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# Marine and coastal ecological potential for the economic development of Colombia

Dr. M.J.C. Rozemeijer



**WAGENINGEN UR**  
*For quality of life*



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# 1 Introduction

Colombia is facing enormous challenges in respect to coastal and marine management. Due to alteration in sediment flows, tectonic movements, sea level rise due to climate change and increasing occupation of the coast, erosion and flooding are becoming more and more severe.

Over the years, the concept of Building with Nature has evolved in the Netherlands as a form of water and coastal management. Since the Netherlands has had to manage water for centuries, there has been an aim on designing protective measures that are cost effective, robust and sustainable. Especially now, while the magnitude of sea level rise is not precisely predictable, flexible solutions are needed. Building with Nature aims to be proactive, utilising natural processes and providing opportunities for nature as part of infrastructure development. Integrating natural processes in the design and realisation phase can reduce the costs of construction and maintenance of coastal defence measures. Designing and integrating ecosystem services that function for coastal protection can even generate a new source of income.

Because of this experience, Colombia was interested in receiving a Dutch delegation in September 2013 to inform Colombia about the potential and possibilities of the Building with Nature concepts. This leaflet is one of the products of that visit.

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## 1.1 Ecosystem services

An important concept is ecosystem services. Humankind benefits from a multitude of resources and processes that are supplied by ecosystems. Collectively, these benefits are known as "ecosystem services" and include products like clean drinking water and processes such as the decomposition of wastes or accretion of sediments (coastal defence). Ecosystem engineers, such as oyster reefs or mangroves, are conspicuous habitats that can influence tidal flow and wave action along coasts and within estuaries. In doing so, they modify patterns of sediment deposition, consolidation and stabilization. Ecosystem engineering offers promising possibilities for sustainable coastal protection.

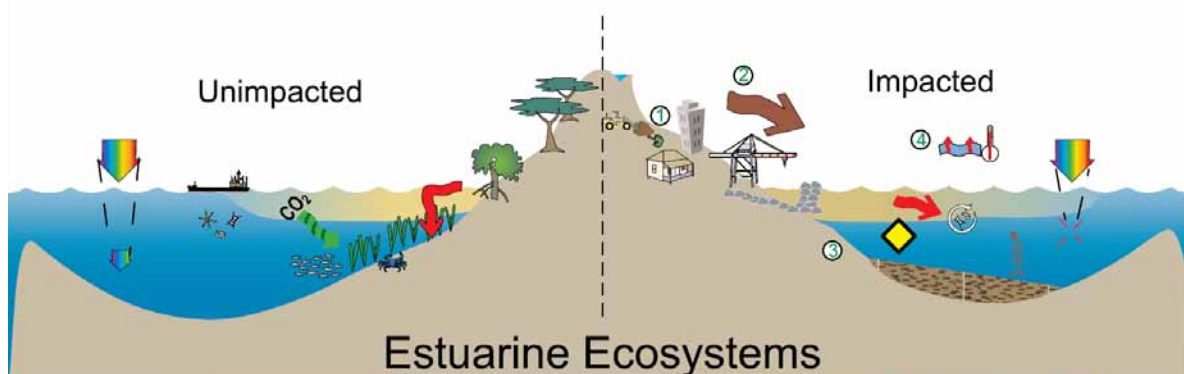


Figure 1 The left side shows a tropical estuary where the system is still capable of delivering ecosystem services like consolidation of sediments, breakwater against waves, production of algae, nurseries for fish and fisheries. On the right side, the ecosystem service potential is markedly reduced.<sup>1</sup>

<sup>1</sup> Figure made available by the Integration and Application Network, University of Maryland Center for Environmental Science.

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## 1.2 Reading guide

This introduction to the contribution that IMARES has made to the Building with Nature concept focuses especially on the potential of ecosystems to aid in increasing the economic potential of coastal areas and seas and to aid in decreasing the costs of management, maintenance and protection of Colombian shorelines and bodies of water.

In this approach we take a bird's-eye view of the Colombian hotspots along the north and west coasts and then focus on relevant sectors where IMARES can provide knowledge and educational programmes for fruitful collaboration. This bird's-eye view is based in part on the insights obtained while supervising the NCCSAP-Colombia Vulnerability Assessment Study (2003).

