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Research article

Coastal zone management indicators for sustainability in ten Latin American countries

Indicadores de gestión de zonas costeras para la sostenibilidad en diez países Latinoamericanos

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Abstract

Introduction: Coastal zones and climate change. This paper analyses coastal zone management and socio-economic indicators regarding sustainability in ten Latin American countries in 2020, using 22 indicators. The study focuses on two key research questions: RQ1: How have these countries performed in terms of sustainability and their socio-economic development indicators? RQ2: Can some countries be identified as benchmarks, according to their overall performance? **Methodology**: Data from secondary sources such as CEPAL and the United Nations were considered using hierarchical cluster analysis (Ward's method) to identify countries with similar patterns of behaviour. **Results:** The analysis revealed four clusters: CL1: Costa Rica, Panama, El Salvador, Guatemala, Nicaragua. CL2: Ecuador, Peru, Colombia. CL3: Chile. CL4: Mexico. **Discussion:** The analysis revealed important differences between these countries in their coastal management for sustainability. Despite efforts to improve, overall progress remains slow. The benchmark countries identified in each cluster offer valuable insights for policymakers in neighbouring regions, in areas such as applying

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blue economy strategies and achieving sustainable development goals. **Conclusion**: This research contributes to increasing public confidence in government effectiveness in optimising the sustainable tourism value chain, thereby promoting broader social-economic improvements in coastal communities in Latin America.

Keywords: Coastal zone management; Socio-economic development; Indicators; Benchmarking; Multivariate analysis; Latin American; Sustainability; Cluster.

Resumen
Introducción: Zonas costeras y cambio climático. Este artículo analiza la gestión de las zonas costeras y los indicadores socioeconómicos relativos a la sostenibilidad en diez países de América Latina en 2020, utilizando 22 indicadores. El estudio se centra en dos preguntas clave de investigación: PI1: ¿Cómo se han comportado estos países en términos de sostenibilidad y sus indicadores de desarrollo socioeconómico? PI2: ¿Se pueden identificar algunos países como puntos de referencia, según su desempeño general? **Metodología**: Los datos procedentes de fuentes secundarias, como la CEPAL y las Naciones Unidas, se examinaron mediante un análisis jerárquico de conglomerados (método de Ward) para identificar países con pautas de comportamiento similares. **Resultados:** El análisis reveló cuatro *clusters*: CL1: Costa Rica, Panamá, El Salvador, Guatemala, Nicaragua. CL2: Ecuador, Perú, Colombia. CL3: Chile. CL4: México. **Discusión**: El análisis reveló importantes diferencias entre estos países en su gestión costera para la sostenibilidad. A pesar de los esfuerzos por mejorar, el progreso general sigue siendo lento. Los países de referencia identificados en cada grupo ofrecen valiosas perspectivas para los responsables políticos de las regiones vecinas, en ámbitos como la aplicación de estrategias de economía azul y la consecución de los objetivos de desarrollo sostenible. **Conclusiones**: Esta investigación contribuye a aumentar la confianza pública en la eficacia de los gobiernos a la hora de optimizar la cadena de valor del turismo sostenible, promoviendo así mejoras socioeconómicas más amplias en las comunidades costeras de América Latina.

Palabras clave: Gestión de zonas costeras; Desarrollo socio-económico; Indicadores; Benchmarking; Análisis multivariante; Latinoamérica; Sostenibilidad; Cluster.

1. Introduction

Coastal areas and ecosystems worldwide, including those in Latin American countries, are increasingly deteriorating. Diagnoses consistently confirm ongoing degradation of this vital natural capital (Windevoxhel et al., 1999, Barragán, 2003, Forst, 2009, Campuzano et al., 2013, UNEP, 1996, 2016, Barragan, 2020).

From a global perspective on the state of the coastal and marine environment in the Latin American countries, the SPINCAM paper was developed in 2009 with the support of UNESCO, the Permanent Commission for the South Pacific (CPPS) and the Government of Flanders (Belgium) to establish a framework of indicators at national and regional level for environmental information to support integrated management processes of coastal areas, including socio-economic aspects. In the European Union, regional seas policy instruments and conventions active around European coasts address regional marine environmental challenges. For example, the 1974 Helsinki Convention for the Baltic Sea, the 1992 OSPAR Convention for the North-East Atlantic, the 1977 Barcelona Convention for the Mediterranean Sea and the 1992 Convention for the Protection of the Black Sea, also known as the Bucharest Convention, among others, have included the use of marine environmental indicators in their monitoring and assessment work.

A legislative initiative of the European Commission during the period 2002-2008 of the Sixth Environmental Action Plan of the European Union (EU) resulted in new comprehensive legislation as a framework for the marine environment in the EU, the so-called Marine Strategy Framework Directive (2008/56/EC). This legislation is also seen as the 'environmental pillar' of the EU's Integrated Maritime Policy. During this period, the International Council for the Exploration of the Sea (ICES) has provided advice on policy concepts such as the "ecosystem approach", which is described as "a comprehensive integrated management of human activities based on the best available scientific knowledge of ecosystems and their dynamics, in order to identify and manage the influences that are critical to the health of marine ecosystems, thereby achieving the sustainable use of ecosystem goods and services and the maintenance of ecosystem integrity" (ICES, 2005).

From a global perspective according to Global Environment Outlook (GEO) report, Latin America and the Caribbean prioritize water, sanitation, poverty reduction, ozone phase-out, and protected areas expansion. Yet, challenges like land degradation, biodiversity loss, pollution, climate vulnerability, and unsustainable consumption persist (Barragan, 2020, UNEP, 1996, 2016).

