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# ASSESSMENT OF CLIMATE ADAPTATION DOCUMENTS IN ATLANTIC COUNTRIES FOR THE MANAGEMENT OF COASTAL AND EXTREME CLIMATE RISKS

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**ABSTRACT:** Populations in coastal zones are more susceptible to risks caused by extreme climate events. Therefore, climate planning is becoming an important tool to adapt these areas to the consequences of climate disasters. This article proposes an assessment of coastal risks and climate adaptation instruments developed by thirty countries in the Atlantic Area region. Climate adaptation strategies, plans and related documents were analyzed in order to understand whether the national planning framework can lead to an efficient management of extreme climate events. The contents of the documents were evaluated by thirty-two indicators within the awareness, analysis, and actions dimensions. Correlation and regression analyses were conducted to verify the influence of independent variables on their content. Results indicate that the documents resulted in medium overall quality to manage the risks of extreme events. Most indicators presented a good performance with a medium to high grade of breadth and depth scores. Based on Cronbach's alpha, this study reliability reached a high level. The regression analysis demonstrated that 20% of variance in content of documents could be explained by independent variables, suggesting a weak relationship. In order to improve the climate change and disaster preparedness and response managements, we recommend an inclusion of new indicators and contextual variables to investigate the quality of planning documents.

**Keywords:** Climate change; Adaptation; Disaster Risk Management; Public policy; Planning.

***Resumo:*** *As populações das zonas costeiras são mais suscetíveis aos riscos causados por eventos climáticos extremos. Nesse sentido, o planejamento climático vem a ser uma ferramenta importante para adaptar essas áreas às consequências dos desastres climáticos. Este artigo propõe uma avaliação dos riscos costeiros e dos instrumentos de adaptação climática desenvolvidos por trinta países banhados pelo Oceano Atlântico. Estratégias, planos e outros documentos relacionados à adaptação climática foram avaliados a fim de compreender como a estrutura de planejamento nacional pode levar a uma gestão eficiente de eventos climáticos extremos. O conteúdo dos documentos foi avaliado por trinta e dois indicadores dentro das dimensões de conhecimento, análise e ações. Foram realizadas análises de correlação e regressão para verificar a influência das variáveis independentes em seu conteúdo. Os resultados indicam que a qualidade geral dos documentos foi média com relação ao gerenciamento dos riscos de eventos extremos. A maioria dos indicadores apresentou um bom desempenho apresentando média a alta pontuação na profundidade e amplitude. A análise de regressão demonstrou que 20% da variação no conteúdo dos documentos poderia ser explicada pelas variáveis independentes, sugerindo uma relação fraca. Para melhorar a gestão das mudanças climáticas e da preparação e resposta a desastres, é recomendável a inclusão de novos indicadores e variáveis independentes para investigar a qualidade dos documentos de planejamento.*

***Palavras-chave:*** *Mudanças Climáticas; Adaptação; Gestão de Risco de Desastres; Políticas públicas; Planejamento.*

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## 1. INTRODUCTION

The climatic system has been unequivocally affected by human activities, causing irreversible, widespread, and rapid changes in climate components (IPCC, 2021; Rocha, 2021). Land-use changes and fossil fuel emissions are key drivers of climate change (Hong *et al.*, 2021; IPCC, 2021). A warmer climate has intensified surface temperature increase, sea level rise and very wet and very dry weather events (IPCC, 2021). Over the last 50 years, the number of disasters has increased fivefold, mainly in developing countries (WMO, 2021). The 2023 Aon Reporting demonstrated that there were 421 notable disaster events in 2022, resulting in economic losses of $313 billion. Nearly 31,300 people have lost their lives, of which 19,200 were linked to the heatwave in the European summer (Lörinc *et al.*, 2023). However, recent data estimated that the heatwave in the last European summer resulted in 61,672 deaths (Ballester *et al.*, 2023). Among the top 10 disaster events in 2022, five events were floods, leading to 4,091 deaths and $42.2 billion dollars of economic losses (Lörinc *et al.*, 2023). Without concrete adaptation interventions, the 136 largest coastal cities can lose 1 trillion USD per year in 2050 due the future floods (Magnan *et al.*, 2019).

