IPReM

Greater Caribbean 2023

IDENTIFICATION | PROTECTION | RESTORATION | MANAGEMENT

JUNE 28th-30th, PANAMA

Science and technology for sustainablebeaches in a climate change scenario

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MINISTERIO DE AMBIENTE

RISK ASSESSMENT AS A TOOL FOR THE COASTAL EROSION MANAGEMENT

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Universidad del Atlántico
AO: Ocean and Coastal Management Journal and Marine Pollution Bulletin
ELSEVIER

Universidad del Atlántico

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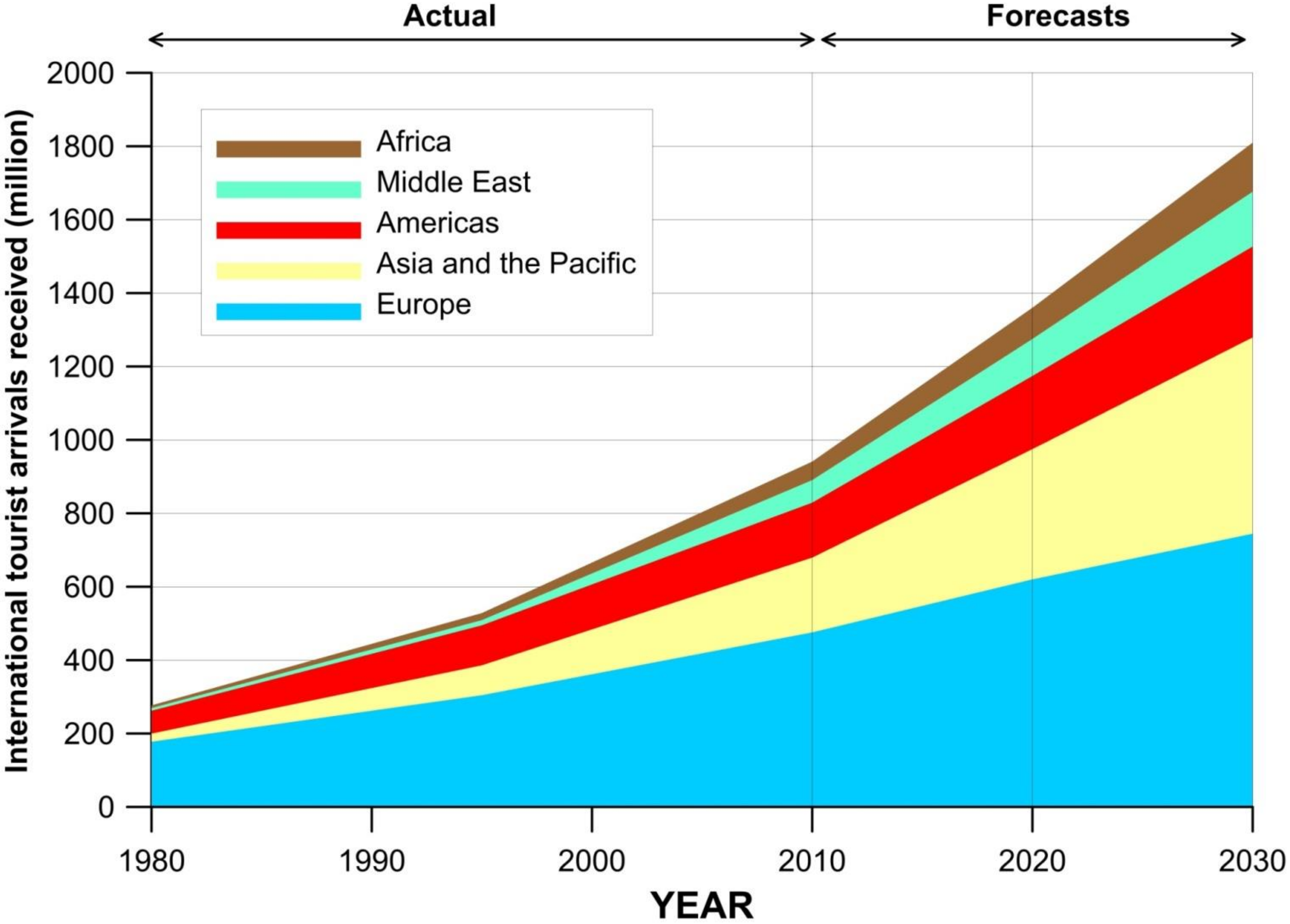
Science and technology for sustainable beaches in a climate change scenario

SAVE THE DATE



Coastal Tourism, also known as **Sun**, **Sand**, **and Sea tourism (3S)** is based on a very particular resource conjunction along the interface between land and sea. This kind of activity offers amenities, such as, good weather conditions, water, beaches, scenic beauty, biodiversity, cultural and historical heritage, healthy food, and **under optimal conditions** an **adequate infrastructure.**

Can you imagine a Caribbean minus its beaches? It's not science fiction, it’s REAL!

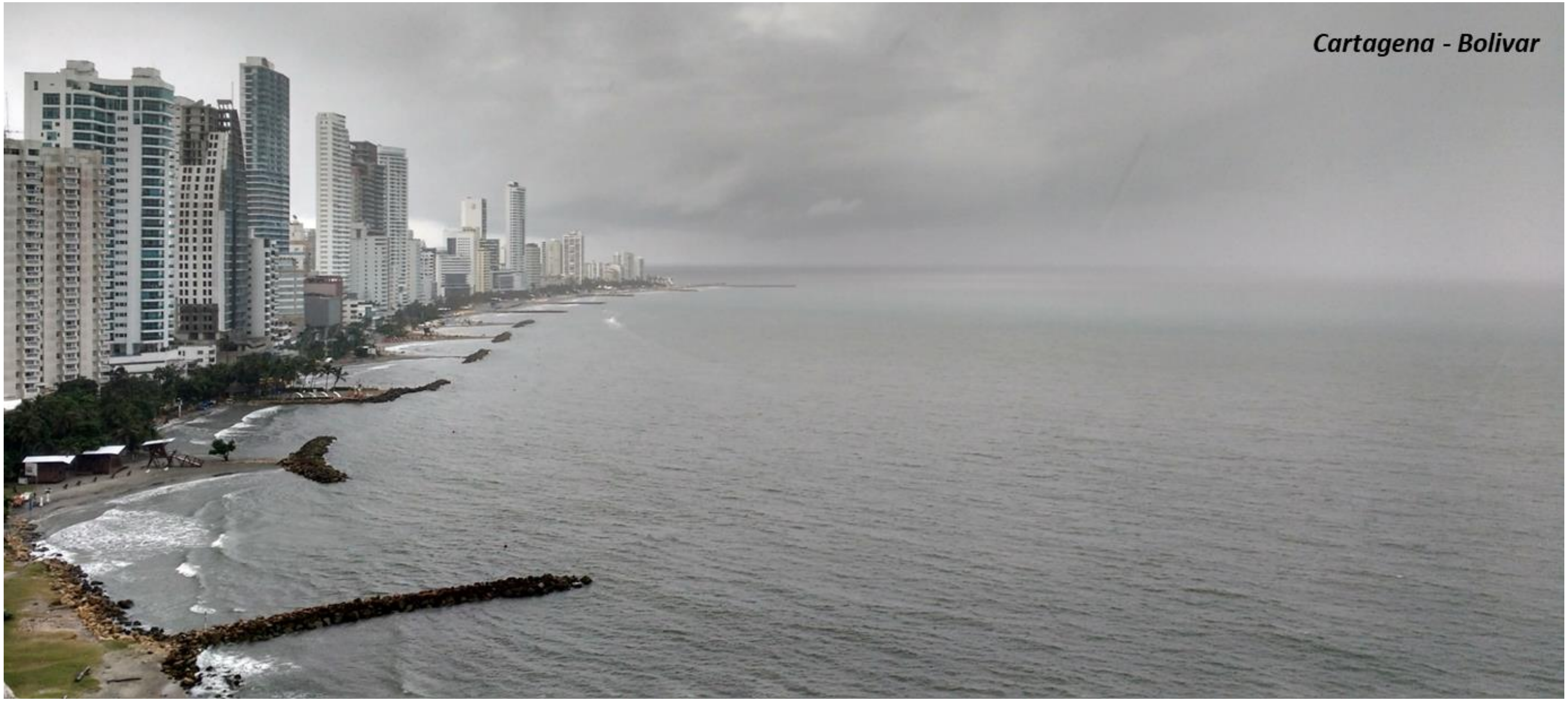
NO BEACHES

↕

NO MONEY…

TO TAKE INTO ACCOUNT!

Coastal Erosion is a normal processes and only becomes a problem when there is no room to accommodate that change.



Cartagena - Bolivar

Coastal Erosion along the Caribbean Coast of Colombia: A big problem!

Department		Type				
		High Erosion	Erosion	Stability	Accumulation	TOTAL
La Guajira	Length (km)	153.0	154.9	348.1	41.1	697
	Percentage (%)	22	22	50	6	
Magdalena		52.1	186.9	24.1	38.9	302
		17	62	8	13	
Atlántico		18.4	18.3	16.5	17.8	71
		26	26	23	25	
Bolívar		111.0	83.0	228.1	46.9	469
		24	18	49	10	
Sucre		26.5	19.8	54.5	11.2	112
		24	18	49	10	
Córdoba		52.8	70.6	36.2	69.4	229
		23	31	16	30	
Antioquia		76.5	128.4	60.4	223.8	489
		16	26	12	46	
San Andres and Providencia		11.3	18.6	44.9	1.3	76
		15	24	59	2	

		High Erosion	Erosion	Stability	Accumulation	TOTAL
TOTAL	Length (km)	502	680	813	450	2445
	Percentage (%)	21	28	33	18	100

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Coastal erosion along the Caribbean coast of Colombia: Magnitudes, causes and management

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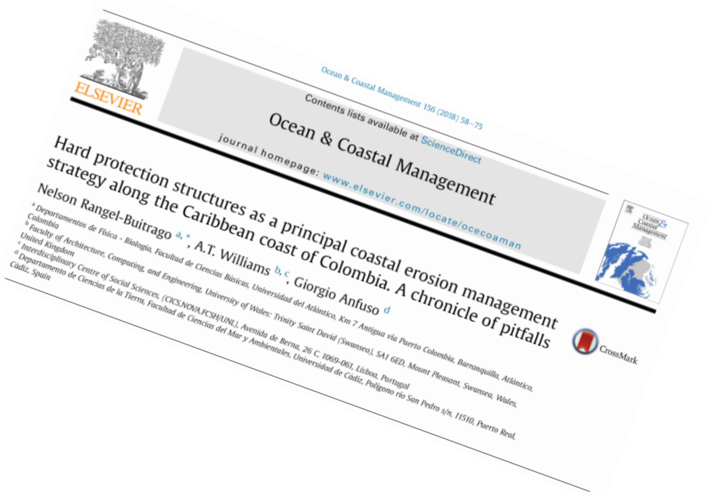
THE CARIBBEAN OF COLOMBIA SOLUTION: COASTAL ENGINEERING STRUCTURES

Action ⟷ Reaction

Action-reaction basis (Rangel-Buitrago et al., 2017).