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## 2 Caribbean coast

The Caribbean coast of Colombia has an enormous potential to be an economic engine. Since it is scarcely occupied, new developments in the direction of ecotourism and occupation industries can still be designed in an integrated manner, taking natural processes into consideration.

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### 2.1 Problem: coastal erosion

Coastal erosion exists: clear examples are the Golfo de Morrosquillo, Cartagena (e.g. Bocagrande) or the coasts near Barranquilla. Causes include the change/alteration of large-scale sediment flows along the coast, shifting tectonic plates and sea level rise. This erosion results in loss of infrastructure, properties, other values and, maybe most importantly, loss of land rights.



Figure 2 Coastal erosion at Cartagena.<sup>2</sup>



Figure 3 Waves overtopping at Cartagena.<sup>3</sup>

2 INVEMAR, Archivo GEZ.

3 © Project Cartagena.

### 2.1.1 Potential solutions: ecological changes with nourishments

Using the Building with Nature philosophy, solutions can be found that include design measures that take natural processes into consideration. A sensible use of natural processes can minimize the costs of construction and maintenance or design. The Netherlands have found out that nourishments are able to stop the retreat of land at substantial lower costs than dikes. Strengthening or designing natural processes and features can generate an added economic value. For a number of locations along the coast, solutions can be defined that consist of a combination of mangroves, large-scale nourishments (soft measures) together with hard or soft breakwaters. Depending on scale, nourishments generate land reclamations and coastal extensions. With such land reclamations, one has the liberty to design specific lay-outs.

For instance, the large sand nourishment Sand Engine on the Dutch coast has been given a lagoon. This lagoon appears to be a richer fish nursery than the shallows along the shore. The nursery phase of fish can be a factor in determining the fish stocks and thereby the fisheries' revenues.

Another option is to design a water flow on the new area that facilitates the potential for open or closed circle aquaculture (e.g. shrimps, fish) with optimal use of resources (Integrated Multi-Trophic Aquaculture (IMTA) systems). In these systems, multiple products are cultured using each other's waste products, increasing efficiency. The end waste waters could be used for the integrated aquaculture-horticulture systems (cultivation of salty crops), another potential income source for the region. Coastal zones can also contribute to a high-quality living environment.



Figure 4 Oyster reef functioning as a breakwater and sediment stabilizer.

To create an optimal design, knowledge needs to be mobilised and generated. For example, the best site-specific strategy has to be defined for nourishments. That could mean small portions in a high frequency or big quantities in a low frequency. Ecoshape IMARES has both the knowledge and the conceptual framework to aid in these decisions.





Figure 5 High-quality living environment at the waterfront in Santa Martha.

### 2.1.2 Potential solutions: ecological changes with breakwaters

Breakwaters can be used to dissipate and reduce wave energy, thereby reducing maintenance costs. Breakwaters can be either soft or hard. They offer excellent potential for aquaculture e.g. clams, lobsters, seaweed and other commercially exploitable resources. Constructions like this also attract fish and can serve as nurseries. Depending on the circumstances, corals and reef structures may also be feasible. The aquaculture installation can be of added value to the coastal defence. Ecoshape IMARES has experience in these fields and with developing an integrated design that optimises the benefits of the breakwater and its aquaculture potential.

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## 2.2 Harbour maintenance

Harbours like Barranquilla incur high maintenance costs for removing fine sediments and silts. A large part of these costs is related to the transport of the removed sediments to other places. However, silts and fine sediments can be used to generate fresh and saltwater marshes, thereby immobilising the sediments and reducing the risk for return flows. These marshes can be used for wastewater treatment, cultivation of biofuel crops or generation of natural values for ecotourism.

Here, Ecoshape IMARES together with Alterra can provide valuable knowledge and experience.



Figure 6 An artificial saltmarsh design using sediments from the nearby harbour.

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## 2.3 Ciénagas: the potential for coastal and river basin protection to be discovered

Ciénagas (brakish water wetlands) represent an enormous potential for ecotourism, fisheries and water sanitation/treatment. An aspect yet to be integrated is the ability to grow with the rising of seas and rivers. The entire system has water and sediments flows. The vegetation is able to capture those sediments, thereby raising the ciénaga's floor. The vegetation then again grows on top of that floor, generating a spiral of system elevation that forms a bastion of sand and protection along the coast. Ciénagas can reduce the costs of coastal maintenance. Taking the almost pristine state of the Caribbean shores, one can imagine a coastal defence system of alternating human occupation and ecosystem coastal protection of mangroves, saltmarshes and ciénagas.