As in many other regions of the world, Latin American faces a number of environmental problems that threaten the sustainability of environmental services, including pollution in all its forms (wastewater, agrochemicals, heavy metals, hydrocarbons, plastics, etc.), overexploitation of resources, population growth, coastal erosion, among others, exacerbated by climate change (Campuzano et al., 2013, CPPS, 2014). The lack of planning, control and information for proper management has led to many natural resources reaching the limits of their exploitation, while the coastal marine environment continues to deteriorate (COI-UNESCO/CPPS, 2016).

Ocean and maritime access are pivotal for economic and political growth in the southern hemisphere. Since Rio 1992, Latin American nations have shown heightened environmental awareness through international agreements and sustainable development legislation (Campuzano et al., 2013, UNEP, 2003). Conserving coastal resources—beaches, coral reefs, mangroves, lagoons—and fisheries, wildlife, and water quality demands integrated land-sea management (Vivas-Aguas and Navarrete-Ramírez, 2014). This requires innovative planning to effectively preserve these interconnected ecosystems amid global growth pressures (Barragan, 2003). Situation of integrated coastal zone management in Central America has been limited by information gaps, restricted technical and financial capacity, and strong sectoralism (Windevoxhel et al., 1999). There have been recent attempts to develop an indicator to measure the progress of (Integrated coastal zone management) ICZM. Pickaver et al., 2004 has elaborated an indicator set to measure the progress the implementation of ICZM throughout the EU coastal states in five phases.

In terms of governance, socio-political processes to promote integrated management of coastal and contiguous marine zones are still in their infancy. However, most countries already have management categories in protected areas (PAs) according to the International Union for Conservation of Nature (IUCN) classification as a reference to achieve conceptual harmonisation (Dudley, 2018).

Some countries have made efforts to implement protected areas as a climate change trend (del Campo et al., 2020, del Vasto et al., 2019). The following countries stand out, Colombia has protected areas (12 wilderness areas, 103 national parks, 2 natural monuments, 10 protected seascapes) as one of the main strategies for biodiversity conservation and, with others, four countries (Ecuador, Peru, Chile, Panama) have conformed to the SPINCAM to register

consolidated protected areas and have an Atlas online that allows decision-makers in coastal marine territory management to understand the state and changes in natural resources, the environment and their social, economic and cultural relationships in the marine and coastal areas of the South Pacific. (RUNAP, 2022).

Chile's natural wealth is protected within the State's National System of Protected Natural Areas, which includes 105 units (41 national parks, 46 reserves and 18 natural monuments). Ecuador has focused on water conservation, with 63 protected areas covering more than 20% of the national territory and 14 water conservation areas covering at least 61,000 hectares. Peru's protected natural areas are divided into 10 categories (15 national parks, 17 national reserves, 9 national protected areas, 4 historical protected areas, 2 landscape reserves, 3 wildlife refuges, 10 communal reserves, 6 protected forests, 2 hunting reserves and 8 reserved areas). Panama is strengthening protected areas by creating the National System of Wildlife Areas, through Resolution 022-92 of the Board of Directors, in accordance with the World Management Categories (IUCN), and has a pilot paper in the Las Perlas Archipelago. The coastline is 14,000 km long, with a population of 60,000,000 and a fish production of 8,500,000 tons.

The region has an extensive institutional and legal framework related to the coastal and marine zone. Through the Permanent Commission for the South Pacific - CPPS, countries have ratified 19 binding agreements and protocols, 10 ministerial declarations and 1 presidential declaration since 1952. The legal component of the South East Pacific Action Plan has been one of the most developed in the context of the Regional Seas Programme (CPPS, 2024).
These instruments provide guidelines and direction for the region in terms of resource exploitation, scientific research, risk management, biodiversity and ecosystem conservation, and have enabled the development of national capacities in various areas, including scientific, socio-economic, legal and environmental. In recent years, integrated coastal zone management and marine planning have become established as methodological tools for public administrators, facilitating decision making together with public participation and citizen activism. Despite differences in latitude, coastal uses or population needs, there is a common interest in moving towards sustainable development of coastal zones (COI-UNESCO/CPPS, 2016).

It is imperative to address the coastal zone management indicators for sustainability. This framework has become increasingly accepted and applied to different case studies to aid problem solving that involve a range of coastal marine environments including estuaries, coastal lagoons and coastal areas (Barragan, 2020, Campuzano et al., 2013, Forst, 2009, Pickaver et al., 2004, Barragán, 2003, Windevoxhel et al., 1999). In many cases this framework has been complemented with use of numerical models, which have been increasingly becoming indispensable tools in management decisions (UNEP, 2016, UNEP, 2003).

The purpose of the paper is analyses the coastal management and socio-economic indicators for the protection of environment and environment in Latin American countries, recognizing the importance of these environments as drivers of the regional economy (Chile, Colombia, Costa Rica, Ecuador, El Salvador, Guatemala, Mexico, Nicaragua, Panama, Peru) for the well-being and sustainable blue development and the Integrated Coastal Zone Management. Therefore, it may be useful to monitor the collection of data and information to feed the indicators and their interpretation-evaluation, as evidence-based policy is generally considered necessary.

This paper can be useful to the Latin American and other regions in their sustainable development trajectories. Henceforth, the paper is organized as follows. First, a literature

review is presented about the coastal zone management indicators and the relationship with sustainability; the use of country performance indicators as benchmarks is also referred. The empirical study starts by explaining the data and methodology used, followed by a presentation and discussion on the findings. The conclusions are summarized in the last section.

2. Literature review

Various academic studies and reports from global institutions (Barragan, 2020; Campuzano et al., 2013; Forst, 2009; Pickaver et al., 2004; Barragan, 2003; Windevoxhel et al., 1999) explore the connections between coastal zone management and socio-economic development indicators. They suggest that improved national performance can enhance coastal conditions, ecosystems, and socio-economic contexts. Developing comprehensive performance indicators remains a challenge. International organizations like UNESCO, ECLAC, the United Nations, SPINCAM, World Bank, CPPS, and UNEP have created frameworks for assessing public management, using key global indicators such as GDP per capita and HDI (United Nations, 2023; World Bank, 2023).

