancia de las políticas públicas y la participación comunitaria para la gestión sostenible de estos valiosos humedales.

Palabras clave: Ecología; Ecosistemas; Manglar Costero; Sustentable.

INTRODUCTION

Urban mangroves are mangrove ecosystems that develop or are conserved within or near urban areas. Despite human pressures, these mangroves persist and provide crucial ecosystem services such as coastal protection, carbon storage, water quality improvement, and biodiversity support.(1) Mangroves are a group of salt-tolerant vegetation found in tropical and subtropical areas. They are composed of true mangroves and associated vegetation (false mangroves) and shrubby halophytes, which make up the mangrove ecosystem.

Among the distinctive characteristics of mangroves are viviparity, absence of seeds, salt-secreting and excreting glands, and aerial roots, which facilitate gas exchange. They are distributed in coastal areas where the ambient temperature in winter is not lower than 11 degrees Celsius and can withstand water temperatures of no less than 18 degrees Celsius. There are species such as those of the Rhizophora genus, which inhabit the coastal strip predominantly flooded by the tides, and species of the Avicennia genus, which colonize marsh areas away from the coastline, where salinity levels exceed 60 units and ambient temperatures exceed 45 degrees Celsius. Species of the genus Laguncularia are usually found between these two extremes, colonizing the intermediate zone of these ecosystems. These trees reach their maximum height (30 meters) in equatorial zones (0-5 degrees north-south latitude) and decrease (average height of 5 meters) as they move away from the equator, to 28 degrees latitude in both hemispheres.[2]

Characteristics of urban mangroves

Mexico is recognized as a megadiverse country, both in terms of its biological wealth—with a high number of flora and fauna species—and its diversity of physical ecosystems, resulting from a wide variety of climates, soil types, and relief. Along its more than 11 000 kilometers of coastline, coastal ecosystems of great ecological importance have developed, including mangroves. Since the 1970s, Mexican coastal areas have experienced significant population growth, driven by the expansion of activities such as industrial fishing, mass tourism, and real estate development targeting high-value segments. This growth has led to the consolidation of large urban centers in coastal areas, intensifying anthropogenic pressure on natural ecosystems.[3]

Mangroves, particularly those located in urban environments, face multiple threats resulting from this rapid transformation of the coastal landscape. The expansion of tourism, port, and urban infrastructure, along with pollution, hydrological modification, and habitat fragmentation, has drastically reduced the extent and ecological functionality of these ecosystems. Despite being legally protected, urban mangroves are often neglected in favor of economic interests, which increases their vulnerability to climate change and extreme hydrometeorological events. Their conservation is crucial not only for their intrinsic value in terms of biodiversity, but also for the ecosystem services they provide, such as storm protection, carbon sequestration, pollutant filtration, and support for local fishing communities.[4]

Impacts of sea level rise on coastal processes

The rise in mean sea level is one of the most significant factors transforming coastal areas. This phenomenon, associated with global warming, has direct implications for the physical and morphological dynamics of the coastline.[5] Among the most immediate effects of sea level rise are the permanent flooding of low-lying land and an increase in the frequency, extent, and depth of floods associated with extreme weather events or extraordinary tides. These changes not only alter the coastal hydrodynamic balance, but also intensify the pressure on the development of settled communities and undermine the sociocultural environment of inhabitants through natural processes such as tides, waves, and coastal currents, amplifying their erosive capacity and destructive potential.[6]

In the medium and long term, the impacts of sea level rise are most clearly evident in coastal morphology. The response of the coastline to these new environmental conditions includes progressive beach erosion, coastline retreat, and loss of dune volume. These transformations occur as part of a natural adjustment process, through which the coast attempts to reach a new dynamic equilibrium in the face of sea level rise.[7] In this context, the conservation and restoration of coastal ecosystems such as mangroves takes on strategic importance. Mangroves act as natural barriers that mitigate the impact of hurricane-generated tides and reduce wave energy, significantly decreasing the magnitude of inland flooding.[8] The roots retain sediments and maintain soil stability, helping to minimize erosion and stabilize the coastline.[9]

Beyond their role as natural coastal protection infrastructure, mangroves play a fundamental ecological role. They are areas of high biological productivity, providing breeding, shelter, and feeding grounds for numerous species of fish, crustaceans, birds, and reptiles, many of which are commercially important or endangered.[10] They also actively participate in the carbon cycle by capturing and storing large amounts of CO_2 (blue carbon), thus contributing to climate change mitigation.[11]

From a social perspective, mangroves support a variety of traditional economic activities, such as artisanal fishing, ecotourism, and the collection of non-timber forest products. They also have cultural and symbolic value for many coastal communities, which have developed ways of life closely linked to these ecosystems.[12] Therefore, their deterioration not only represents an environmental loss, but also a direct impact on food security, economic livelihoods, and the identity of local populations.