In addition ciénagas are important for fisheries and represent an enormous potential for ecotourism. However, these natural dynamics are vulnerable so it is necessary to understand the system in order to be able to optimise the full economic potential of fisheries, ecotourism and coastal protection.

Ecoshape IMARES, working together with Alterra, offers an elaborate set of knowledge and models that can improve system understanding and help make the best integral evaluation of how to manage these important areas.



Figure 7 Ecotourism values in Ciénaga de Pijíño.

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## 2.4 San Andrés, Islas del Rosario: coral gardens, tourist paradise

The San Andrés archipelago, Islas del Rosario and other reef-spots are beautiful destinations for tourists, especially due to their beautiful corals. The coral garden offers protection, fishery resources and tourist income from diving. It is essential to keep these essential and vulnerable reef structures in the best shape to deliver the highest ecosystem services. Threats include over-exploitation, sedimentation and wastewater.

With programmes like Triple-P@sea for the Dutch Caribbean islands, IMARES aims for economic development in combination with preservation and development of ecosystems. Tourism and other activities are expected to increase and new agricultural and maricultural developments are being explored. Coastal occupation will rise with increasing tourism, but the associated increasing quantities

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of wastewater will threaten the vulnerable corals. For example, in Bonaire, the sources of freshwater fluxes were inventoried and the associated impacts on water quality were assessed.

The concept of ecosystem services offers opportunities to link economic activities sustainably to the rich biodiversity of the Colombian Caribbean. Utilising the full potential benefit of ecosystem services in developing the San Andrés archipelago, Islas del Rosario etc. requires comprehensive evaluation, functional management, specific education and appropriate preservation and strengthening of existing ecological qualities. For all initiatives it is necessary to start with an integrated evaluation of the impacts of the sectors involved or affected in order to make the best planning and realisation for this valuable and vulnerable area. An approach could be:

- A) Knowledge development on coastal morphodynamics and understanding of erosion and sedimentation processes through modelling the effects of underwater eco-infrastructures on beach and biological development;
- B) Determining how biotic and abiotic factors, natural and artificial colonisation of relevant reef building/mangrove development organisms and the eco(toxico)logy of pollution (incl. waste water components) that can affect biodiversity development;
- C) Quantifying the project's potential to stimulate economic development and social appreciation in relation to the local socioeconomic development plan;
- D) Development and optimisation of an extractive IMTA concept/local sea food species population development for local conditions (and the potential impact of nutrients on the natural environment).



Figure 8 Coral reefs: coastal protection, food source and ecotourism.<sup>4</sup>

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## 2.5 Rivers and deltas like Río Sinú and Río Magdalena with important Building with Nature and ecosystem services potential

Rivers and deltas like the Río Sinú and Córdoba also represent important sand engines that grow with the sea. They are ecologically most important for nurseries of fish and fishing grounds for birds and mammals (e.g. humans). In both the Magdalena and the Sinú Rivers, dams have been constructed and more dams are being planned. These dams will strongly influence water and sediment supply to the coastline. When sediment flows are cut off or changed, coastal degeneration starts and valuable ecosystem services are lost. In addition, saltwater intrusion can be enhanced and "biological flows" can stop. Think of migratory fish that need to migrate upstream or downstream to spawning grounds

4 © Royal Netherlands Institute for Sea Research.

and nursery grounds; fish passage measures can be designed and IMARES has the technology to monitor and optimise these measures.

Upstream sediment catchment areas can help modulate sediment flows. Newly formed barrier islands with shallows can help prevent saltwater intrusion and enhance sediment flows, yielding bird refuges and spawning grounds as well. IMARES and Alterra can help designing these measures to improve river basin and coastal management and ecosystem services.