In Latin American countries, coastal population concentrations heighten the impacts of natural coastal processes. Recent years have seen increased severity in erosion effects attributed to human activities, underscoring the need for effective environmental management strategies.

In several countries of Latin American, population is concentrated at or near the coast, and therefore some natural coastal processes increase their impacts. In recent years, erosion effects have been more severe due to the action of humanity. The interactions between land and sea along the Latin American coast directly impact shorelines, causing coastal erosion, wetland loss, and salt intrusion in coastal aquifers. Global change scenarios predict rising sea levels and more frequent, intense storms exacerbating these effects because human activity is having a growing impact on coastal development (Isla and Schnack, 2009).

Numerous issues and conflicts affect many coastal areas in Latin America and the Caribbean (LAC) too such as chaotic urbanization processes, threats to indigenous cultures, degradation of coastal marine ecosystems, loss of biodiversity, effects of climate change on the socio-ecological system, coastal erosion, contamination of soil, water and living resources, etc. (Barragan, 2020).

It has been demonstrated that Integrated coastal zone management (ICZM) has a significant impact on economic development and investment. Important evidence was presented in a study on the implementation of integrated coastal zone management in Europe by Pickaver et al., 2004, which these initiatives have garnered ministerial and presidential support through numerous political agreements under the 'Alliance for Sustainable Development' (ALIDES). (Windevoxhel et al., 1999).

Indicators set to measure the progress in the integrated coastal zone management is researched as a cause for improving efficiency and effectiveness in public administrations. When socio-economic development increases, citizens expect to receive better services and demand more system managements performance, by showing the usefulness and advantages of using numerical modeling as an important tool in the decision making process within ICZM, produce at least loss of natural patrimony, and promote sustainable of coastal resources (Campuzano et al., 2013, Pickaver et al., 2004).

Coastal management legislative frameworks are undergoing revision in many countries, aiming to integrate sectoral approaches. This shift addresses the challenge of managing coastal ecosystems in South American countries, fostering implementation through shared methodologies (Campuzano et al., 2013).

Currently, numerous organizations measure integrated coastal zone management indicators internationally, regionally, and nationally. Case studies highlight Central American experiences in sustainability and combating strong sectoralism (Windevoxhel et al., 1999). Integrated Coastal Zone Management (ICZM) is emerging as a tool to address these challenges (Clark, 1996), offering a strategy for ecosystem-based management in complex and dynamic coastal marine environments sensitive to social needs (Agardy et al., 2011).

Barragan (2020) used four indicators of Integrated Coastal Zone Management (ICZM) that reflect each country's institutional capacity: Policies, Regulations, Institutions and Instruments. The results are mostly heterogeneous in Latin America and the Caribbean (LAC). In order to improve the performance of coastal zone management, public institutions need to be equipped with efficient management systems.

Academic literature has highlighted promote sustainable management of coastal zones as a requirement and, effective tool for achieving sustainable development of coastal ecosystem (e.g., Barragan, 2020), which implies that Cooperation between more and less advanced countries in the region for Integrated Coastal Zone Management (ICZM) is feasible. South-South cooperation capitalizes on regional commonalities in history, culture, and language to enhance collaborative efforts.

In both developed and developing countries, the coastal zone is likely to experience the most profound changes in the near future. Coastal zones around the world have long been heavily exploited. Integrated Coastal Zone Management (ICZM) aims to harness the rich resources of coastal zones in a sustainable manner through goal setting, planning and implementation involving a significant proportion of the coastal population, estimated at around half of the global total (Post and Lundin, 1996).

2.1 Studies and actions related to coastal management strategies

This sub-section provides a review of the academic and professional literature that addresses country performance issues overall, including matters such as political and administrative reforms, environmental laws and socio-economic development in Latin American countries.

According to Barragan, 2020 some countries have advanced in implementing ICZM Strategies over several decades, while others have been slower to adopt these coastal management strategies. Furthermore, in the aforementioned policies, coastal zones are present although they do not constitute the main center of interest (Barragan, 2020). This author acknowledges that these strategies should be positively evaluated because they encompass the coastal zone. A sectoral policy aligns with ICZM, which, being more specialized, enhances government action directed towards coastal management and sustainability.

In **Colombia**, the National Ocean and Coastal Spaces Policy (PNOEC) was implemented on 1 January 2017 by CCO, the National Environmental Policy for the Sustainable of Oceanic Spaces and Coastal and Island Areas (2000) PNAOCI, updated by the Ministry of Environment (DNP_DPA) National Council of Economic and Social Policy 3164, Colombia's National Planning Department approved "CONPES 3990" in 31 March 2020, updating coastal policies and charting a path for Colombia to achieve "Bioceanic Power" status by 2030.

Chile resolves coastal limits, referencing ecosystems or physiographic units, to address the issue effectively and sustainably. The National Policy of the Use of the coastal edge of the republic's coastline and creates the national commission it indicates – Supreme Decree No. 475 (1994)

In 2008, **Ecuador** became the first country in the world to recognise nature as a subject of rights in its Constitution. Ecuador uses boundary issues in relation to coastal ecosystems, the publication of the National Oceanic and Coastal Policy (PNOC), 20 October 2014. The Coastal Marine Spatial Plan (2017-2030), 2020.

El Salvador, has adopted national strategies, in 2011 the Strategy for the Integral and Sustainable Development of the Marine Coastal Strip 2012–2024.