In short, mangrove conservation must be understood as a strategy with multiple benefits: ecological, climatic, economic, and social. Its incorporation into public policies on coastal management and climate change adaptation is essential to ensure the resilience of coastal areas to sea level rise and other environmental impacts.[13]

Ecological and social function of mangroves

With the increase in socio-cultural activities in coastal areas, with growing coastal cities and current scenarios of hurricanes and droughts, which will become more intense due to climate change, coastal ecosystems are of great value for their ability to protect against storms.[14] As already mentioned, the intensity of severe weather events can damage coastal ecosystems, altering their resilience and the quality of the ecological and ecosystem services they provide.

Mangroves play a key role in nutrient regulation by acting as filters between terrestrial and marine ecosystems, recycling elements such as nitrogen, phosphorus, and carbon, and improving water quality by retaining sediments and pollutants.[8] Their root structure cushions the impact of storms and tsunamis, providing coastal protection, and they are notable for their high carbon capture capacity, contributing to climate change mitigation. In addition, these ecosystems serve as habitat, refuge, and breeding grounds for numerous aquatic and terrestrial species, many of which are ecologically important or threatened, making them critical biodiversity hotspots.[15]

Mangroves are essential for coastal communities, providing resources such as wood, fuel, honey, and medicinal products, as well as supporting local fisheries that are key to food security.[16] They also have profound cultural value for many indigenous peoples and traditional communities, which integrate them into their practices, beliefs, and ways of life. They also offer opportunities for ecotourism and environmental education, generating income and awareness about conservation, provided that these activities are managed sustainably.[17]

Despite their importance, it is estimated that between 30 and 50 % of the world's mangroves have been degraded or destroyed in the last century, mainly due to intensive aquaculture, urban expansion, and coastal infrastructure.[15] In addition, climate change is exacerbating the effects of sea level rise and soil salinization.

Conservation challenges

Urban mangroves face several important conservation challenges related to fragmentation, habitat loss, and land use conflicts:

- Habitat fragmentation: Urban and tourist expansion fragments mangrove forests, reducing connectivity between remnants of these ecosystems. This affects biodiversity by limiting the dispersal of species and the flow of nutrients essential for mangrove health.[18,19,20]
- Habitat loss: Land use change for activities such as urbanization, agriculture, livestock, aquaculture, oil and tourism industries causes significant reduction in the natural extent of mangroves. This means the disappearance of refuge, breeding, and feeding areas for many species, as well as the loss of fundamental ecosystem services such as coastal protection and carbon sequestration.[20,21,22,23]
- Land use conflicts: Pressure to allocate land for urban, tourist, agricultural, or industrial development generates conflicts with mangrove conservation. In some cases, the privatization of communal lands and the transformation of mangroves into areas for hotels, golf courses, or aquaculture farms intensify ecosystem degradation and affect traditional community management.[24,25]
- Taken together, these challenges call for adequate land-use planning, public policies that integrate conservation with sustainable urban development, and the active participation of local communities to manage and protect urban mangroves from increasing anthropogenic pressure.

Restoration of mangrove ecosystems

The restoration of mangrove ecosystems currently includes several recent and effective actions such as the installation of fences, cleaning, and reforestation. These interventions are part of comprehensive strategies based on ecological restoration principles that seek to promote natural regeneration and succession processes in the ecosystem.

- Fences: These are used to protect restored mangrove areas, limiting access by people and vehicles that can cause physical damage to the ecosystem, as has occurred in projects where anthropogenic impact has been reduced by physical barriers that increase the distance between the source of disturbance and the mangrove.
- Cleanup: This consists of removing solid waste and pollutants that affect the quality of the habitat and the health of the mangrove, thus facilitating the natural recovery of the associated vegetation and fauna.
- Reforestation: This is an active action that involves planting native mangrove species in degraded or deforested areas, using techniques based on knowledge of the species' autoecology to ensure their establishment and growth. This action is usually complemented by hydrological rehabilitation and topographical modifications to restore the water flows necessary for the ecosystem.

These actions are part of an ecological restoration strategy that includes site diagnosis, community participation, monitoring, and adaptive management to ensure the long-term sustainability and success of the

projects. Restoration seeks not only reforestation, but also the recovery of ecological processes and the natural structure of the mangrove.[26,27,28]

Living with mangroves

Coexistence with mangroves in urban areas, especially in tourist areas and ecological parks, is based on ecological restoration that integrates social, ecological, and economic aspects to ensure sustainability and shared benefits.