Erosion ⟷ Structure

A rigid cost-benefit approach (Cooper and McKenna, 2008).



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Hard protection structures as a principal coastal erosion management strategy along the Caribbean coast of Colombia. A chronicle of pitfalls

CrossMark

Nelson Rangel-Buitrago [a, *], A.T. Williams [b, c], Giorgio Anfuso [d]

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SPECIAL ISSUE: MANAGEMENT STRATEGIES FOR COASTAL EROSION PROCESSES
SPECIAL ISSUE EDITORS: NELSON RANGEL-BUITRAGO, ALLAN T. WILLIAMS, ENZO PRANZINI AND GIORGIO ANFUSO

Ocean & Coastal Management

Editor-in-Chief
Victor N. de Jonge

Associate Editors
Xiuzhen Li
Monica Ferreira da Costa

ELSEVIER

THE CARIBBEAN OF COLOMBIA SOLUTION:
COASTAL ENGINEERING STRUCTURES

+1500 hard structures

⬍

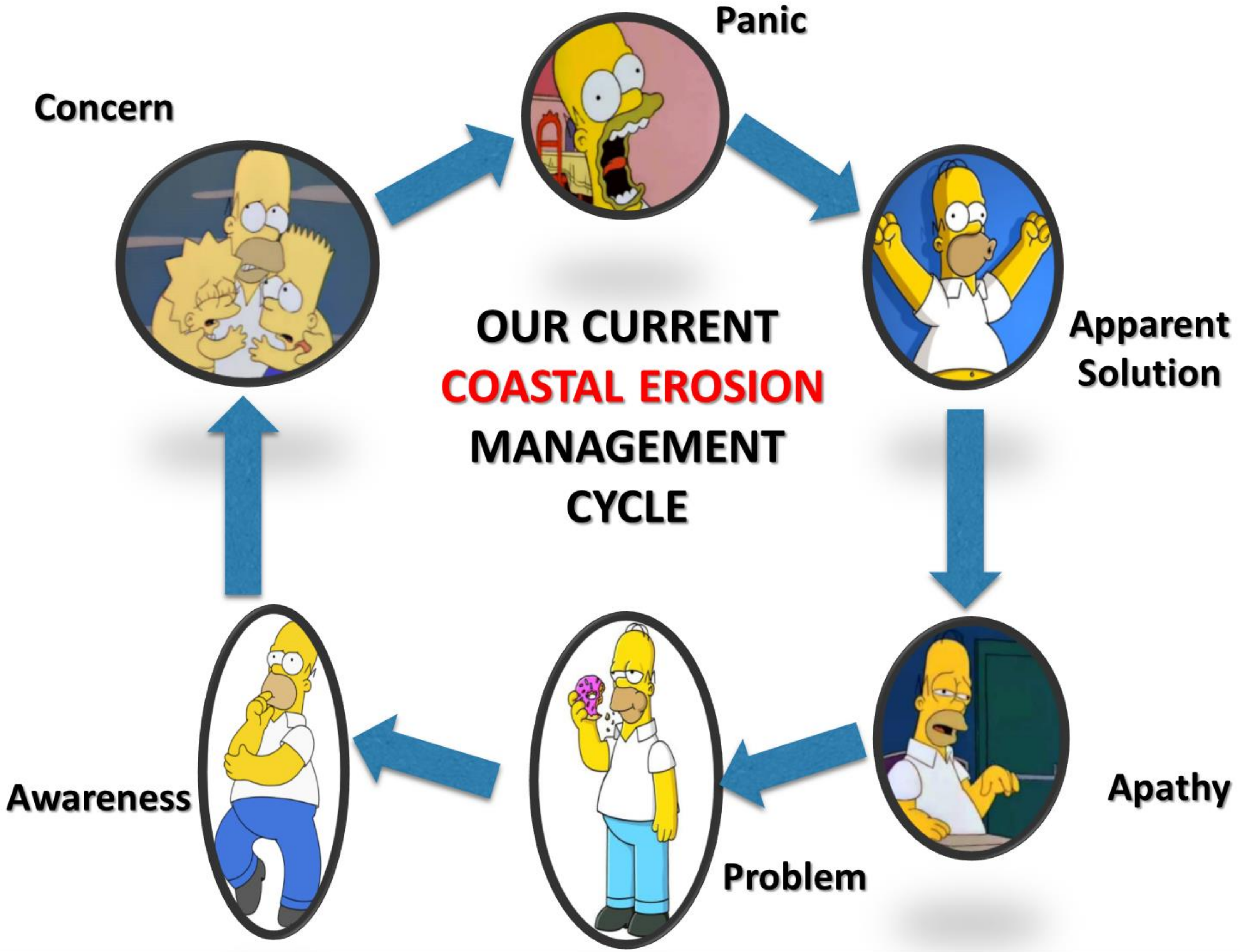
+100 km of Armouring Coastline.

¿Mitigation or Protection?

¿Systematic or empiric? development

The" Domino" effect.

DEPARTMENT	Groin		Breakwater		Seawall, Revetments, Rip-Raps		Other		Total	
	N	Length (m)	N	Length (m)	N	Length (m)	N	Length (m)	N	Length (m)
LA GUAJIRA	55	1689	8	456	18	426	33	636	**114**	**3207**
MAGDALENA	56	1265	23	1005	17	942	29	5214	**125**	**8426**
ATLANTICO	31	2123	0	0	12	523	19	7596	**62**	**10242**
BOLIVAR	185	5364	32	2365	62	13523	42	28399	**321**	**49651**
SUCRE	254	9426	32	901	23	1356	15	586	**324**	**12269**
CORDOBA	135	3845	25	920	52	1562	28	462	**240**	**6789**
ANTIOQUIA	156	4961	23	5785	23	486	21	447	**223**	**11679**
SAN ANDRES	33	521	0	0	24	469	18	456	**75**	**1446**
TOTAL	**905**	**29194**	**143**	**11432**	**231**	**19287**	**205**	**43796**	**1484**	**103709**