Coastal zones exhibit high rates of urbanization and are the most densely populated in the World. At the same time, these areas are exposed to a range of climate risks, mainly in low-elevation zones (Batista, 2018; Neumann *et al.*, 2015). Estimates suggest that the global population living in low elevation coastal zones is between 750 million and approximately 1.1 billion persons (Macmanus *et al.*, 2021). Coastal areas have high diversity of marine and terrestrial ecosystems that support complex food-chains and are home for many species, including endemic and threatened species (Bijlsma, 1997; Figueiredo & Nicolodi, 2022; Veron *et al.*, 2019). They can support a variety of activities, such as fishery, aquaculture, ocean shipping, housing, tourism, mining, agriculture, and waste disposal. For this reason, coastal zones tend to have higher population and strong economic growth (Bijlsma, 1997; Blackburn *et al.*, 2019). The heavy urbanization is a driving force for ecosystem fragmentation and degradation (Blackburn *et al.*, 2019).

The Intergovernmental Panel on Climate Change and the United Nations Framework Convention on Climate Change have emphasized that Integrated Coastal Zone Management is a key tool for adapting to climate change and improving current conditions in coastal zones (Nicholls *et al.*, 2007). Climate Adaptation is defined "in human systems, as the process of adjustment to actual or expected climate and its effects in order to moderate harm or take advantage of beneficial opportunities" (IPCC, 2022). Adaptation is essential for reducing exposure and vulnerability to climate change and involves activities of an anticipatory, reactive, incremental and/or transformational nature. Adaptation can play a key role to build resilience, that is defined "as the capacity of social, economic and ecosystems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity and structure as well as biodiversity in case of ecosystems while also maintaining the capacity for adaptation, learning and transformation" (IPCC, 2022). There are a set of adaptation options that include transition systems in land and ocean ecosystems management, urban and infrastructure, energy, and cross-sectoral options (IPCC, 2022). In coastal areas, three types of adaptations can be incorporated into their planning and management. Planned retreat options are related to abandonment of highly vulnerable areas and population resettlement. Accommodate options comprise ecosystem conservation and resilience actions to be harmonized with socioeconomic development. Protect options can involve hard structural measures, such as dikes, barriers, sea walls, and soft structural options, like beach nourishment and dune restoration (Bijlsma, 1997). Effectiveness, efficiency, equity, and legitimacy are important elements to be considered for the judgment of adaptation success (Adger *et al.*, 2005). The mitigation potential of land use activities related to forest conservation and sustainable agriculture has been recognized as fundamental to achieve the Paris Climate Agreement goals (Winkler *et al.*, 2021). Adaptation and mitigation actions must be included and integrated to limit warming and reduce damages and losses (Hurlimann *et al.*, 2021; Morecroft *et al.*, 2019).

For disaster risk management, it is fundamental that prospective or proactive integrated actions are priority in relation to corrective responses (Lavell, 2009). As a result, the development and integration of climate and coastal plans represent good devices to disaster preparedness in coastal areas, mainly in context of the extreme weather events (UNDP, 2010). Climate adaptation documents, like adaptation strategies and plans are relevant measures to reduce natural hazard and prevent disasters (UNDP, 2010). Disaster Preparedness Programs have intensified since the International Decade for Natural Disaster Reduction (IDNDR) was launched in 1989 (ISDR, 2022). From then on, there have been three events known as the World Conference on Disaster Risk Reduction in the cities of Yokohama (1994), Kobe (2005) and Sendai (2015). These conferences published three important disaster management frameworks: Yokohama Strategy and Plan of Action for a Safer World, Hyogo Framework for Action 2005 - 2015 and Sendai Framework for Disaster Risk Reduction 2015-2030 (Rodrigues, 2010; Coppola, 2015). The Sendai Framework aims to the substantial reduction of disaster risk and losses in lives, livelihoods, and health and in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries, over the next 15 years (UNISDR, 2015). Each member state must propose national targets to implement concrete actions to minimize disaster risks, in accordance with their national priorities (UNISDR, 2015). The Sendai Framework also is aligned to other agreements, including the Sustainable Development Goals, The Paris Agreement on Climate Change, The Addis Ababa Action Agenda on Financing for Development, and the New Urban Agenda (UNDRR, 2023).

Considering that the development of public policies is essential for climate adaptation in coastal areas, the aim of this study was to assess the content of national climate adaptation documents from countries bordering the Atlantic Ocean.