Costa Rica is a country with a great diversity of coastal and marine ecosystems. It was the first developing country to initiate an ICZM programme. The country has also taken into account strategies such as the National Adaptation Policy for Climate Change (2018), National Strategy for the Conservation and Protection of Sea Turtles (2018), Wetlands 2017-2030, Biodiversity 2015-2030, Water 2015-2030, etc. (2018).

Mexico has approved National Strategies, such as: National Strategy for Ecological Management in Seas and Coasts in 2018. Define a sustainable ocean economy, prioritize short-term goals, map transition initiatives, and outline elements for the Sustainable Ocean Plan.

Guatemala boasts rich biodiversity along its 402-kilometer coastline, spanning 7 departments, 17 municipalities, and nearly 300 communities, directly impacting almost 300,000 people in coastal areas. The Policy for the integral management of the coastal marine areas of Guatemala (2009) – Agreement 328. This country has integrated ICZM strategies, considering policy documents that establish principles for national policies and strategies.

Nicaragua, the Coastal Law (2009/690) in Nicaragua establishes a comprehensive framework for environmental protection, public access rights, commercial activities, and property rights along the shorelines of all bodies of water throughout the country. This law gave the Nicaraguan Institute of Tourism responsibility for coordination, policy and concessions in the coastal zone.

Panama is the first country in Latin America to protect more than 50% of its total marine area. On 2 March 2023, Panama signed a decree expanding the Banco Volcán Marine Reserve from 14,200 to over 90,000 square kilometres. Half of this area is now fully protected, safeguarding marine ecosystems and fisheries resources in Panama's Caribbean national waters. Law 371, enacted on March 1, 2023, protects and conserves sea turtles and their habitats. It has implemented a National Ocean Policy (2022) - Executive Order No. 27. By 2021, the country will have protected more than 30% of its oceans.

Peru published, in 2015, the Guidelines for the Integrated Management of Coastal Marine Areas. By means of Ministerial Resolution N° 189 – 2015, National Wetland Strategy (2015), National Policy and Strategy of Water Resources (2015), National Strategy for Climate Change 2050 (2015), Law 31.973 of 19 March 2024 declares the Marañón River as a legal entity with inherent rights (as a subject of rights).

2. Methodology

This paper uses data from the ten Latin American countries for the period up to 2020. These countries are, in an alphabetical order: Colombia, Chile, Costa Rica, Ecuador, El Salvador, Guatemala, Mexico, Nicaragua, Panama and Peru. Since the aim is to analyse the countries' performance in terms of coastal zone management indicators and to link them to sustainability issues, secondary official data sources have been used, as has been done by other researchers. Accordingly, the indicators used in the study (Table 1) were collected from the databases of CEPAL, the United Nations and the World Bank.

Table 1.

Indicators used in the empirical analysis

No.	Abbreviation	Indicator	Source	Year
		Land and Soil		
1	TSA	Total Surface Area	CEPALSTAT	2020
2	CW	Inland Waters	CEPALSTAT	2020
3	LS	Land Surface	CEPALSTAT	2020
4	AA	Agricultural Area	CEPALSTAT	2020
		Biotas, Waters and Seas		
5	ATSP	Proportion of Terrestrial and Marine Protected Areas	CEPALSTAT	2020
6	WRAMSAR	Wetland Area (RAMSAR)	CEPALSTAT	2020
7	CFP	Capture Fisheries Production	CEPALSTAT	2020
8	TAP	Total Aquaculture Production (T)	CEPALSTAT	2020
		Energy		
9	PEP	Primary Energy Production	CEPALSTAT	2020
10	SEP	Secondary Energy Production	CEPALSTAT	2020
11	PEC	Primary Energy Consumption %	CEPALSTAT	2020
12	SEC	Secondary Energy Consumption %	CEPALSTAT	2020
13	RSES	Renewable Share of Energy Supply (%)	CEPALSTAT	2020
		Air and Atmosphere		
14	CO2EPC	CO2 Emissions per Inhabitant (2019) T	CEPALSTAT	2020
15	CO2EGDP	CO2 Emissions per 1000US$ of GDP at current prices T	CEPALSTAT	2020
16	CODS	Consumption of Ozone-depleting substances (CODS)	CEPALSTAT	2020
		Transport		
17	MVF	Vehicle fleet (per 100 inhabitants)	CEPALSTAT	2020
18	ATP	Air traffic (passenger Km)	CEPALSTAT	2020
19	ATC	Air traffic (Tn km of freight)	CEPALSTAT	2020
		Environmental Management		
20	NCC	Number of 14001 Certified Companies	CEPALSTAT	2020
		Socio-Economic		
21	HDI	Human Development Index	United Nations	2020
22	GDPPPS	Gross Domestic Product Per Capita	World Bank	2020

Source: Own elaboration (2024).

The calculation methodology of the Environmental Indicators is based on several general methods and classifications-based environment data. It also assesses a variety of issues. More specifically, the data sources include land and soil, as well as biotas, waters and seas, energy, air and atmosphere, transports, environmental management. It is the gateway to all the statistical information of Latin America and the Caribbean countries collected, systematized and published by Economic Commission for Latin America ECLAC, 2023 or CEPALSTAT.

The socio-economic domain covers data on GDP per capita and the Human Development Index. GDP per capita is estimated on the basis of a complete series of data for each country. The methodology related to the compilation of the official national accounts data is provided by the national statistical office. GDP data are converted into US dollars using the appropriate monthly or end-of-month exchange rate quotations published by the World Bank. The Human Development Index (HDI) measures average performance across three key dimensions: health (life expectancy at birth), education (average years of schooling and expected years of schooling), and living standards (logarithm of gross national income per capita). It assigns values between 0 and 1, with higher scores indicating higher human development levels published by United Nations.