OUR CURRENT COASTAL EROSION MANAGEMENT CYCLE

Concern

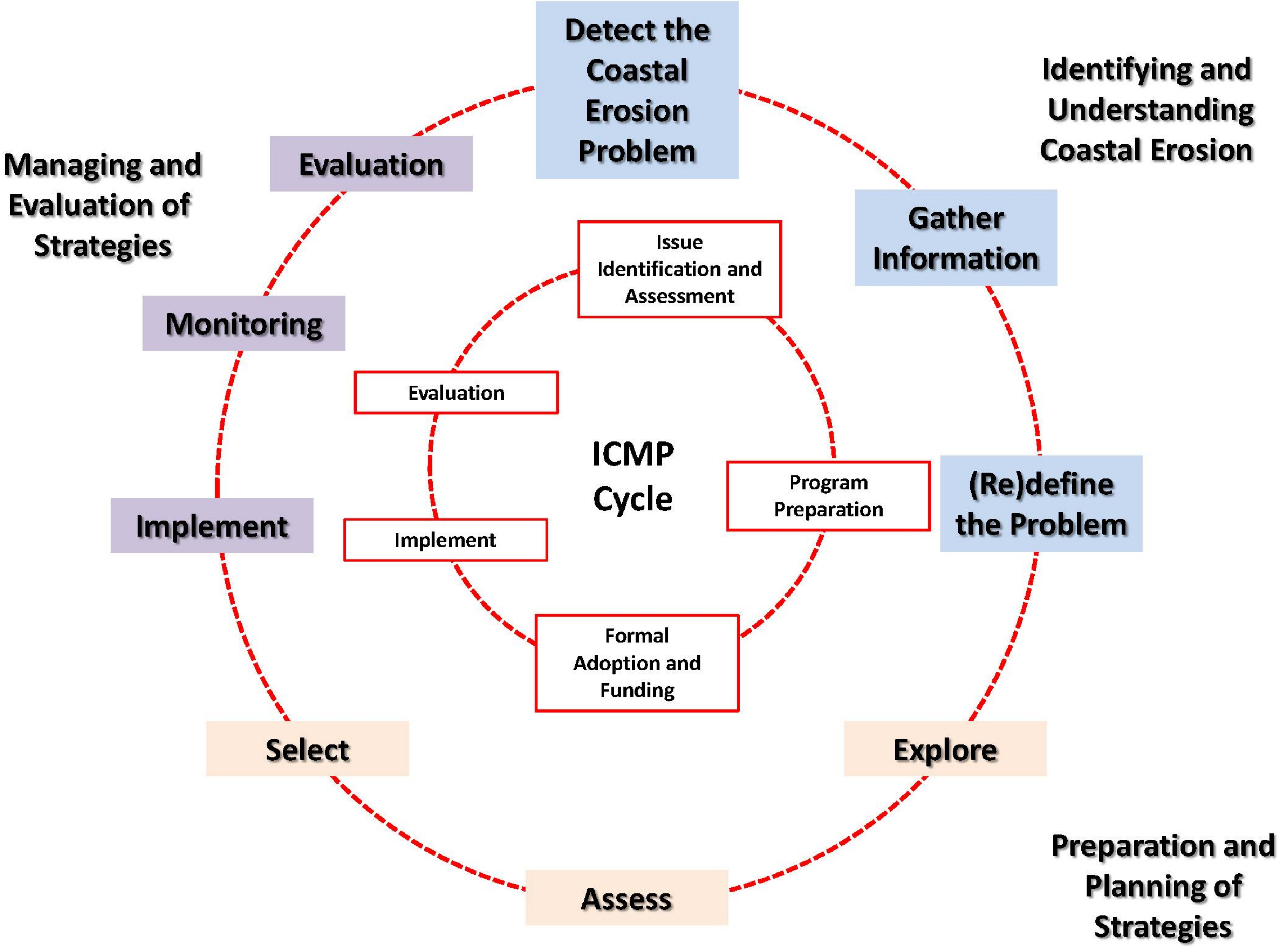
Panic

Apparent Solution

Apathy

Problem

Awareness



Detect the Coastal Erosion Problem

Identifying and Understanding Coastal Erosion

Gather Information

(Re)define the Problem

Explore

Preparation and Planning of Strategies

Assess

Select

Implement

Monitoring

Evaluation

Managing and Evaluation of Strategies

ICMP Cycle

Issue Identification and Assessment

Program Preparation

Formal Adoption and Funding

Implement

Evaluation

The Approaches

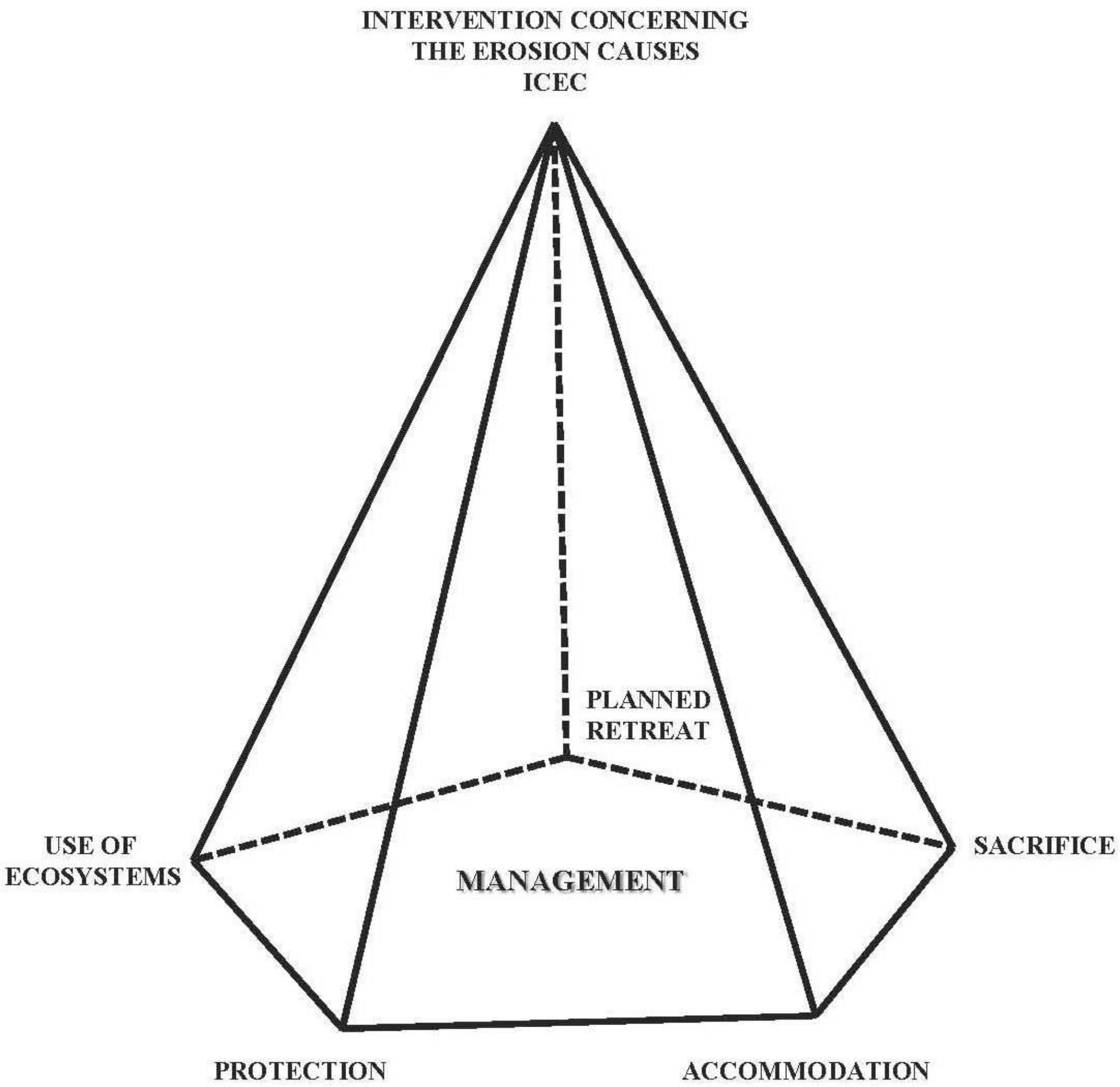
1. Protection: preservation of population centers, economic activities and natural resources (vulnerable areas) using hard structures and/or soft protection measures.

2. Accommodation: occupying sensitive regions, but acceptance of a higher degree of flooding by changing land use, construction methods and improving preparedness.

3. Managed/Planned retreat: removing structures in developed areas, resettling inhabitants with the requirement that new development is set back from the coast, as appropriate.

4. Use of Ecosystems: Influence over processes related to coastal erosion (e.g., sediment capture and energy attenuation) by means of the creation and restoration of coastal ecosystems, such as wetlands (e.g., mangroves), biogenic reef structures (e.g., corals, oysters, and mussels), seagrass beds and dune vegetation.

5. Abandonment/Sacrifice (do nothing): allowing property loss when the suggested protection is not viable, or the accommodation and retreat option does not exist.

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How to make Integrated Coastal Erosion Management a reality

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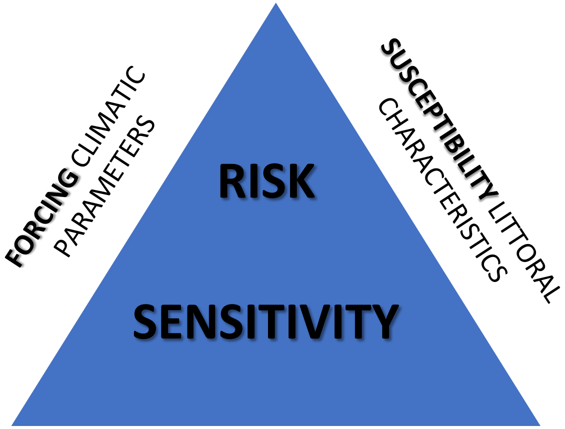
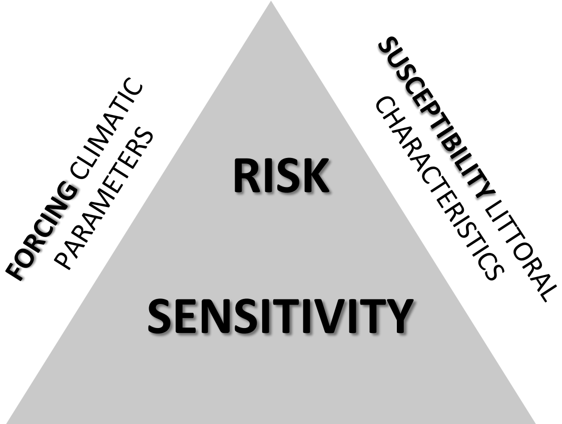
The new ICEC approach includes all existing strategies plus a new endpoint: intervention concerning the erosion causes. Different weightings, which are fluid, can pinpoint a position within the radar chart based on which strategies can be developed, tracked or changed.

As a concept, ICEC is more than just implementing one or a combination of the previously existing approaches. ICEC asks for a policy and implementation process involving more profound knowledge of the coastal erosion and accretion processes as well, and a similar adequate strategy and an operative, management framework. That strategy should be based on historical and scientific knowledge to come to a solution that of course needs to fit management frameworks and should be carried out following the best available techniques.

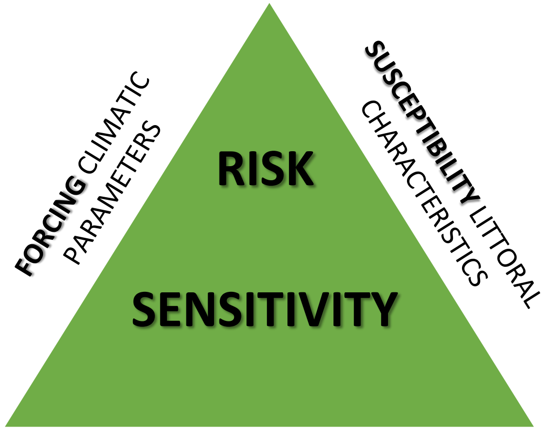
METHODOLOGICAL APPROACH



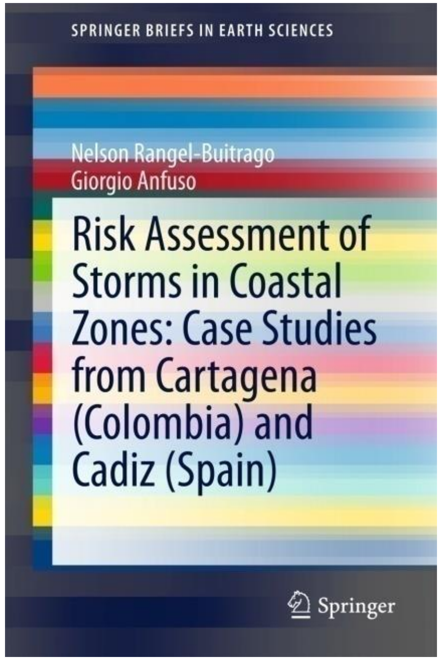
VULNERABILITY
SOCIAL
CONTEXT



VULNERATIBITY
CONSERVATION CONTEXT



VULNERATIBITY
HERITAGE CONTEXT



SPRINGER BRIEFS IN EARTH SCIENCES

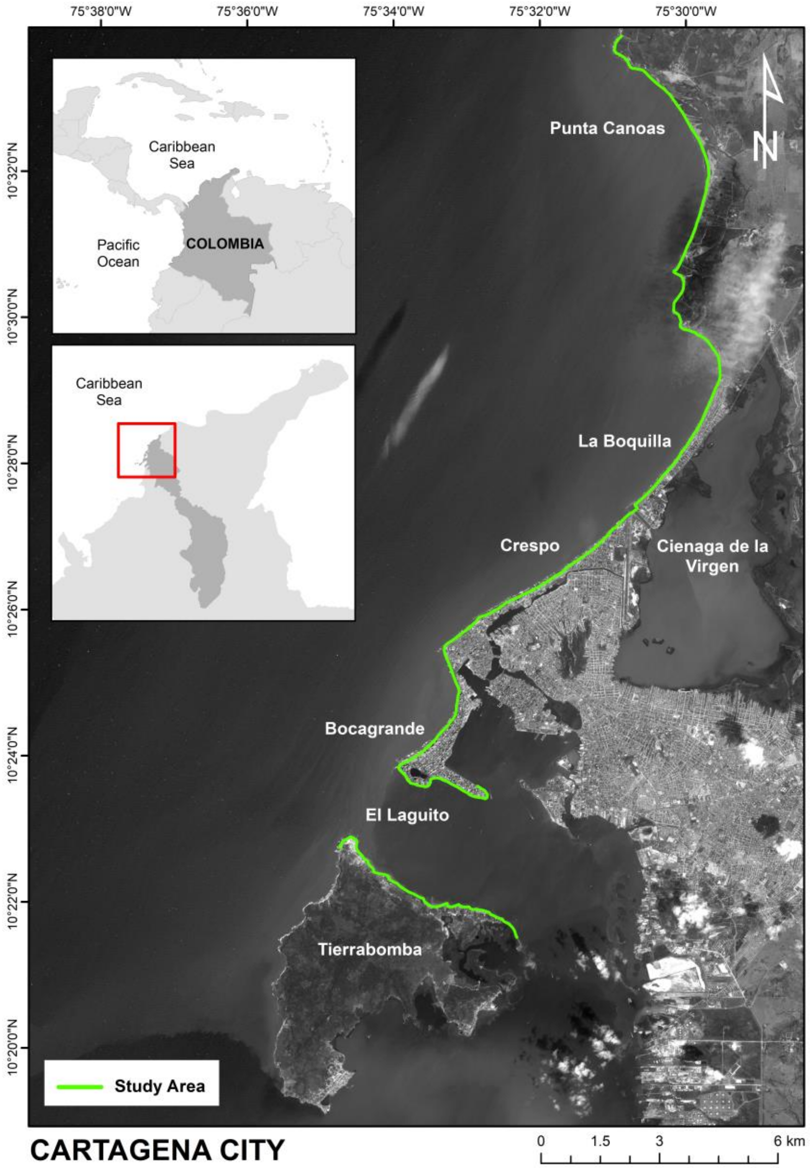
Nelson Rangel-Buitrago
Giorgio Anfuso

Risk Assessment of Storms in Coastal Zones: Case Studies from Cartagena (Colombia) and Cadiz (Spain)