## 2. METHODS

### 2. 1. Study area

To include the largest number of Atlantic coastal countries from different continents of the World, we selected the 30 longest Atlantic coastline countries. Coastline data was collected from "The World Factbook 2020" (CIA, 2021). We selected 16 countries from Europe (Croatia, Denmark, Estonia, France, Germany, Greece, Iceland, Italy, Norway, Portugal, Spain, Russia, Sweden, Turkey, Ukraine and the United Kingdom), 4 countries from South America (Argentina, Brazil, Chile and Venezuela), 4 countries from Central America (Bahamas, Cuba, Haiti and Panama), 3 countries from Africa (South Africa, Angola and Morocco) and 3 countries from North America (Canada, United States and Mexico).

### 2.2. Data Collection and Measurement

#### *2.2.1. Selection of National Climate Adaptation Documents*

This study source comprises federal government documents regarding climate adaptation management and planning, such as national adaptation plans, national adaptation strategies, climate risk assessments, climate vulnerability assessments and adaptation reports. Most of the plans and strategies were collected from the "Climate Change Laws of the World and Climate Change Litigation of the World" website (https://climate-laws.org/) developed by the Grantham Research Institute at the London School of Economics and Political Science. Additional climate-related documents were also obtained from government entities of each country. Table 1 lists all selected documents.

#### *2.2.2. Dependent Variable*

The content of national climate adaptation documents for disaster risk management is measured by thirty-two indicators, according to Tang (2008) and Tang *et al*. (2010; 2013). Each indicator is scored on a 0-2 scale. The score "0" means that the indicator is not identified and recognized. The score "1" means that the indicator has been identified or mentioned without details. The score "2" means that the indicator has been thoroughly identified in full, with details.

Table 1. List of National Climate Adaptation Documents.

| Countries | Coastline (Km) | Document Titles | Publication Year |
|---|---|---|---|
| Canada | 202080,00 | 1.Policies for In-Water and Shoreline Works and Related Activities<br>2.Human Health in a Changing Climate: A Canadian Assessment of Vulnerabilities and Adaptive Capacity<br>3. Land use planning tools for local adaptation to climate change<br>4. Federal Adaptation Policy Framework<br>5. Canada's marine coasts in a changing climate<br>6. An Emergency Management Framework for Canada<br>7. Measuring Progress on Adaptation and Climate Resilience: Recommendations to the Government of Canada<br>8. Canada's Top Climate Change Risks | 2007, 2008, 2012, 2016, 2017, 2018, 2019 |

Table 1. (cont.) List of National Climate Adaptation Documents.