In these spaces, restoration includes hydrological rehabilitation, cleaning of degraded areas, and reforestation with native species, which allows for the recovery of ecosystem functionality and environmental services, such as protection against hurricanes and floods, in addition to promoting local biodiversity.[26,29]

Mangroves restored in urban ecological parks and tourist areas also serve as attractions for ecotourism, generating sustainable employment and strengthening the local economy, while educating the population and visitors about the importance of conserving these ecosystems.[29,30]

The active participation of local communities and collaboration between authorities, academics, and the private sector are key to the success of these projects, as they promote governance, adaptive management, and social ownership of mangroves, reducing pressures and conflicts over land use in urban contexts.[26,29,30]

Coexisting with mangroves in urban tourist areas and ecological parks involves restoring and protecting these ecosystems through comprehensive strategies that combine ecological restoration, environmental education, and community management, achieving a balance between conservation and sustainable development.

Alternative tourism and environmental education

Uses and benefits of alternative tourism in mangroves

Mangroves offer valuable ecosystem services such as coastal protection, provision of fishing and timber resources, carbon sequestration, and recreation, which can be harnessed through sustainable ecotourism.

Ecotourism in mangroves attracts visitors interested in nature, biodiversity, and local culture, generating income for surrounding communities through guides, lodging, food, and transportation, promoting alternative and sustainable livelihoods.[33,34,35]

Examples such as the Ciénaga de Mallorquín in Colombia and the Los Manglares de Tumbes National Sanctuary in Peru demonstrate that mangrove restoration and conservation can boost responsible tourism, which in turn contributes to the protection of the ecosystem and its biodiversity.[32,35,36]

Economic valuation of mangroves

Studies indicate that the economic benefits derived from mangrove ecosystem services far outweigh the costs of conservation and restoration, making them a profitable investment for communities and governments.[31]

The coastal protection provided by mangroves reduces storm and flood damage, avoiding high infrastructure costs and economic losses, while fishing and tourism generate sustainable direct income.[31,32]

Environmental education linked to alternative tourism raises awareness among visitors and residents about the importance of conserving mangroves, strengthening local governance and reducing harmful practices, which in the long term ensures the continued provision of economic and ecological benefits.[33]

Alternative tourism and environmental education in mangroves promote sustainable use that economically values these ecosystems, while encouraging their conservation and the well-being of local communities.

Other urban wetlands

Urban wetlands comprise a wide variety of aquatic and semi-aquatic ecosystems found within or around cities and their suburbs, including not only mangroves, but also other types such as lakes, hot springs, irrigation canals, dams, and fjords.

Types of urban wetlands other than mangroves

- Lakes and lagoons: These are bodies of fresh or brackish water with little or no circulation, which may be natural or artificial, and function as reservoirs of biodiversity and hydrological regulators in urban areas.
- Hot springs: Hot water springs that form unique aquatic ecosystems with flora and fauna adapted to these conditions, which may be found in urban or peri-urban areas.
- Irrigation canals and dams: Artificial wetlands that, although created for agricultural or supply purposes, also perform important ecological functions, such as providing habitat for aquatic species and regulating the water cycle.
- Fjords: In urban coastal areas with glacial relief, fjords can constitute deep marine wetlands that interact with estuarine ecosystems and mangroves.

These urban wetlands, whether natural or artificial, perform essential functions for the environmental and social sustainability of cities, such as regulating the water cycle, controlling flooding, conserving biodiversity, providing recreational spaces, and improving air quality and the urban microclimate.

The integrated management of these wetlands requires management plans that identify their characteristics, functions, and threats, promoting their conservation and sustainable use within the urban context to ensure a sustainable and resilient urban future.

Mangroves are only one part of urban wetlands, which also include lakes, hot springs, canals, dams, and fjords, all of which play a key role in the ecology and quality of life in cities.[37,38,39,40,41]

Public Policies

Legal, Institutional, and Conservation Framework for Mangroves in Mexico

Mexico has a solid legal and institutional framework for the protection of mangroves, backed by laws such as the General Law of Ecological Balance and Environmental Protection (LGEEPA), which prohibits their destruction without prior authorization, and the General Wildlife Law, which requires technical studies before intervening in these ecosystems. NOM-022-SEMARNAT-2003[42] regulates their use, conservation, and restoration through specific technical criteria.

The National Mangrove Restoration Program,[43] the National Wetlands Strategy (2018–2024),[44] and the Payment for Environmental Services Program[45] promote restoration, conservation, and community participation in mangrove protection.

Mexico also complies with key international commitments such as the Ramsar Convention, the Convention on Biological Diversity, and the Sustainable Development Goals, which strengthen its global environmental action.