Springer

MODULAR PROGRAMATION

APPROACH



Segmentation of all coastline
500 m x 500 m

KEY POINT : SCALE!

$$Coastal\ Forcing\ Index = \frac{\sum Cfn - nCf}{nCf{*}n} * 100$$

$$Coastal\ Susceptibility\ Index = \frac{\sum CSn - nCS}{nCS{*}n} * 100$$

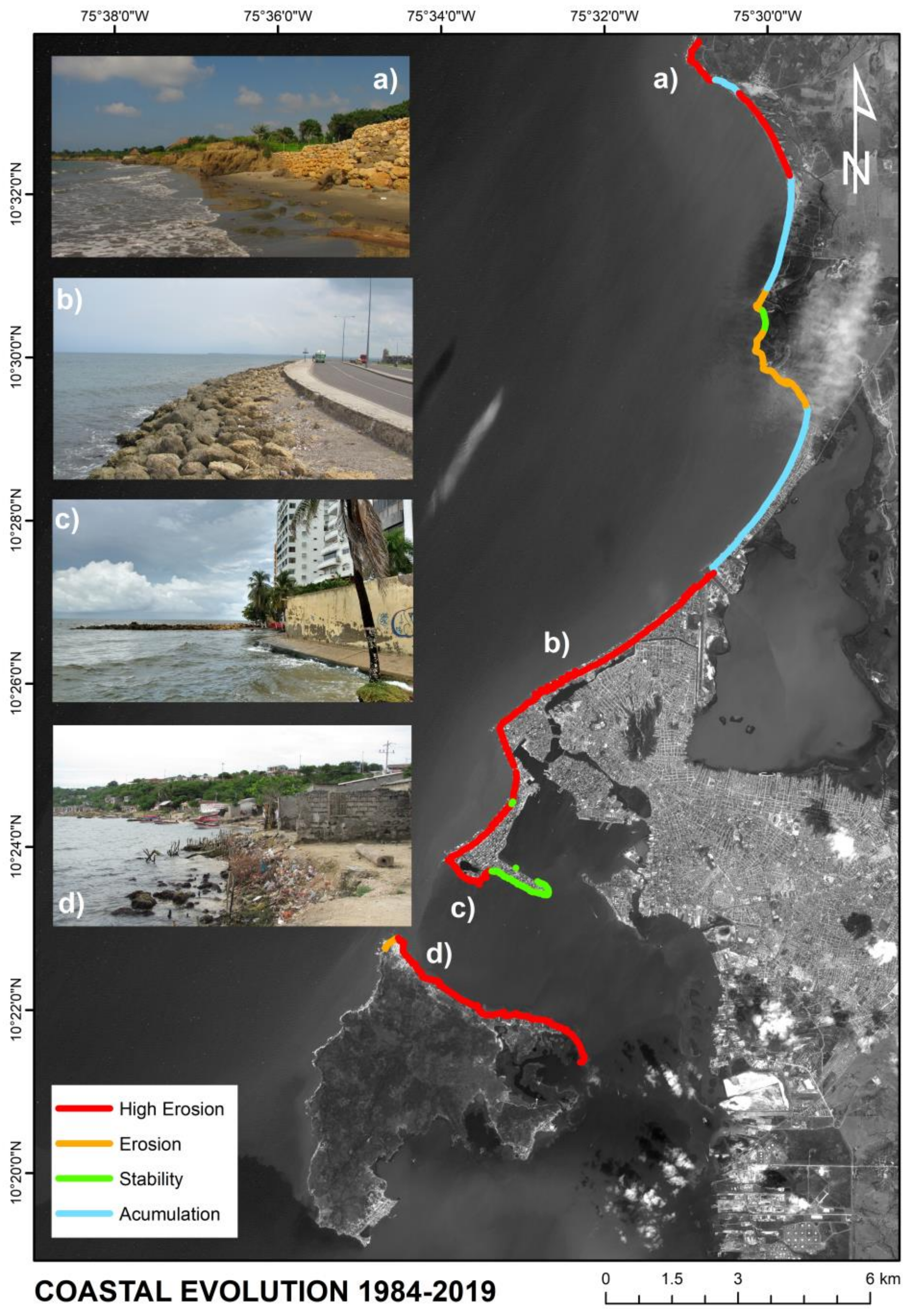
$$Hazard = \frac{(CoastalForcingIndex{*}nCf) + (Coastal\ SusceptibilityIndex{*}nCS)}{nCf + nCS} \tag{3}$$

$$Vulnerability = \frac{\sum Vn - nV}{nV{*}n} * 100 \tag{4}$$

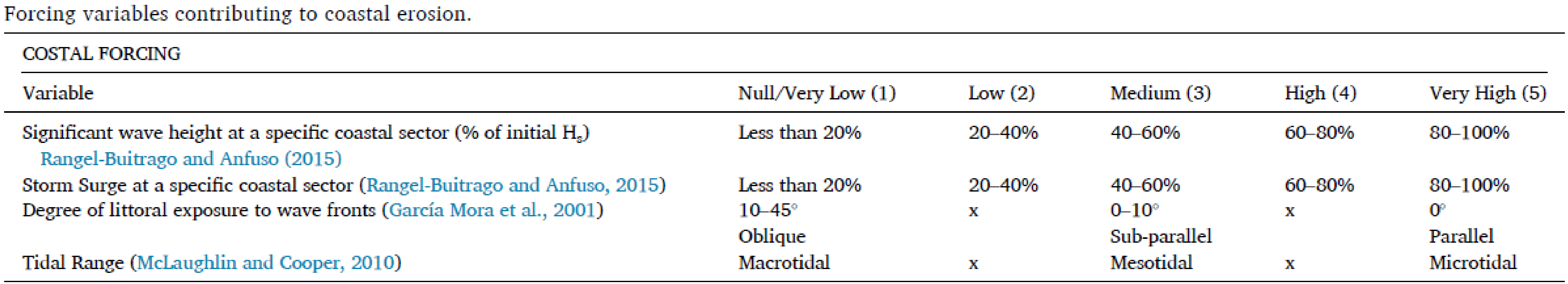
$$Risk = \frac{[Hazard{*}(nCf + nCS)]{*}[Vulnerability{*}(\ nV{*}n)]}{(nCf + nCS) + (nV{*}n)}$$

Coastal evolution trend categories along the Cartagena coastline.

Type	Length (km)	Percentage %
High Erosion	20.0	61.3
Erosion	3.4	10.4
Stability	2.3	7.1
Accumulation	6.9	21.3
Total	32.6	100



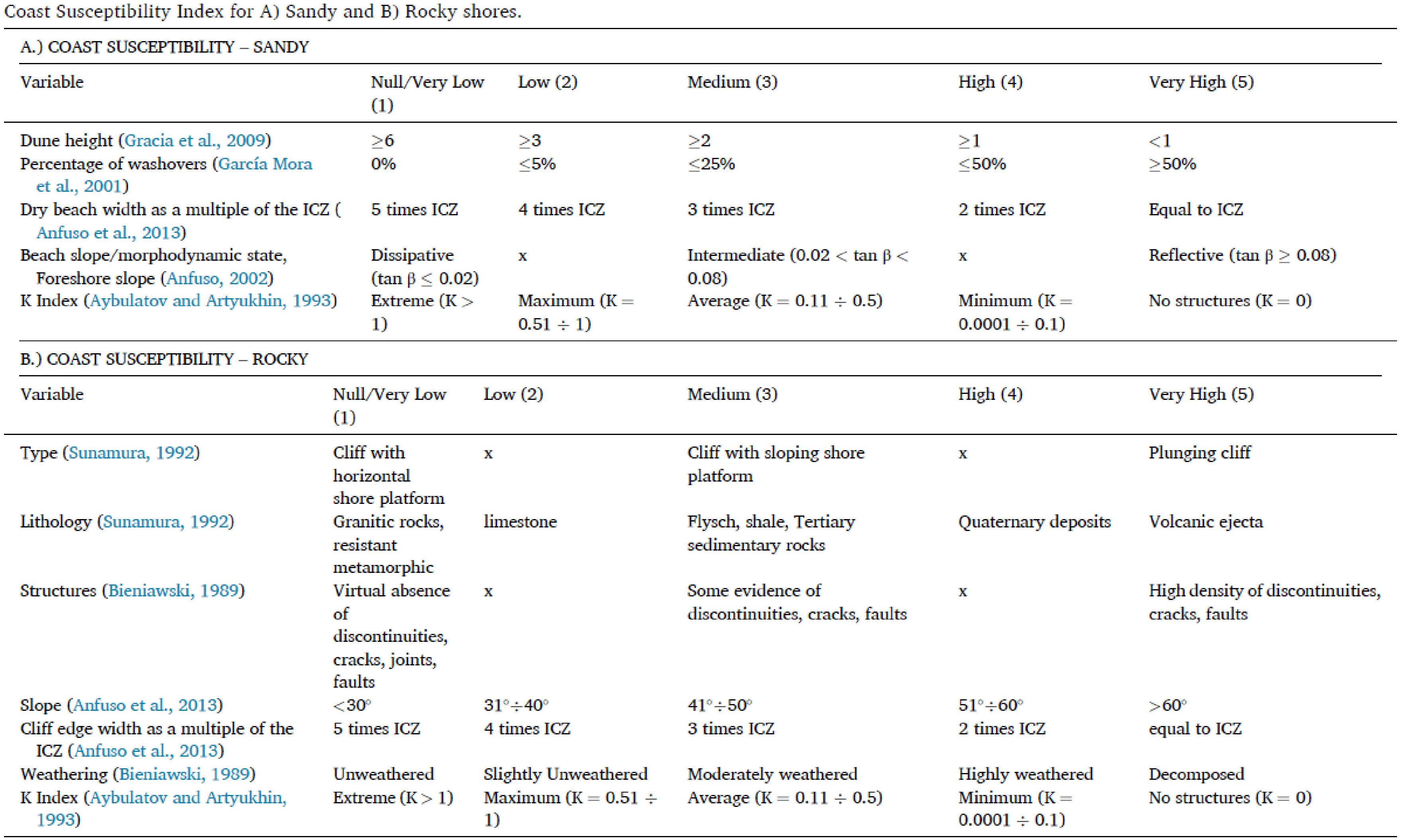
UNISDR (2009) defines **Hazard** as a dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage. In this work, the Hazard Index is defined as a numerical value that indicates the potential of an area to experience damages when it is subjected to coastal erosion, and it depends on two sub-indexes: **Coastal Forcing** and **Susceptibility**.