| Countries | Coastline (Km) | Document Titles | Publication Year |
|---|---|---|---|
| Norway | 83281,00 | 1. Climate Change Adaptation in Norway<br>2. Norway's First Adaptation Communication<br>3. Norway's Climate Action Plan<br>4. Norway's Seventh National Communication: Under the Framework Convention on Climate Change<br>5. Adapting to a Changing Climate Norway's vulnerability and the need to adapt to the impacts of climate change. | 2008, 2012, 2013, 2020, 2021 |
| Russia | 37653,00 | 1. National Action Plan for the First Phase of Adaptation to Climate Change | 2019 |
| United States | 19924,00 | 1. U.S. Environmental Protection Agency Climate Change Adaptation Plan - 2012<br>2. U.S. Environmental Protection Agency Climate Change Adaptation Plan - 2013<br>3. U.S. Environmental Protection Agency Climate Change Adaptation Plan - 2014<br>4. U.S. Environmental Protection Agency Climate Change Adaptation Plan – 2021 | 2012, 2013, 2014, 2021 |
| Greece | 13676,00 | 1. The Environmental, Economic and Social Impacts of Climate Change in Greece<br>2. Climate Change Adaptation Strategy<br>3. Greece's Recovery and Resilience Plan | 2011, 2016, 2021 |
| United Kingdom | 12429,00 | 1. The National Adaptation Program: Making the Country Resilient to a Changing Climate<br>2. The National Adaptation Program and the Third Strategy for Climate Adaptation Reporting<br>3. Climate Adaptation Risk Assessment Progress Update – 2016<br>4. UK Climate Change Risk Assessment 2022 | 2013, 2016, 2018, 2022 |
| Mexico | 9330,00 | 1. National Climate Change Strategy<br>2. Decree Approving the Special Climate Change Program<br>3. Adaptation to Climate Change in Mexico: Vision, Elements and Criteria for Decision-Making<br>4. National Strategy for REDD+ 2017-2030 | 2012, 2014, 2017, 2018 |
| Italy | 7600,00 | 1. Climate Adaptation Strategy for Climate Change<br>2. Seventh National Communication under the UN Framework Convention on Climate Change<br>3. Italy's Integrated National and Energy Climate Plan<br>4. Italy's National Plan for Resilience and Recover | 2015, 2017, 2019, 2021 |
| Brazil | 7491,00 | 1. Adaptation Climate Change Guide for Federal Entities<br>2. National Plan for Adaptation Climate Change | 2013, 2016 |
| Denmark | 7314,00 | 1. Danish Strategy for Adaptation to a Changing climate<br>2. The Action Plan for a Climate-proof Denmark<br>3. The Danish Climate Policy Plan<br>4. Denmark's Integrated National Energy and Climate Plan<br>5. Denmark's Recovery and Resilience Plan | 2008, 2012, 2013, 2019, 2021 |
| Turkey | 7200,00 | 1.Turkey's National Climate Change Adaptation Strategy and Action Plan<br>2. Climate Change Action Plan 2011-2023 | 2011, 2012 |
| Chile | 6435,00 | 1. National Climate Change Action Plan 2008-2012<br>2. National Climate Change Action Plan 2017-2022<br>3. Climate Change Adaptation Plan for the Agricultural and Fishery sectors<br>4. Climate Change Adaptation Plan for Biodiversity<br>5. National Climate Change Adaptation Plan<br>6. Climate Change Adaptation Plan for the Health Sector<br>7. National Strategy on Forests and Climate Change 2017-2025 | 2008, 2013, 2014, 2014, 2016, 2017, 2020 |
| Croatia | 5835,00 | 1. Integrated National Energy and Climate Plan for the Republic of Croatia<br>2. Climate Change Adaptation Strategy in the Republic of Croatia for the period to 2040 with a view to 2070<br>3. Regulation on the Adoption of the Plan for the Air Protection, Protection of the Ozone Layer and Climate Change Mitigation in the Republic of Croatia for the period 2013-2017 | 2017, 2019, 2020 |
| Argentina | 4989,00 | 1. National Action Plan for Energy and Climate Change<br>2. National Plan for Adaptation and Mitigation to Climate Change<br>3. Law 27520 on Minimum Budgets for Adaptation and Mitigation to Global Climate Change | 2017, 2019 |

Table 1. (cont.) List of National Climate Adaptation Documents.

| Countries | Coastline (Km) | Document Titles | Publication Year |
|---|---|---|---|
| Iceland | 4970,00 | 1. Iceland's Climate Action Plan for 2018-2030 and 2020 Update<br>2. Iceland's 2020 Climate Action Plan | 2018, 2020 |
| Spain | 4964,00 | 1. National Climate Change Adaptation Plan 2006-2020<br>2. National Climate Change Adaptation Plan 2021-2030<br>3. Spain's integrated National Energy and Climate Plan for 2021-2030<br>4. Spain's Recovery and Resilience Plan | 2006, 2020, 2021 |
| France | 4853,00 | 1. National Climate Change Adaptation Plan 2018-2022<br>2. France's Integrated Energy and Climate Plan<br>3. France's Recovery and Resilience Plan | 2018, 2020, 2021 |
| Estonia | 3974,00 | 1. Climate Change Adaptation Development Plan until 2030 (2017)<br>2. Estonia's 2030 National Energy and Climate Plan (NECP 2030) 2019<br>Estonia's Recovery and Resilience Plan | 2017, 2019, 2021 |
| Cuba | 3735,00 | 1. Cuba's State Plan to Confront Climate Change | 2017 |
| Bahamas | 3542,00 | 2. National Policy for the Adaptation to Climate Change | 2005 |
| Sweden | 3218,00 | 1. National Strategy for Climate Change Adaptation (Government Proposition 2017/18:163)<br>2. The Swedish Climate Policy Framework<br>3. Sweden's Integrated National Energy and Climate Plan | 2017, 2018, 2020 |
| Morocco | 2945,00 | 1. National Plan Against Climate Change<br>2. The National Climate Plan: Horizon 2030 | 2019, 2020 |
| Venezuela | 2800,00 | 1. Venezuela (Bolivarian Republic of) First Nationally Determined Contribution<br>2. Venezuela (Bolivarian Republic of) First Nationally Determined Contribution (Updated submission)<br>3. Venezuela National Communication 2 | 2017, 2021 |
| South Africa | 2798,00 | 1. National Climate Change Response Policy White Paper<br>2. National Climate Change and Health Adaptation Plan 2014-2019<br>3. RSA's National Climate Change Adaptation Strategy | 2011, 2014, 2020 |
| Ukraine | 2782,00 | 1. Concept of State Climate Change Policy Implementation until 2030 | 2016 |
| Panama | 2490,00 | 1. National Strategy for Climate Change 2050 (Executive Decree 34/2019) | 2019 |
| Germany | 2389,00 | 1. Climate Action Plan 2050 (2016)<br>2. Germany's Integrated National Energy and Climate Plan 2019<br>3. Germany's Recovery and Resilience Plan 2021<br>4. German Strategy for Adaptation to Climate Change (DAS) 2008 | 2008, 2016, 2019, 2021 |
| Portugal | 1793,00 | 1. National Adaptation Strategy to Climate Change<br>2. Portugal's National Energy and Climate Plan for 2021-2030<br>3. Portugal's Recovery and Resilience Plan | 2015, 2021 |
| Haiti | 1771,00 | 1. National Policy to Fight Climate Change | 2019 |
| Angola | 1600,00 | 1. National Strategy for Climate Change (ENAC)<br>2. Climate Change Adaptation Plan for Angola's Coastal Zone | 2017; 2019 |