Missing data for Suriname, Guyana, Uruguay, Brazil and Venezuela were noted. Often, in such cases, years or countries with missing indicators are excluded. To ensure consistency across measurements, variables were standardized to z-scores (mean of 0, standard deviation of 1) to mitigate scale differences.

This study employs descriptive and cluster analysis. Cluster analysis categorizes countries based on similarity, creating typologies that reflect distinct patterns of performance and transparency, ensuring homogeneity within groups and heterogeneity between them. The software, which was in use for our methodology is the SPSS.

In this analysis, cluster analysis identifies top-performing countries in sustainability and socio-economic development, tracing their evolution towards improved coastal zone management and sustainability. It encourages benchmarking among governments for continuous improvement. Groups of Latin American countries with similar characteristics will be identified based on these indicators, highlighting their roles across the continent.

Cluster analysis has a rich history. While hierarchical methods are the oldest, the rise in computational power has popularized non-hierarchical k-means clustering. Given the time series nature of the variables in this study, modern approaches like model-based clustering are also considered. With only 10 SA countries, hierarchical methods' typical complexity is mitigated, highlighting their benefits. Thus, Ward's method with squared Euclidean distances is chosen due to its proven effectiveness in such scenarios. For a deeper understanding, refer to Everitt et al. (2011), Hair et al. (2009), Kaufman and Rousseeuw (2009), Aghabozorgi et al. (2015), and (del Campo et al., 2020) for comprehensive discussions on clustering techniques.

3. Results and Findings

The descriptive statistics of the coastal zone management and socio-economic indicators in Latin American countries in 2020 are presented in Table 2.

Table 2.

Database of study Indicators

	Land and Soil Indicators				Biotas, Waters and Seas Indicators				Energy Indicators					Air and Atmosphere Ind.			Transport Indicators			Environment Management Ind.	Socio-Economic Ind.	
	TSA	CW	LS	AA	ATSP	WRAMSA	CFP	TAP	PEP	SEP	PEC	SEC	RSES	CO2EPC	C02EGP	CODS	MVF	ATP	ATC	NCC	HD	GDPPPS
CHILE	75.670	1.256	74.353	10.596	6,8	363.927	46.816	1.505.486	86.325	119.522	46,9	136,9	29,7	4,8	328,0	15	20	17.527	1.179,1	994	0,852	24.941,2
COSTA RICA	5.110	4	5.106	1.811	3,0	569.742	50	16.269	24.387	7.992	11,8	325,3	51,8	1,6	127,9	3,3	18,8	2.854	13,3	139	0,816	21.693,7
COLOMBIA	114.062	3.225	110.950	42.718	17,4	936.442	54.336	179.351	747.238	193.608	9,9	83,6	25,6	1,6	250,8	25,4	7,1	11725,2	171,2	2926	0,756	15.103,1
ECUADOR	25.637	801	24.836	5.470	15,4	1.064.483	7.243	774.569	201.563	78.482	1,6	118,0	18,9	2,3	363,5	10,2	7,1	4.247,9	103,4	169,0	0,731	10.937,1
EL SALVADOR	2.104	32	2.072	1.196	2,0	228.719	675	8.500	5.840	4.017	16,8	491,5	32,6	1,2	289,9	4,0	10,2	3.515,8	15,3	23,0	0,672	8.760,3
GUATEMALA	10.889	173	10.716	4.612	15,7	629.312	2.360	33.651	78.808	9.711	68,4	466,6	63,8	1,2	250,8	2,9	7,0	174,8	0,2	35,0	0,635	8.859,0
MEXICO	196.438	2.043	194.395	97.126	6,0	8.721.911	144.663	278.694	1.200.658	540.090	11,9	119,9	10,7	3,5	353,9	130,3	27,8	24.860,5	459,6	1.805,0	0,756	18.522,0
NICARAGUA	13.037	1.003	12.034	5.091	22,0	406.852	405	29.410	14.385	6.426	56,0	168,9	54,1	0,8	415,7	2,7	5,4	480,7	0,2	6,0	0,654	5.523,5
PANAMA	7.532	114	7.418	2.181	5,2	220.737	277	3.879	8.165	8.664	21,3	280,2	24,9	3,1	199,2	10,8	13,8	9.316,4	42,2	26,0	0,801	28.096,6
PERU	128.522	522	128.000	25.516	19,4	6.789.685	15.586	143.830	220.009	108.978	16,9	98,9	27,3	1,8	248,5	9,4	6,7	8.765,0	106,5	914,0	0,762	11.814,0

Source: Own elaboration (2024)

The dendrogram clearly shows the heterogeneity of the Latin American countries, and the performance leader in the Pacific Ocean to the west and the Gulf of Mexico and the Caribbean Sea to the east – Mexico (Cluster 4)

Regarding the land and soil indicators, the following issues are noticeable:

- With regard to land and soil, the first quartile is formed by El Salvador, Costa Rica and Panama, which have the smallest agricultural area, taking into account the agriculture and water indicators. The 4th quartile is made up of Peru, Colombia and Mexico (see Table No. 3). The Total Surface Area indicator shows that Mexico, Peru and Colombia stand out in terms of area, while El Salvador and Costa Rica have the smallest area. The Inland Waters indicator shows significant potential for Colombia, Mexico and Chile, while Costa Rica, El Salvador and Panama do not have much of this indicator. The Land Surface indicator shows the greatest extent for Mexico, Peru and Colombia, while El Salvador and Costa Rica have the least. Mexico was the leading Agricultural Area in the region, followed by Colombia and Peru. These countries are among the world's top ten producers of maize or corn. Latin American is also the world's leading producer of coffee, with El Salvador and Costa Rica at the bottom of the list (see Table No. 2).

Table 3.