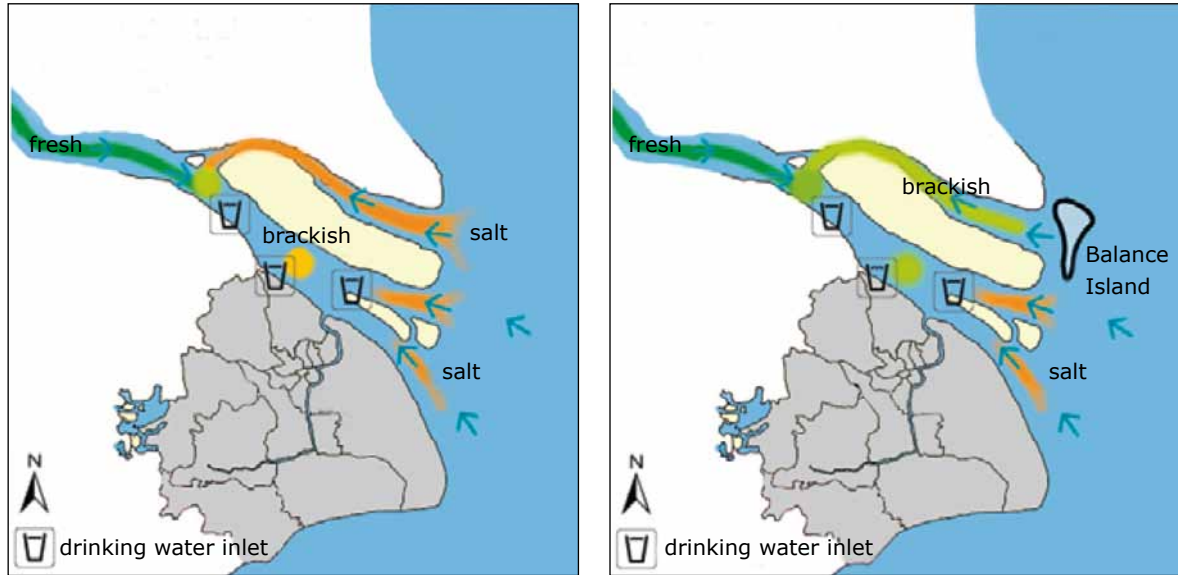


Figure 9 Saltwater intrusion can be hampered by Newly formed barrier islands.

### 3 Pacific coast

Even more than the Caribbean coast, the Pacific west coast is an almost pristine coast, one of the last in the world in this scale. It is a biodiversity top spot, including whales and birds. It also is a spot where fisheries for fish, shrimps and shellfish can be optimised. Most of the potential and problems mentioned for the Caribbean are applicable here. In addition, there are some others features: tsunamis, earthquakes, low economic resilience and the elaborate mangrove systems. For tsunamis, breakwater systems integrating aquaculture can both yield protection and boost local economics.

Mangroves are also important breakwaters that give natural protection and provide ecosystem services like fisheries, fish nurseries and ecotourism. On the Pacific west coast, the mangrove areas are extensive and well developed. The entire system is an example of an enormous water energy absorbing system. Older mangrove systems have a well-established rooting that can withstand tsunamis better than recent systems. Due to sediment accretion, these coastal protection systems will grow with the sea level rise. The challenge in this region is to develop the coast line in such a manner that the true value of the ecosystem services is maintained as much as possible.

Ecoshape IMARES, Wageningen UR and Alterra have extensive experience in exploiting the potential of these natural systems for protection, food production and fisheries and achieving maximum sustainable yield from the ecosystem services.



Figure 10 Mangroves are able to accrete sediment and thereby keep level with sea level rise.<sup>5</sup>

5 © UNEP Silvestri & Kershaw, 2010.

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## 4 Realisation 1: integrated coastal and marine spatial planning

As shown, the Colombian coastal zones (both land and sea) are productive areas, offering a wide variety of valuable habitats and ecosystems services. They are also areas that are vulnerable to climate change and natural hazards. These impacts are far reaching and are already changing the lives and livelihoods of Colombian coastal communities. But also measures can have large unwanted impacts.

Integrated coastal management and marine spatial planning aim for the coordinated application of the different policies that affect the coastal zone and are related to activities such as nature protection, aquaculture and fisheries. It is important to involve all stakeholders across the different sectors to ensure broad support for the implementation of management strategies. It starts with the horizontal integration of sectors and departments and vertical integration of local, regional and national authorities exchanging information, wishes and knowledge. IMARES has several integrated management tools (concepts, models and guidelines) for decision-making that focus on marine spatial planning and producers. IMARES also has a lot of experience in maximising stakeholder involvement (e.g. bottom-up stakeholders for fishery stock management and Serious Gaming on Spatial Planning and Risk Awareness).