Forcing variables contributing to coastal erosion.

COSTAL FORCING					
Variable	Null/Very Low (1)	Low (2)	Medium (3)	High (4)	Very High (5)
Significant wave height at a specific coastal sector (% of initial H_s) Rangel-Buitrago and Anfuso (2015)	Less than 20%	20–40%	40–60%	60–80%	80–100%
Storm Surge at a specific coastal sector (Rangel-Buitrago and Anfuso, 2015)	Less than 20%	20–40%	40–60%	60–80%	80–100%
Degree of littoral exposure to wave fronts (García Mora et al., 2001)	10–45° Oblique	x	0–10° Sub-parallel	x	0° Parallel
Tidal Range (McLaughlin and Cooper, 2010)	Macrotidal	x	Mesotidal	x	Microtidal

Coastal Forcing is a numeric value that measures the energy level of all physical processes involved in coastal erosion. This sub-index measures the level of physical stress that any coastal segment could experience during erosion.



Coast Susceptibility Index for A) Sandy and B) Rocky shores.

A.) COAST SUSCEPTIBILITY – SANDY

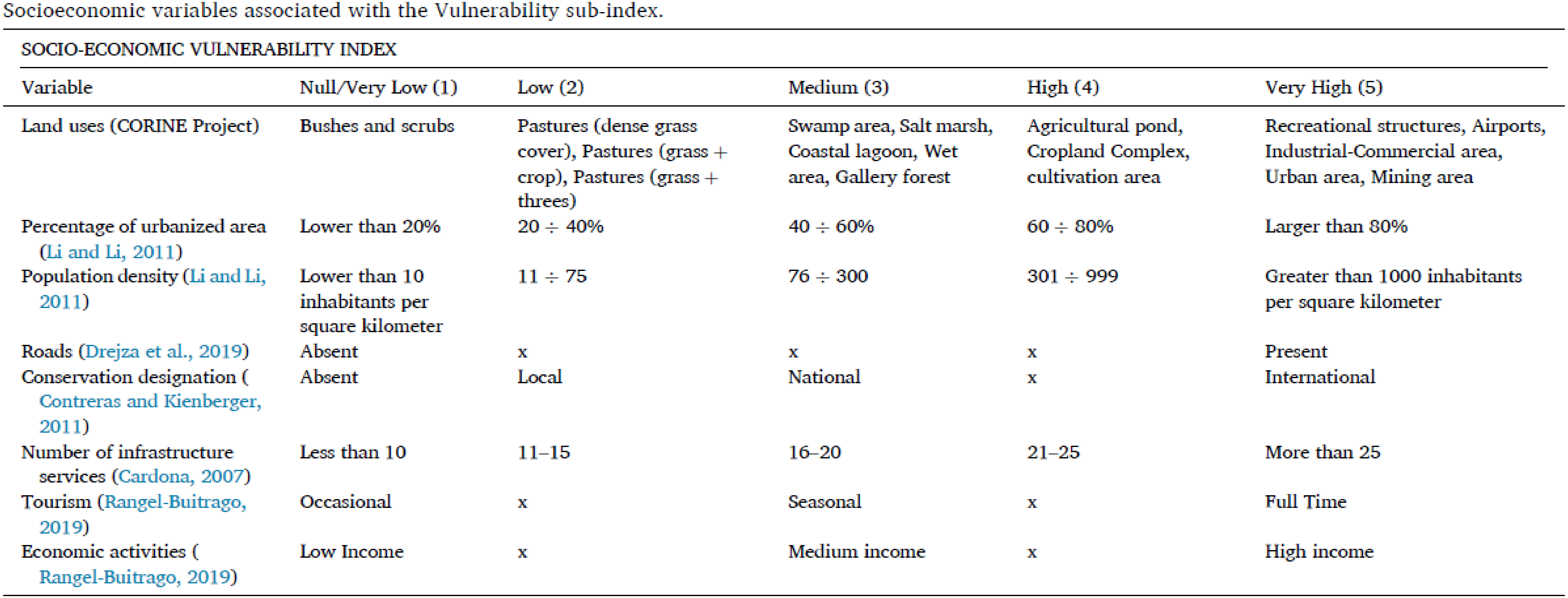
Variable	Null/Very Low (1)	Low (2)	Medium (3)	High (4)	Very High (5)
Dune height (Gracia et al., 2009)	≥ 6	≥ 3	≥ 2	≥ 1	<1
Percentage of washovers (García Mora et al., 2001)	0%	$\leq$5%	$\leq$25%	$\leq$50%	$\geq$50%
Dry beach width as a multiple of the ICZ (Anfuso et al., 2013)	5 times ICZ	4 times ICZ	3 times ICZ	2 times ICZ	Equal to ICZ
Beach slope/morphodynamic state, Foreshore slope (Anfuso, 2002)	Dissipative ($\tan \beta \leq 0.02$)	x	Intermediate ($0.02 < \tan \beta < 0.08$)	x	Reflective ($\tan \beta \geq 0.08$)
K Index (Aybulatov and Artyukhin, 1993)	Extreme ($K > 1$)	Maximum ($K = 0.51 \div 1$)	Average ($K = 0.11 \div 0.5$)	Minimum ($K = 0.0001 \div 0.1$)	No structures ($K = 0$)

B.) COAST SUSCEPTIBILITY – ROCKY

Variable	Null/Very Low (1)	Low (2)	Medium (3)	High (4)	Very High (5)
Type (Sunamura, 1992)	Cliff with horizontal shore platform	x	Cliff with sloping shore platform	x	Plunging cliff
Lithology (Sunamura, 1992)	Granitic rocks, resistant metamorphic	limestone	Flysch, shale, Tertiary sedimentary rocks	Quaternary deposits	Volcanic ejecta
Structures (Bieniawski, 1989)	Virtual absence of discontinuities, cracks, joints, faults	x	Some evidence of discontinuities, cracks, faults	x	High density of discontinuities, cracks, faults
Slope (Anfuso et al., 2013)	$<30^\circ$	$31^\circ \div 40^\circ$	$41^\circ \div 50^\circ$	$51^\circ \div 60^\circ$	$>60^\circ$
Cliff edge width as a multiple of the ICZ (Anfuso et al., 2013)	5 times ICZ	4 times ICZ	3 times ICZ	2 times ICZ	equal to ICZ
Weathering (Bieniawski, 1989)	Unweathered	Slightly Unweathered	Moderately weathered	Highly weathered	Decomposed
K Index (Aybulatov and Artyukhin, 1993)	Extreme ($K > 1$)	Maximum ($K = 0.51 \div 1$)	Average ($K = 0.11 \div 0.5$)	Minimum ($K = 0.0001 \div 0.1$)	No structures ($K = 0$)

Coastal Susceptibility is a numeric value that reflects the level of exposure, and definitive intrinsic characteristics of the coastline (e.g., sandy vs rocky shorelines). The coastal susceptibility index includes all factors that control littoral susceptibility to erosion in the function of the coast typology. The susceptibility value depends on the geological and geomorphological characteristics of the coast, and for assessment, it is necessary to differentiate the coast type (between sandy and rocky) because each typology has its own characteristics, and these cannot be combined.

Vulnerability can be defined as the characteristics and circumstances of a community, system, or asset that make it susceptible to the damaging effects of a hazard (UNISDR, 2009). The vulnerability index calculated here corresponds with a value that denotes the ability of the coastal system to cope with and recover from an erosion event. This index allows the evaluation of the potential impacts of coastal erosion in a socioeconomic, ecological, and cultural framework. There are many aspects of vulnerability arising from various socioeconomic, ecological, cultural, and even physical factors. Examples may include: i) poor building design and/or construction, ii) inadequate protection of assets, iii) absence of public information and awareness, iv) limited recognition of hazards and preparedness measures, amongst others. Vulnerability can vary significantly within the same community and over time. The vulnerability definition used here identifies these aspects as a characteristic of the element of interest (the coast), which is independent of its exposure to eroding forces. However, it is essential to highlight that in common use, the vulnerability concept is often used more broadly to describe the degree of exposure.

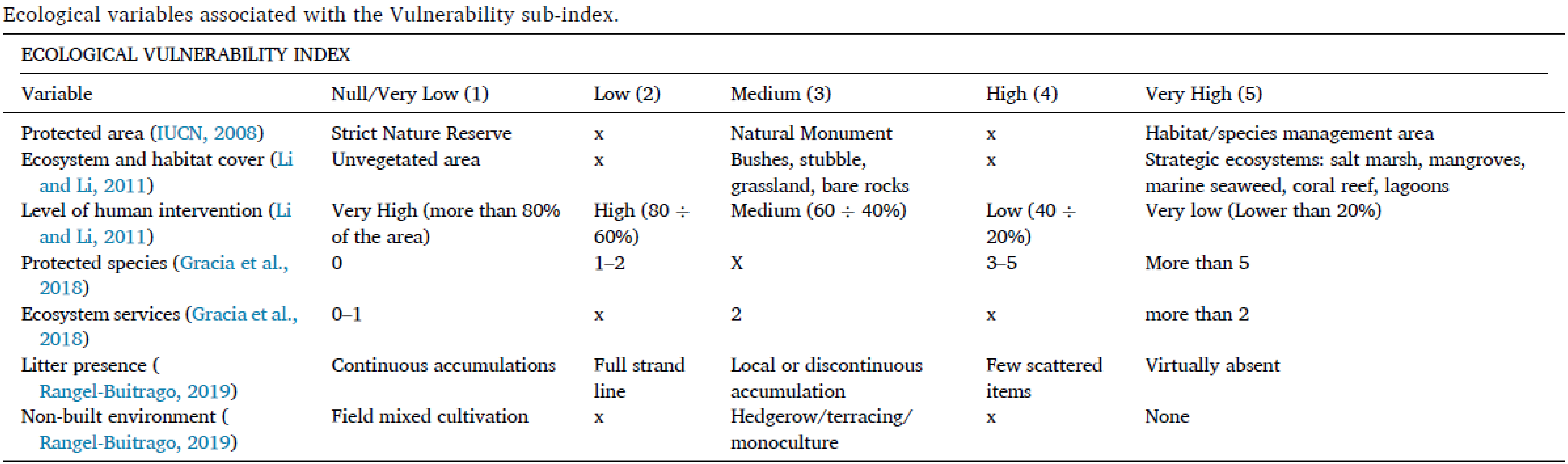


Socioeconomic variables associated with the Vulnerability sub-index.