Descriptive statistics used in the Land and Soil Indicators

Land and Soil Indicators					
COUNTRIES	CW	AA	CW (%)	AA (%)	Quartiles
EL SALVADOR	32	1196	0,35	0,61	
COSTA RICA	4	1811	0,04	0,92	
PANAMA	114	2181	1,24	1,11	1,42 1º Quartil
GUATEMALA	173	4612	1,89	2,35	
NICARAGUA	1003	5091	10,93	2,59	2,69 Qº Cuartil
ECUADOR	801	5470	8,73	2,79	
CHILE	1256	10596	13,69	5,40	
PERU	522	25516	5,69	13,00	11,10 3º Quartil
COLOMBIA	3225	42718	35,16	21,76	
MEXICO	2043	97126	22,27	49,47	
	9173	**196317**	**100,00**	**100,00**	

Source: Own elaboration (2024).

The indicators related to Biotas, Waters and seas:

- Taking into account the indicators Biotas, Waters and Seas, the countries that make up the group of countries with the lowest fisheries production (1st quartile) are Costa Rica, Panama and Nicaragua. While the countries with an average fisheries production are Salvador, Guatemala, Ecuador and Peru. While the countries with a very high fishery production (above the 3rd quartile) are Costa Rica, Panama and Nicaragua. Countries with very high fisheries production (above the 3rd quartile) are Chile, Colombia and Mexico (see Table 4). The indicator of Proportion of Terrestrial and Marine Protected Areas shows the highest values for Nicaragua, followed by Peru and Colombia, while El Salvador and Costa Rica have the lowest values. The countries with the largest Number of Wetlands (RAMSAR) are Mexico, followed by Peru, while Panama and El Salvador have no significant area. The three countries with the highest of Capture fisheries production (Mexico, Colombia and Chile), while Costa Rica, Panama and Nicaragua have the lowest values. The Total Aquaculture Production highlights Chile, followed by Ecuador and Mexico, compared to Panama, El Salvador (see Table No. 2).

Table 4.

Descriptive statistics used in the Biotas, Waters and Seas Indicators

Biotas, Waters and Seas Indicators					
COUNTRIES	WRAMSAR	CFP	WRAMSAR (%)	CFP (%)	
COSTA RICA	569742	50	2,86	0,02	
PANAMA	220737	277	1,11	0,10	
NICARAGUA	406852	405	2,04	0,15	0,1735
EL SALVADOR	228719	675	1,15	0,25	
GUATEMALA	629312	2360	3,16	0,87	
ECUADOR	1064483	7243	5,34	2,66	1,7626
PERU	6789685	15586	34,06	5,72	
CHILE	363927	46816	1,83	17,19	14,32
COLOMBIA	936442	54336	4,70	19,95	
MEXICO	8721911	144663	43,76	53,10	
	19931810	**272411**	**100,00**	**100,00**	

Source: Own elaboration (2024).

The indicators related to energy:

- The group of countries with the lowest primary energy production includes El Salvador, Panama and Nicaragua. Countries with average primary energy production include Costa Rica, Guatemala, Chile and Ecuador. The countries with the highest energy production are Peru, Colombia and Mexico (see Table 5). In other words, the top Primary Energy Production and the Secondary Energy Production (Mexico) with respect to El Salvador with lower measurement. The top Primary Energy Consumption (Guatemala) with respect to Ecuador with lower measurement, and Secondary Energy Consumption % (El Salvador) while Colombia shows lowest values, the Renewable Share of Energy Supply (Nicaragua) with respect to Mexico with lower values (see Table No. 2).

Table 5.

Descriptive statistics used in the Energy Indicators.

Energy Indicators			
COUNTRIES	PEP	PEP (%)	
EL SALVADOR	5840	0,23	
PANAMA	8165	0,32	
NICARAGUA	14385	0,56	0,652610481
COSTA RICA	24387	0,94	
GUATEMALA	78808	3,05	3,191126306
CHILE	86325	3,34	
ECUADOR	201563	7,79	
PERU	220009	8,50	8,324933581
COLOMBIA	747238	28,88	
MEXICO	1200658	46,40	
	2587378	**100,00**	

Source: Own elaboration (2024).

The indicators related to Air and Atmosphere:

- In terms of pollution, the countries with the lowest CO2 emissions per inhabitant are Nicaragua, El Salvador and Guatemala. On the other hand, among the countries that produce an average amount of CO2 per inhabitant are Costa Rica, Colombia, Peru and Ecuador. The countries with very high CO2 emissions are Panama, Mexico and Chile (4.8) (see Table No. 6). Moreover, as mentioned above the countries with the highest CO2 emissions per capita (2019) are Chile, followed by Mexico, which are the most industrialised countries, in contrast to Nicaragua, El Salvador and Guatemala, which are less polluted. Costa Rica has the lowest CO2 emissions per 1000US$ GDP at current prices. The country with the highest consumption of ozone-depleting substances (TPAO) is Mexico, despite having signed the Montreal Protocol to eliminate the use of substances that deplete the Earth's ozone layer, which came into force in January 1989. Guatemala and Costa Rica, Nicaragua and El Salvador highlighted their progress in protecting the ozone layer (see Table No. 2).

Table 6.

Descriptive statistics used in the Air and Atmosphere Indicators

Air and Atmphosfere Indicators			
COUNTRIES	**CO2EPC**	**CO2EGDP**	
NICARAGUA	0,8	415,7	
EL SALVADOR	1,2	289,9	
GUATEMALA	1,2	250,8	1,30 1er Q
COSTA RICA	1,6	127,9	
COLOMBIA	1,6	250,8	
PERU	1,8	248,5	1,70 2do. Q
ECUADOR	2,3	363,5	
PANAMA	3,1	199,2	2,90 3er. Q
MEXICO	3,5	353,9	
CHILE	4,8	328	
		2828,2	

Source: Own elaboration (2024).