A central aspect is social participation and co-management, where local communities, including indigenous peoples, collaborate in conservation, ecotourism, and environmental monitoring activities, generating economic and ecological benefits.

Notable conservation cases include Sian Ka'an (Quintana Roo), National Marshes (Nayarit and Sinaloa), and Laguna de Términos (Campeche), where community, institutional, and civil society organizations are working together to restore and protect these strategic ecosystems.

METHOD

This research was carried out using a documentary and qualitative approach, focused on the systematic review of scientific and technical literature related to urban mangroves. The methodological process was structured in three main phases: information search, selection, and analysis.

Information search

Exhaustive searches were conducted in high-impact academic databases such as Scopus, Web of Science, ScienceDirect, and Google Scholar, as well as in institutional repositories and university library catalogs (both national and international). The searches were conducted using combinations of keywords in Spanish and English, such as: "urban mangroves," "coastal mangroves," "wetland sustainability," "urban ecosystems," "coastal ecology," among other synonymous or related terms.

Additionally, complementary sources such as reports from international organizations (e.g., Ramsar, WWF, UNESCO) and specialized newspaper articles were included to understand the public and media focus on the issue.

Selection criteria

To ensure the relevance and quality of the documents included, the following inclusion criteria were applied:

- Direct thematic relevance to urban mangroves or mangroves in coastal and urban environments.
- Peer-reviewed academic publications.
- Documents published mainly in the last ten years (2015–2025), also considering classic or foundational sources if they offered solid and current conceptual frameworks.
- Studies with a clearly described methodology, with reliable empirical or theoretical evidence.
- Duplicate works, documents without academic review (such as blog entries or notes without technical support), irrelevant publications or those with redundant information, and those lacking scientific rigor were excluded.

Information analysis

The selected information was systematized through thematic analysis sheets, allowing the content to be organized according to key categories: urban mangrove ecology, ecosystem services, threats and conservation, sociocultural and economic value, public policies, and community participation. This process facilitated

the identification of recurring patterns, key findings, research gaps, and emerging proposals related to the sustainable management of urban mangroves.

CONCLUSIONS

The analysis carried out in this chapter identifies a series of key findings on the ecological, social, and environmental dynamics of urban mangroves in the context of global change:

- Despite intense anthropogenic pressures from coastal urban growth, urban mangroves have shown remarkable resilience. These ecosystems continue to provide essential ecosystem services, including storm protection, hydrological regulation, carbon sequestration, and biodiversity support.
- Mangroves are unique in the world of higher plants, exhibiting particular physiological adaptations—such as viviparity, aerial roots, and salt excretion mechanisms—that allow them to survive in extreme environmental conditions. Their distribution is restricted to tropical and subtropical zones, with well-defined thermal limits. The ecological zoning of genera such as Rhizophora, Avicennia, and Laguncularia responds to gradients of salinity, humidity, and flooding.
- In Mexico, the rapid growth of coastal cities since the 1970s has intensified pressure on mangrove ecosystems, particularly in urbanized areas. The expansion of tourism, port infrastructure, and real estate development has contributed to the fragmentation and loss of functionality of these ecosystems, despite the existence of a regulatory framework for their protection and their classification as endangered species.
- The rise in sea level, linked to climate change, has been identified as a critical factor increasing the exposure of mangroves to coastal erosion, habitat loss, and extreme flooding. In this context, mangroves function as natural barriers that mitigate the effects of extreme hydrometeorological events, stabilize the coastline, and cushion impacts on human communities.
- Mangroves are notable for their high biological productivity and their role as habitat, refuge, and nursery for aquatic species, many of which are commercially valuable or at risk of extinction. They also support traditional practices such as artisanal fishing and the collection of non-timber forest products, and have important symbolic and cultural value for indigenous and coastal communities.
- It is estimated that between 30 % and 50 % of the world's mangroves have been degraded or eliminated in the last century, mainly due to the expansion of aquaculture, urban growth, and coastal infrastructure construction. This trend, exacerbated by climate change, underscores the urgent need to implement comprehensive conservation, restoration, and sustainable management strategies.

RECOMMENDATIONS

- Reaching out to users at different levels (primary, secondary, tertiary) is essential to raise social awareness about the conservation of mangrove ecosystems.
- The implementation of public policies where mutual benefit allows for the coexistence of society and the environment.
- In the case of Mexico, conduct an assessment of the health, coverage, and vulnerability of mangroves.
- Develop an economic value scheme per square meter, based on the ecological and ecosystem services provided by mangroves in Mexican territory.
- The conservation of urban mangroves and their recognition as essential forests for the quality of life of coastal city dwellers should be established at the constitutional level.

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