SOCIO-ECONOMIC VULNERABILITY INDEX

Variable	Null/Very Low (1)	Low (2)	Medium (3)	High (4)	Very High (5)
Land uses (CORINE Project)	Bushes and scrubs	Pastures (dense grass cover), Pastures (grass + crop), Pastures (grass + threes)	Swamp area, Salt marsh, Coastal lagoon, Wet area, Gallery forest	Agricultural pond, Cropland Complex, cultivation area	Recreational structures, Airports, Industrial-Commercial area, Urban area, Mining area
Percentage of urbanized area (Li and Li, 2011)	Lower than 20%	20 ÷ 40%	40 ÷ 60%	60 ÷ 80%	Larger than 80%
Population density (Li and Li, 2011)	Lower than 10 inhabitants per square kilometer	11 ÷ 75	76 ÷ 300	301 ÷ 999	Greater than 1000 inhabitants per square kilometer
Roads (Drejza et al., 2019)	Absent	x	x	x	Present
Conservation designation (Contreras and Kienberger, 2011)	Absent	Local	National	x	International
Number of infrastructure services (Cardona, 2007)	Less than 10	11–15	16–20	21–25	More than 25
Tourism (Rangel-Buitrago, 2019)	Occasional	x	Seasonal	x	Full Time
Economic activities (Rangel-Buitrago, 2019)	Low Income	x	Medium income	x	High income

The socio-economic context of the vulnerability index has been constituted by a series of variables representing social, economic and human activities that, because of their intrinsic characteristics, may be negatively impacted by coastal erosion. The socio-economic context reaches significant importance in any vulnerability assessment because the original concept of vulnerability always was linked to humans and society (Li and Li, 2011; De Serio

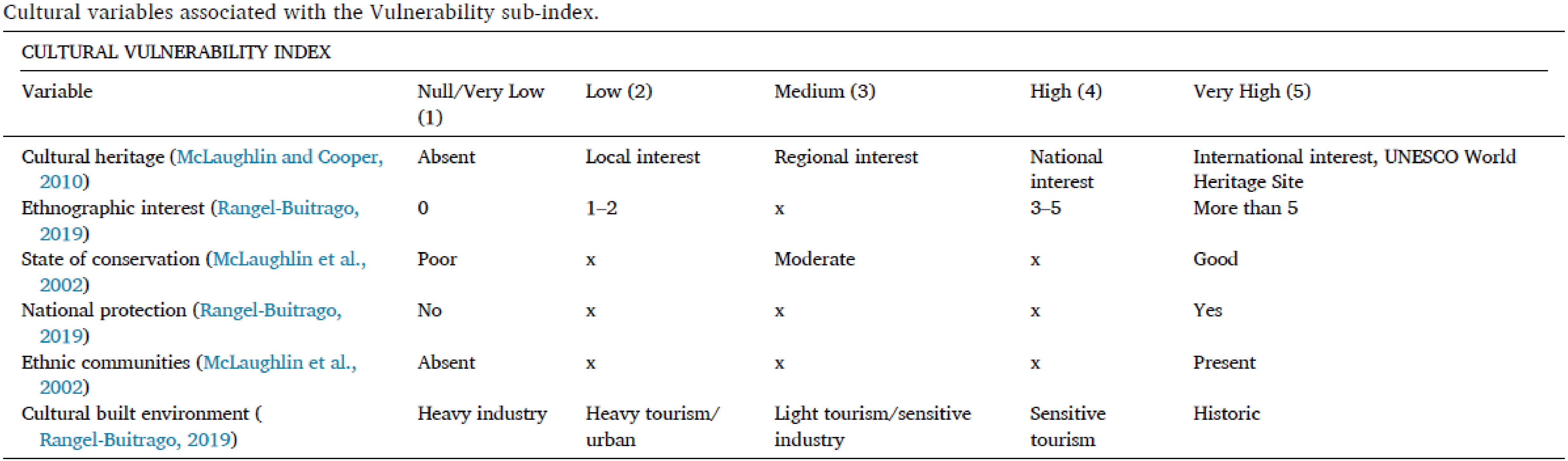


Ecological variables associated with the Vulnerability sub-index.

ECOLOGICAL VULNERABILITY INDEX

Variable	Null/Very Low (1)	Low (2)	Medium (3)	High (4)	Very High (5)
Protected area (IUCN, 2008)	Strict Nature Reserve	x	Natural Monument	x	Habitat/species management area
Ecosystem and habitat cover (Li and Li, 2011)	Unvegetated area	x	Bushes, stubble, grassland, bare rocks	x	Strategic ecosystems: salt marsh, mangroves, marine seaweed, coral reef, lagoons
Level of human intervention (Li and Li, 2011)	Very High (more than 80% of the area)	High (80 ÷ 60%)	Medium (60 ÷ 40%)	Low (40 ÷ 20%)	Very low (Lower than 20%)
Protected species (Gracia et al., 2018)	0	1–2	X	3–5	More than 5
Ecosystem services (Gracia et al., 2018)	0–1	x	2	x	more than 2
Litter presence (Rangel-Buitrago, 2019)	Continuous accumulations	Full strand line	Local or discontinuous accumulation	Few scattered items	Virtually absent
Non-built environment (Rangel-Buitrago, 2019)	Field mixed cultivation	x	Hedgerow/terracing/ monoculture	x	None

The ecological context is based on the conservation premise of natural habitats since these provide natural protection that reduces vulnerability to coastal erosion. Most of the existing vulnerability assessment methodologies only take into account the socio-economic aspect (human component). However, when coastal erosion strikes, all ecosystems located over the coastal environment can be affected, losing their quality, health, status, and conservation degree (Gracia et al., 2018). The integration of ecological variables inside of any vulnerability assessment represents a significant challenge (McLaughlin et al., 2002). The main question lies in deciding how to rank specific sites that sometimes lose their "natural status" because of human alteration. However, 'protection' of a conservation site can hardly include protection from the action of natural processes that formed a particular habitat

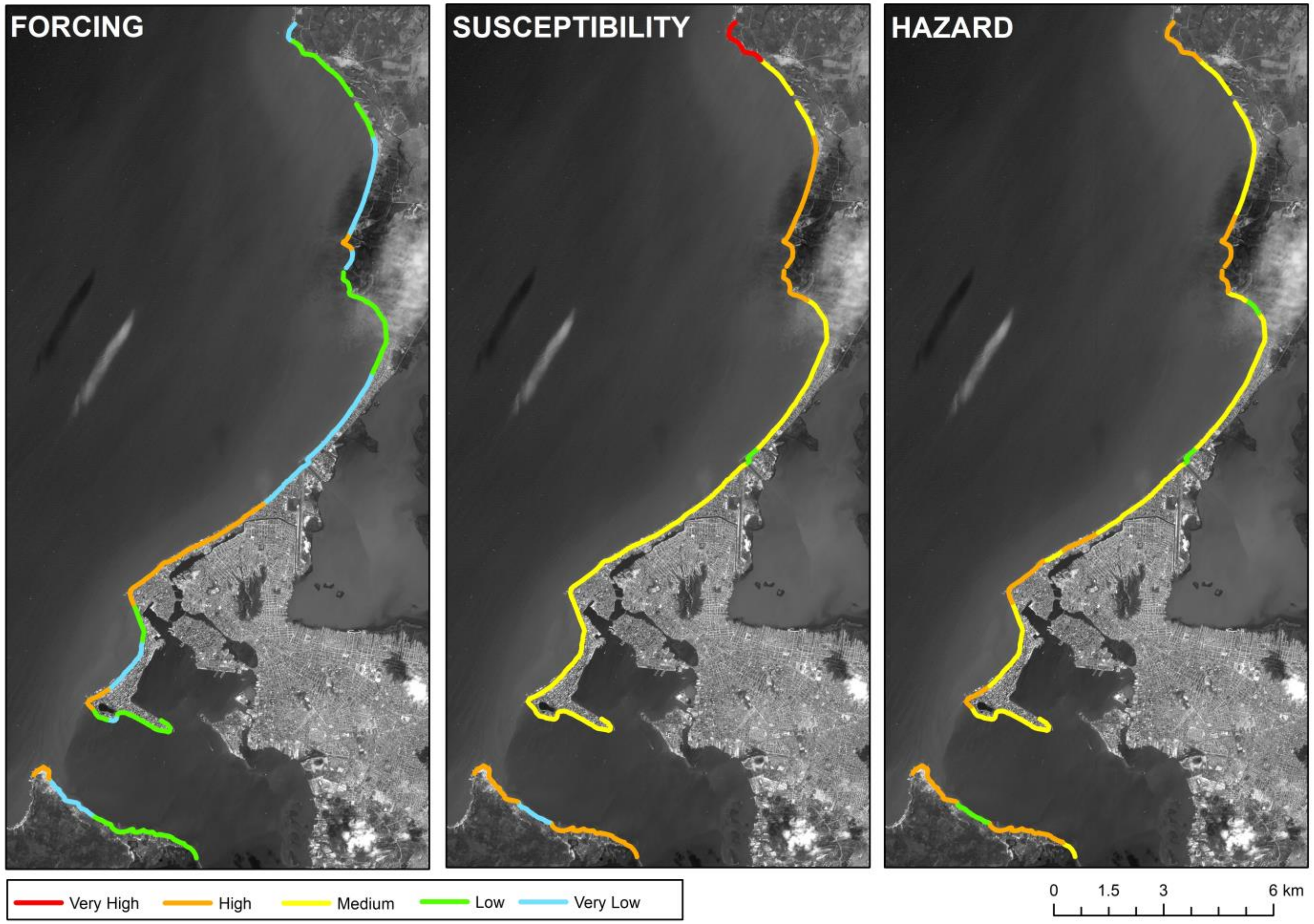


Cultural variables associated with the Vulnerability sub-index.