In terms of Transports indicators:

- In this case, the countries with the lowest air traffic per km are Guatemala, Nicaragua and Costa Rica. The countries with an average number of flights per km are: El Salvador, Ecuador, Peru, Panama, Colombia and Chile. The country with the highest number of flights per km is Mexico (see Table No 7). For the above reasons, Mexico tops the list of countries with the largest vehicle fleet (per 100 inhabitants), with figures that exceed those of Nicaragua, Peru and Guatemala combined. Mexico recorded an all-time high of 24860.5 passenger-kilometres, followed by Chile with 17527.4, while Guatemala recorded the lowest figure of 174.8. The market size of Chile's air transport (Tn km of freight) is estimated at 1179.1, putting it at the top of the list, compared to Guatemala and Nicaragua, both with 0.2 (see Table No. 2).

Table 7.

Descriptive statistics used in the Transport Indicators

Transports Indicators				
COUNTRIES	MVF	ATP	ATP (%)	
GUATEMALA	7	174,8	0,21	
NICARAGUA	5,4	480,7	0,58	
COSTA RICA	18,8	2854	3,42	3,62 1er. Q
EL SALVADOR	10,2	3515,8	4,21	
ECUADOR	7,1	4247,9	5,09	
PERU	6,7	8765	10,50	
PANAMA	13,8	9316,4	11,16	11,16 2do. Q
COLOMBIA	7,1	11725,2	14,05	
CHILE	19,8	17527,4	21,00	25,39 3er. Q
MEXICO	27,8	24860,5	29,78	
		83467,7	100,00	

Source: Own elaboration (2024).

The indicator related to Environmental Management:

- The countries with the lowest number of certified companies are Nicaragua, El Salvador and Panama. Countries with a medium number of certified companies are Guatemala, Costa Rica, Ecuador and Peru. The countries with a high number of certified companies are Chile, Mexico and Colombia (see Table No. 8). The top is Mexico with the highest Number of 14001 Certified Companies with 1805, while Nicaragua has not developed this indicator with a figure of 6.0 (see Table No. 2)

Table 8.

Descriptive statistics used in the Environment Management Indicators

Envrionment Management Indicator			
COUNTRIES	NCC	NCC (%)	
NICARAGUA	6	0,09	
EL SALVADOR	23	0,33	
PANAMA	26	0,37	0,40 1er. Q
GUATEMALA	35	0,50	
COSTA RICA	139	1,98	2,19 2do. Q
ECUADOR	169	2,40	
PERU	914	12,99	
CHILE	994	14,13	13,84 3er. Q
MEXICO	1805	25,65	
COLOMBIA	2926	41,58	
	7037	100,00	

Source: Own elaboration (2024).

As for indicators Socio-Economic indicators:

- Looking at the Human Development Index, the countries with very low scores on this index are Guatemala, Nicaragua and El Salvador. The countries with a medium HDI are Ecuador, Colombia, Mexico and Peru. Finally, the countries with a high HDI were: Panama, Costa Rica and Chile (see Table No. 9). For example, Guatemala is the country that experienced the sharpest drop in the Human Development Index (HDI) in the

region with 0,635 while Chile has grown steadily in this indicator with 0,852 followed by Costa Rica with 0,816. Panama's Gross Domestic Product per capita was a total of 28096.61, followed by Chile with 24941.23, while Nicaragua had the lowest value at 5523.54 (see Table No. 2)

Table 9.

Descriptive statistics used in the Socio-Economic Indicators

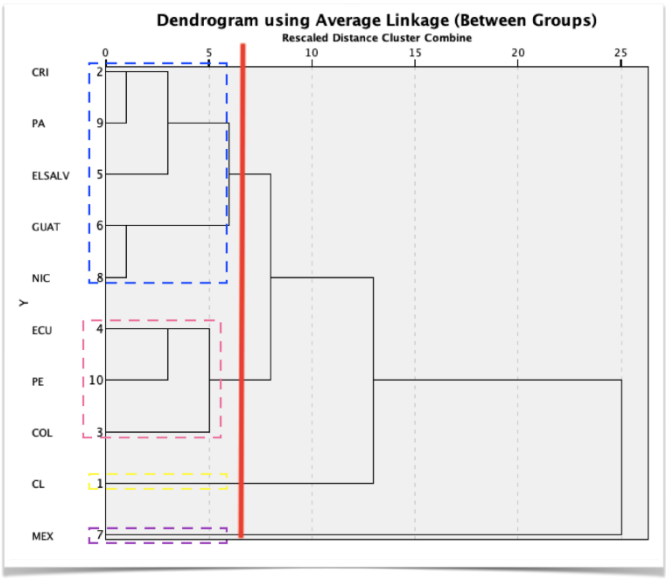
Socio-Economic Indicators

COUNTRIES	HDI	GDPPPS	
GUATEMALA	0,635	8859	
NICARAGUA	0,654	5524	
EL SALVADOR	0,672	8760	0,687 1er. Q
ECUADOR	0,731	10937	
COLOMBIA	0,756	15103	0,756 2do. Q
MEXICO	0,756	18522	
PERU	0,762	11814	
PANAMA	0,801	28097	0,791 3er. Q
COSTA RICA	0,816	21694	
CHILE	0,852	24941	

Source: Own elaboration (2024).

Figure 1.

Dendogram of the cluster analysis



Source: Own elaboration (2024).

The dendrogram in Figure 1 visually depicts clusters of American countries. By analyzing increases in distances where clusters merge (vertical axis of intergroup sum of squares), a sensible choice suggests a four-cluster solution (dashed line in Figure 1).

Based on the dendrogram, countries in the Americas can be grouped into four clusters:

Cluster 1 - Costa Rica, El Salvador, Guatemala and Nicaragua;

Cluster 2 - Ecuador, Peru and Colombia;

Cluster 3 - Chile;

Cluster 4 - Mexico.