For spatial planning in the sea it is very important to locate special areas like spawning grounds, nursery areas for fishes or other natural values. Locations of resources like gas, oil or sand for nourishments should also be investigated. For example, for sand extraction it means finding the right balance between reducing the costs of transport versus safeguarding the morphological aspects and important natural values. In addition, designing sand pits with an ecological eye could increase their ecological potential.

IMARES has the conceptual frameworks to aid in making balanced decisions. Essential information is gathered through monitoring and evaluation programmes. IMARES has ample experience in designing, guiding and managing these type of programmes.

## 5 Realisation 2: environmental impact assessments

Once decisions are anticipated, environmental impact assessments of the scenarios become a useful tool for evaluation and studying feasibility. Again it requires an integrated approach encompassing juridical demands and systems requirements to the scale that is relevant for the natural and economic systems. Ecoshape IMARES has extensive experience in managing, participating in and evaluating these types of studies. In addition, it participates in large-scale research programmes for impact estimation, impact modelling and decision supporting for projects such as those related to e.g. the oil and gas industry, sand extraction, nourishment and windmills on the sea.

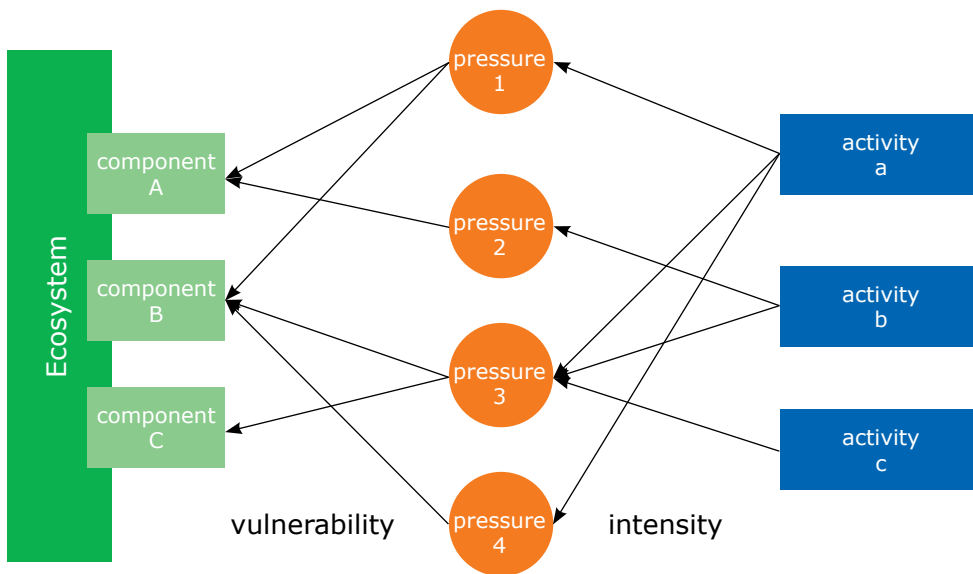


Figure 11 A possible conceptual framework for environmental impact assessment.

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## 6 Summarising the strengths of Ecoshape IMARES

Ecoshape IMARES, working together with Alterra and Wageningen UR, can provide crucial knowledge in the fields of utilising Building with Nature principles, aquaculture, fisheries (especially monitoring, impact estimation, policy and bottom-up fisheries management) and stock assessment. An extensive knowledge base is also available about Caribbean corals, islands and coasts, and their integrated development, taking the economic potential of ecological services into consideration with other stakeholders. Other strong points are aquaculture and the recent developments in IMTA systems, stakeholder processes and monitoring.

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### 6.1 IMARES and Alterra

IMARES is part of Wageningen University & Research centre (Wageningen UR) in the Netherlands. IMARES Wageningen UR is a leading research institute that concentrates on research into strategic and applied marine ecology. IMARES has knowledge about fisheries and aquaculture; delta and maritime technology; water technology and quality; marine policy skills at its disposal to be able to work in cooperation with the parties involved – at both the national and international level – towards the development of better stewardship of the sea.

The university link facilitates new research through academic PhD projects. IMARES uses this newly acquired expertise in applied contract research and offers consultancy and policy support services for both public and private organisations.

Alterra is part of Wageningen University & Research centre (Wageningen UR) in the Netherlands. Alterra Wageningen UR contributes by qualified and independent research to the realisation of a high quality and sustainable green living environment. The fields of expertise are water resources and climate change; spatial planning, land and spatial use and ecology; green economy and biodiversity; soil, water & food security.



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