CULTURAL VULNERABILITY INDEX

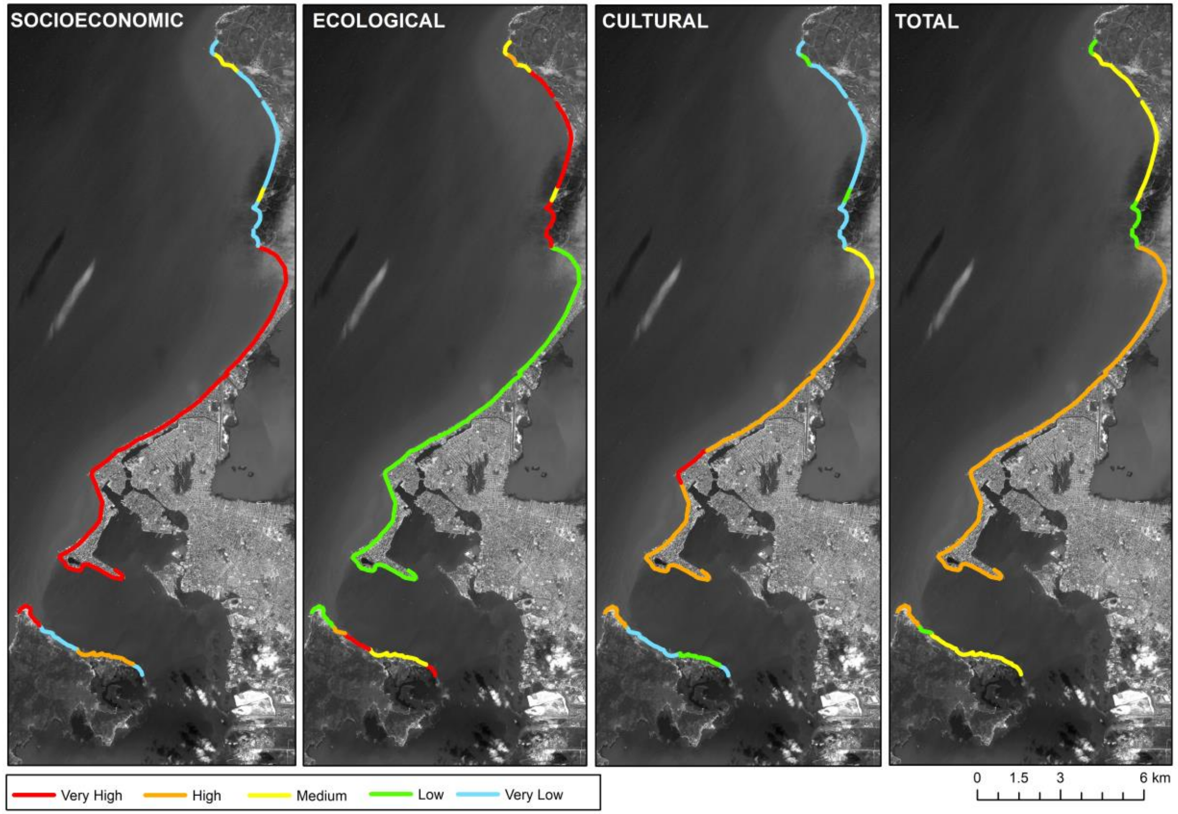
Variable	Null/Very Low (1)	Low (2)	Medium (3)	High (4)	Very High (5)
Cultural heritage (McLaughlin and Cooper, 2010)	Absent	Local interest	Regional interest	National interest	International interest, UNESCO World Heritage Site
Ethnographic interest (Rangel-Buitrago, 2019)	0	1–2	x	3–5	More than 5
State of conservation (McLaughlin et al., 2002)	Poor	x	Moderate	x	Good
National protection (Rangel-Buitrago, 2019)	No	x	x	x	Yes
Ethnic communities (McLaughlin et al., 2002)	Absent	x	x	x	Present
Cultural built environment (Rangel-Buitrago, 2019)	Heavy industry	Heavy tourism/ urban	Light tourism/sensitive industry	Sensitive tourism	Historic

The cultural context is that aspect of vulnerability that places emphasis on protecting/conserving important cultural components such as archaeological, historical, heritage, scientific, and scenic sites. Unfortunately, coastal erosion is responsible for the destruction and loss of world archaeological and heritage sites (Hoogland and Hofman, 2015; Stancioff et al., 2018). Many examples exist where coastal erosion has affected many natural and cultural World Heritage properties (e.g., the Moais on Easter Island, Chile; Slave huts and obelisks in Bonaire; Costiera Amalfitana in Italy).



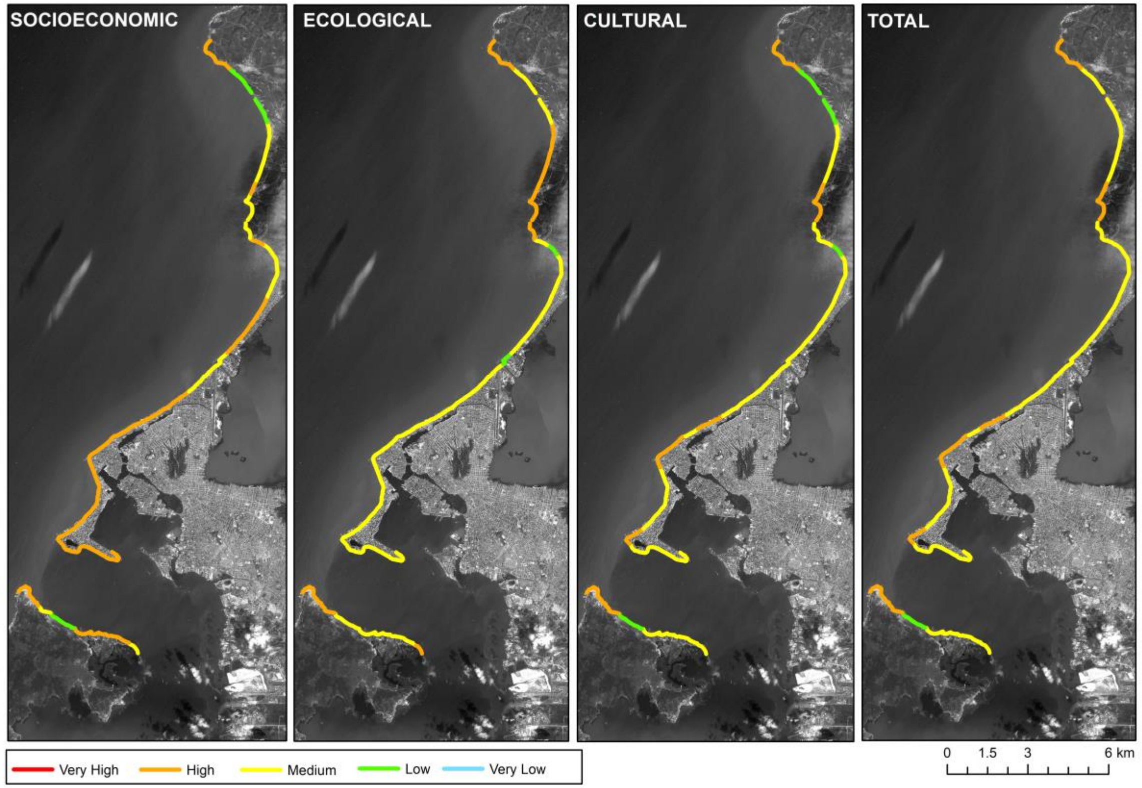
Distribution of forcing, susceptibility and hazard calculated for Cartagena.

		Type					
		Very low	Low	Medium	High	Very high	Total
Forcing	**Length (km)**	0.0	13.6	11.9	7.1	0.0	32.6
	Percentage (%)	0.0	41.6	36.5	21.9	0.0	100
Susceptibility		1.1	0.6	19.7	9.8	1.6	32.6
		3.2	1.8	60.3	29.9	4.8	100
Hazard		0.0	2.1	18.7	11.8	0.0	32.6
		0.0	6.6	57.3	36.1	0.0	100



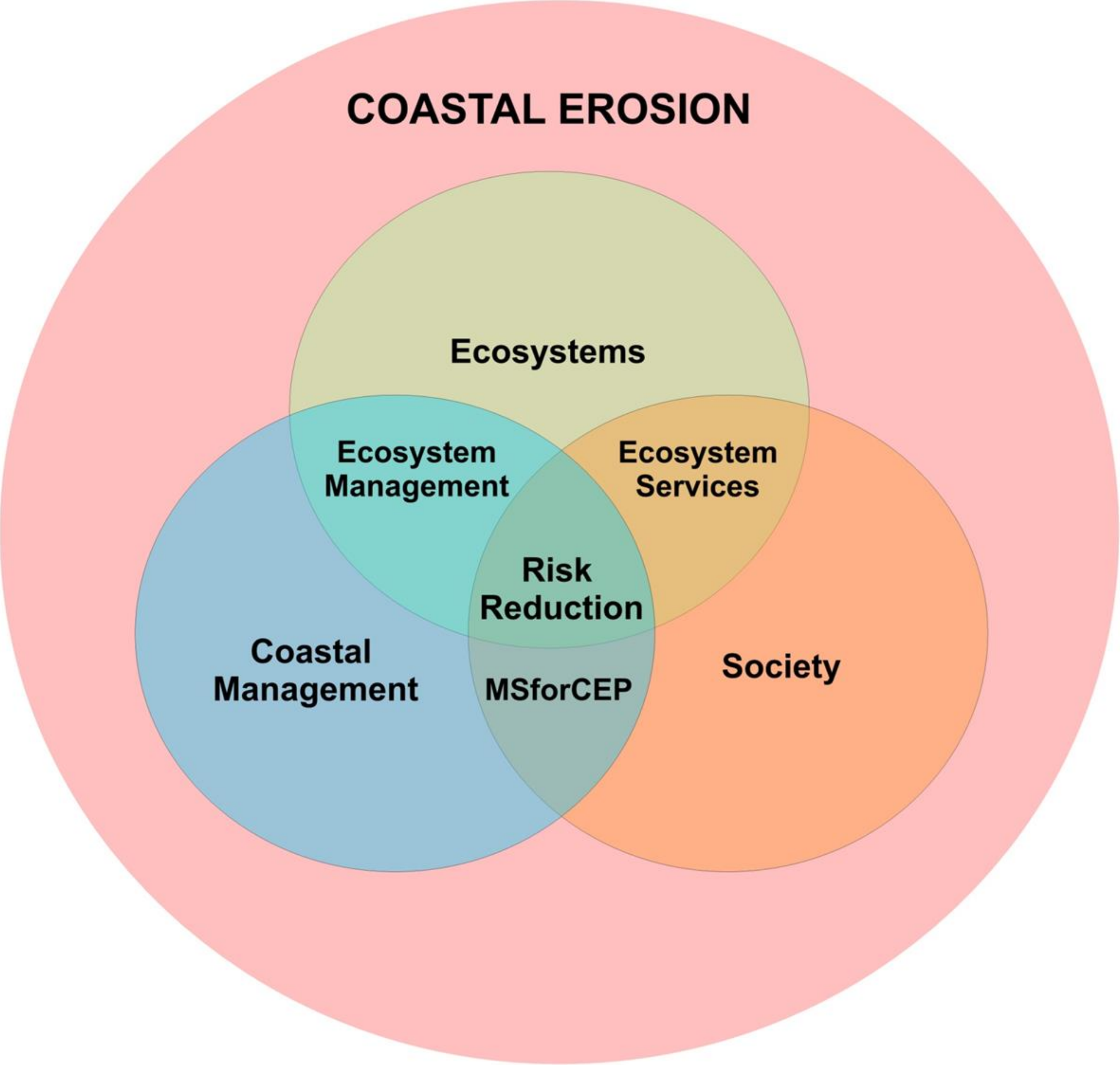
Distribution of Vulnerability calculated for Cartagena.