There are notable differences between the American countries. A detailed description of the four clusters follows.

Cluster 1 – This is the largest cluster in number of countries includes Costa Rica, El Salvador, Guatemala and Nicaragua. The values for most indicators are below their respective means in particular, for the Land and Soil indicators, the Biotas, Waters and Seas indicators, the Primary and Secondary Production indicators, the Air and Atmosphere has lowest level of CO2 emissions, the Environmental Management indicator, and also the Socio-economic Development indicators too, while only a few improve such as: the Primary and Secondary Energy Consumption indicators and the Renewable Share of Energy Supply (%), the Transport indicators. Nevertheless, in the last 2020, CO2 emissions indicators have decreased, the primary and secondary energy consumption and Renewable Energy Supply indicator have improved while the indicators more related to socio-economic development have generally deteriorated in all countries except of Costa Rica. Costa Rica's dynamic, integrated approach considers the relationship between terrestrial human activities and the marine environment, addressing impacts, problems, and conflicts.

Cluster 2 - This is the cluster included Ecuador, Peru, Colombia, which on the one hand, share a unique biological, ecosystem and cultural wealth. Overall, they highlighted in the Land and Soil indicators, the Biotas, Waters and Seas indicators have improved especially in the Proportion of Terrestrial and Marine Protected Areas indicator, with the exception of Socio-economic indicators that seemed to have maintained the same trend. Ecuador has the highest CO2 emissions of this group of countries, and Colombia has the highest consumption of ozone-depleting substances (CODS) indicator. In terms of air transport (passenger km), all of them have a high indicator. Colombia and Peru stand out in Environmental management.

Cluster 3 – This is the largest cluster in terms of the geographical area covered by Chile, located in the East of the continent. Values for all indicators are close to or above their respective means, with some above, e.g. Inland water, Land surface, Capture fisheries production, Total aquaculture production, Secondary energy production, Primary energy consumption %, CO2 emissions per inhabitant (2019), CO2 emissions per inhabitant (2019), Air atmosphere indicators, Environmental management indicator and Socio-economic development indicators with only a few below (agricultural area, percentage of terrestrial and marine protected areas, wetland area (RAMSAR), primary energy production, secondary energy consumption %, share of renewable energy in energy supply (%), consumption of ozone-depleting substances (CODS). Chile excelled in the land and soil indicators and in fisheries production, while its CO2 emissions worsened.

Cluster 4 – Mexico is the country included in this cluster of best performers in terms of coastal zone management and social-economic development indicators, this cluster has the best mean values in most of the variables, well above the other three clusters. Furthermore, over time, many of these indicators have clearly improved, with the exception of the indicators Consumption of ozone-depleting substances (CODS), the Vehicle fleet (per 100 inhabitants) and, Air traffic (passenger Km).

Despite efforts to improve coastal zone management and socio-economic indicators, most American countries are progressing very slowly overall.

4. Conclusions

This paper looks into the performance of American countries in the 2020. It uses 22 indicators of coastal zone management and socio-economic development indicators to analyze how countries have evolved and how they are positioned relatively to each other, evidencing and encouraging benchmarking.

By applying multivariate statistical techniques, the research was able to group the ten Latin America countries into four clusters with similar characteristics. Results show explicit differences between the countries under analysis, in terms of behavior patterns concerning performance linked with coastal zone management towards socio-economic development. Although Latin American countries have developed initiatives, recent implementations and future plans aim to establish integrated coastal zone management principles, based on regional experiences and best practices that significantly improve overall performance.

Latin American's abundant marine coastal resources support an economic base for sustainable development, promoting long-term growth and environmental stewardship. A point to be highlighted is the promote integrated coastal zone management in each country's sectoral actions and develop a regional agenda for shared ICZM resources, fostering collaboration and sustainable development across Latin American.

Strong ocean protections enhance ocean health, enabling greater resilience and faster recovery from climate impacts. Marine Protected Areas (MPAs) are crucial for addressing the rising stress on marine ecosystems due to human activities, offering reduced-stress zones to buffer climate change impacts and rebuild ecological and social resilience. MPAs are essential tools for ensuring sustainable marine environments and supporting biodiversity conservation.

The research advances theoretical concepts by examining the interrelationship between coastal zone management, and socio-economic development indicators, offering opportunities to enhance understanding and address key issues in these interconnected areas.

The results from this classification exercise allow us to state that the majority of countries are in the medium levels. According to Barragan (2020) Mexico exemplifies institutions like the General Directorate of the Federal Maritime Terrestrial Zone and Coastal Environments of SEMARNAT, complemented by coordinating bodies like the Inter-Secretarial Commission for the Sustainable Management of Seas and Coasts (CIMARES). Chile's National Commission of the Coastal Edge includes representation from major public institutions, alongside Regional Commissions for Coastal Border Use, crucial for tasks like zoning and management.

Mexico and Chile have significantly improved their coastal zone management and socio-economic development indicators. On the other hand, El Salvador is still the country with the lowest average for these indicators, and shows a lower level of performance. Mexico and Chile also have significant environmental legislation and major challenges in coastal systems, while CO2 emissions, vehicle fleet and air traffic show high levels. Most countries, with the exception of El Salvador, improved their performance on the Biotas, Waters and Seas indicators. In terms of socio-economic development indicators, Chile, Costa Rica, Mexico and Panama achieved the highest scores in the region in 2020, in contrast to Guatemala, Nicaragua and El Salvador.

From the empirical point of view, it also provides information of value for the practitioners in the form of comparable and reliable performance indicators. Such studies, especially using a comparative-international perspective, are practically no longer present in the Latin American countries.

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