		Type					
		Very low	Low	Medium	High	Very high	Total
Socio-economic	**Length (km)**	8.8	0.0	1.6	2.3	19.9	32.6
	Percentage (%)	26.9	0.0	4.9	7.1	61.1	100
Ecological		0.0	19.9	3.9	1.1	7.7	32.6
		0.0	61.1	11.9	3.3	23.7	100
Cultural		9.9	2.8	1.6	16.7	1.7	32.6
		30.5	8.5	4.9	51.0	5.2	100
Total		0.0	2.9	9.8	19.9	0.0	32.6
		0.0	8.9	30.1	61.1	0.0	100



Distribution of Risk calculated for Cartagena.

		Type					
		Very low	Low	Medium	High	Very high	Total
Socioeconomic	**Length (km)**	0.0	3.2	9.4	20.1	0.0	32.6
	Percentage (%)	0.0	9.8	28.8	61.5	0.0	100.0
Ecological		0.0	1.1	23.1	8.5	0.0	32.6
		0.0	3.4	70.7	26.0	0.0	100.0
Cultural		0.0	3.7	20.1	8.8	0.0	32.6
		0.0	11.4	61.5	27.1	0.0	100.0
Total		0.0	1.1	22.7	8.8	0.0	32.6
		0.0	3.2	69.7	27.1	0.0	100.0



COASTAL EROSION

Ecosystems

Ecosystem Management

Ecosystem Services

Risk Reduction

Coastal Management

MSforCEP

Society

SPECIFIC MANAGEMENT RECOMENDATIONS

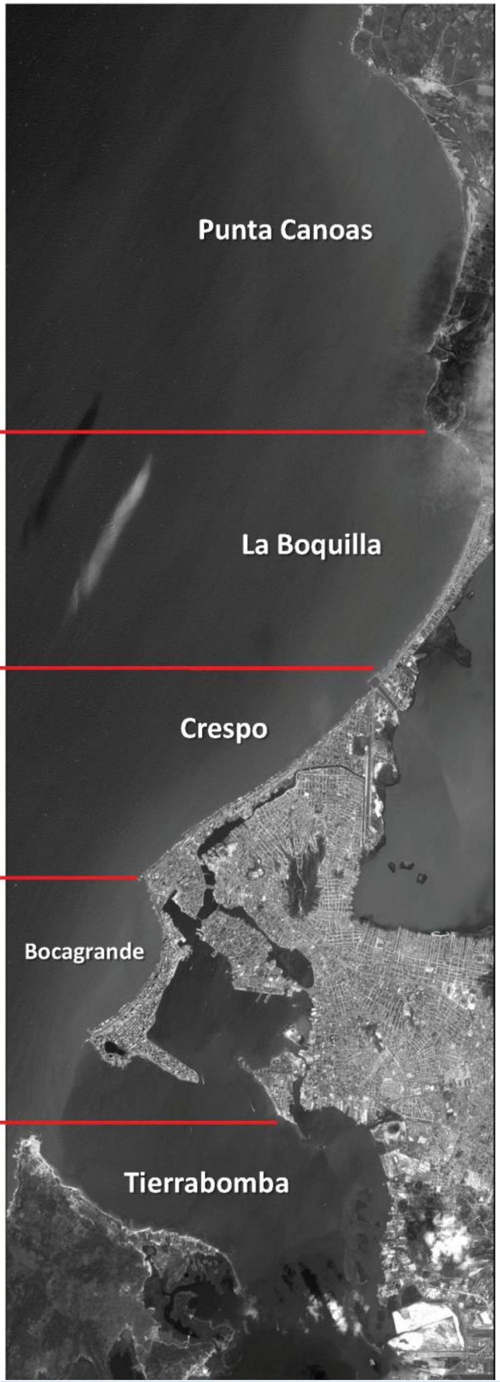
Conserve Sand Supply
[No development or shore-hardening on spits]
Maintain and Strengthen Set-Back Requirements
[Remove beach buildings/structures]
Strengthen Zoning Requirements
[Maintain rural land usage]
Establish Beach Nourishment Plan
[Response to erosion 'hot spots']
No new shore-hardening projects

Conserve Sand Supply
[No development or shore-hardening on northern spit complex]
Keep Existing Beaches Free of Seawalls and Groins
Ban Development of New Buildings that Increase Population Density
Develop New Strict Set-Back Requirements for New Buildings
Reduce Number of Buildings that Abut Back of Beach
[Disallow replacement of buildings destroyed in storms]
Maintain Integrity of Barrier Landform
[No new artificial inlets]

See above: over-urbanization has induced erosion; destroyed natural system.
Restore Sand Supply
[Depends on up-stream districts removing groin fields.
Will require massive on-going nourishment projects.]
Building Code Improvement
[Require buildings to elevate, floodproof, and new infrastructure.]
Develop new programs to finance ever-escalating costs of recovery

Restore Beach Sand Supply
[Systematic Removal/Modification of Shore-Hardening Structures from N to S. Develop sand by-passing system at inlet. Remove Groin Fields. Rebuild protective beach - using replenishment.]
De-urbanize
[Limit size of new buildings/ban replacement buildings. Flood- proof all buildings subject to flooding, and develop sacrificial uses of ground floors.]
Elevate Existing and New Construction based on projected sea-level rise.
Replace Infrastructure to meet expected erosion/flooding from sea-level rise and increased storm energy.

Strengthen Set-Back Requirements
[No new construction within 600 m of shoreline. Planned retreat of existing buildings within 0 to 60 m of shoreline.]
Maintain Existing Landforms and Habitats
[Zones of prohibited construction.]
Reduce Impacts of Shore-Hardening Structures/Maintain Sand Supply
[Ban on new structures; selective removal of existing structures.]



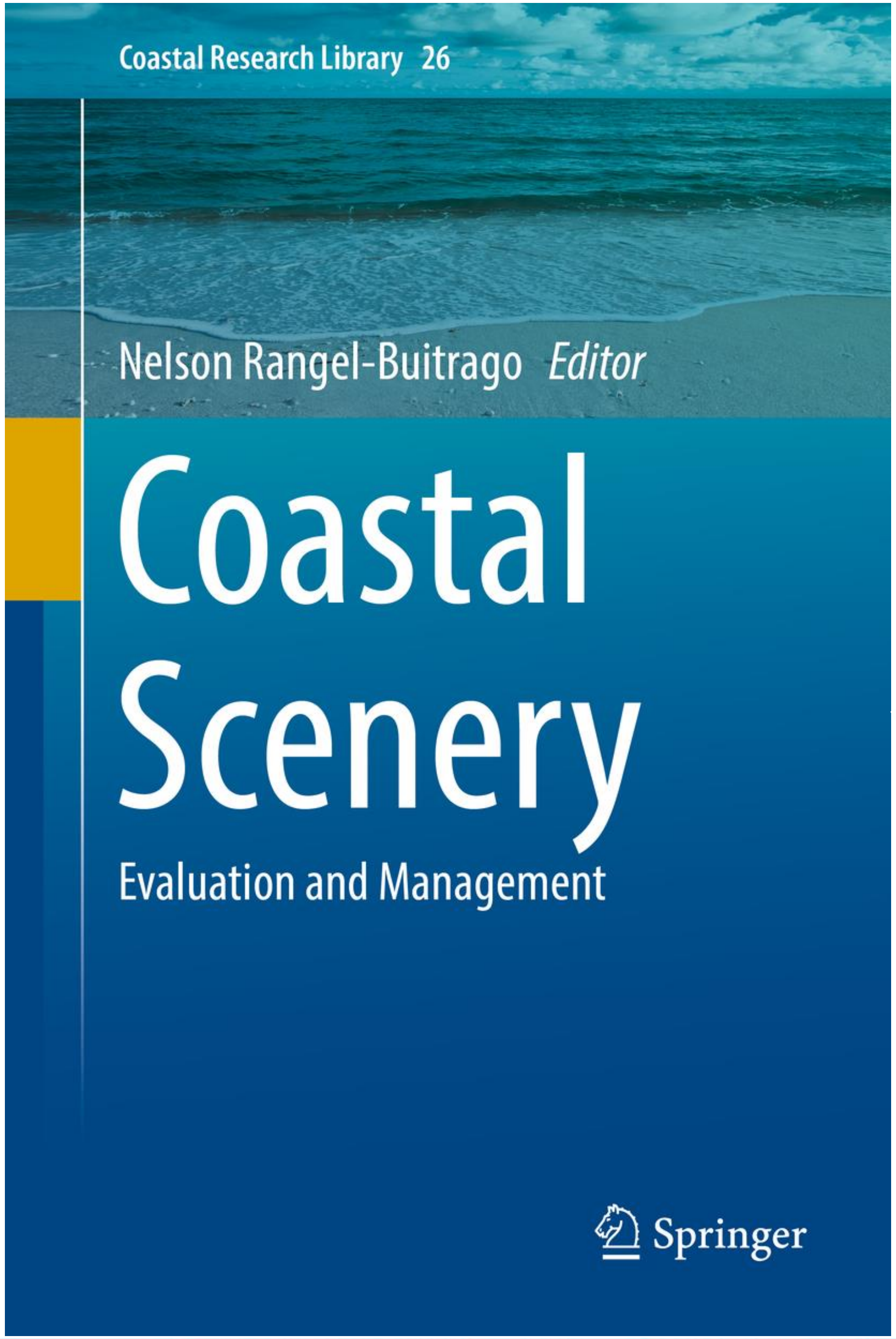
Which one?

a)

b)

c)

d)



Coastal Scenery

Evaluation and Management

Edited by Nelson Guillermo Rangel-Buitrago
Universidad del Atlántico

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Can coastal scenery be managed? The Valparaíso region, Chile as a case study

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Not all that glitters is gold: Can the real scenic value of the Colombian Caribbean coast be restored?

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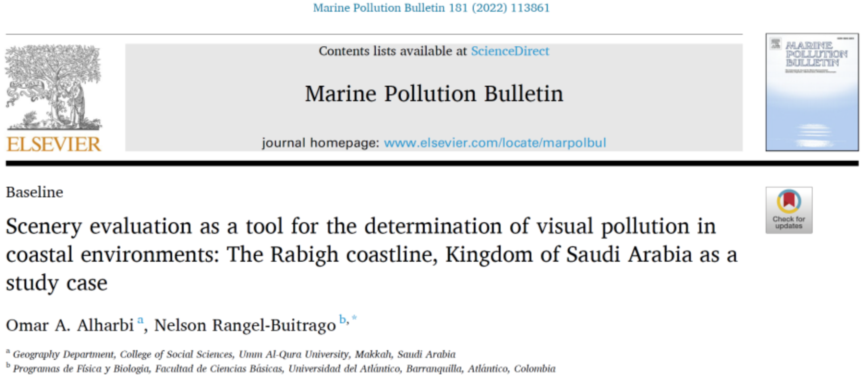

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Baseline

Scenery evaluation as a tool for the determination of visual pollution in coastal environments: The Rabigh coastline, Kingdom of Saudi Arabia as a study case

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