Each set of documents has received a final score ranging from 0 to 10, after normalizing the sum of the indicators evaluated using Equation 1.

$$QDj = \frac{10}{2m_j} \cdot \sum_{j=1}^{m} I_j \tag{1}$$

where $QD_j$ is the quality of the $j_{th}$ set of documents, $m_j$ is the number of indicators and $I_j$ represents the score of the $i_{th}$ indicator (ranging from 0 to 2).

The performance of the indicators was measured using two indices: breadth and depth scores. These two indices measure each indicator's quality. Breadth score (Equation 2) assesses the extent to which each of the indicators is addressed across the set of documents, measuring their coverage. The depth score (Equation 3) of an indicator measures its level of importance and analyzes how much importance is stated in the documents where it is addressed.

$$BS_j = \frac{P_j}{N} \cdot 100 \tag{2}$$

where $BS_j$ is the $j_{th}$ indicator breadth score (ranging 0-100%), $P_j$ is the number of countries with documents that address the $j_{th}$ indicator and $N$ is the total number of countries whose documents have been assessed.

$$DS_j = \frac{\sum_{j=1}^{P_j} I_j}{2P_j} \cdot 100 \tag{3}$$

where $DS_j$ is the $j_{th}$ indicator depth score (ranging 0-100%); $I_j$ is the rating on the $j_{th}$ indicator (ranging 0–2); and $P_j$ is the number of countries with documents that address the $j_{th}$ indicator.

### *2.2.3. Dependent variables: awareness, analysis, and action components*

The "Awareness" component indicates the degree to which every set of documents understand climate change concepts and the relevance of extreme climate events, including evidences from IPCC reports (Tang *et al.*, 2010). The set of documents should recognize the role of climate variability and uncertainty. Climate resilience goals must be presented (Tang *et al.*, 2010).

The "Analysis" component assesses the hazards, vulnerabilities, risks, and costs of climate adaptation. This component is also divided into four indicators. The first indicator is related to the identification of coastal hazards from climate change. The vulnerability analysis considers whether there has been a characterization of the exposed populations and properties to a hazardous event in coastal areas. The physical and social vulnerabilities need to be identified. Risk assessment must be a description of the risks from possible hazard events in coastal areas. The analysis of adaptation costs estimates the mitigation and adaptation costs from the potential strategies (Tang *et al.*, 2010).

The "Action" component examines policies, tools, and strategies to adapt to climate change and reduce the risk of extreme events in coastal areas. Disaster risk management must develop resilience to potential climate impacts (Tang *et al.*, 2010). This component has 24 indicators, with six subcomponents. The first set of subcomponents shows important tools for reducing exposure. These tools are land use and development regulations, property acquisition programs, shoreline regulations and requirements, and defensive infrastructure and critical facilities policies (Tang *et al.*, 2013). The second set involves indicators to verify actions that increase resilience to changing risks, such as public awareness and education activities, the incorporation of risk management into decision-making processes, structure to enhance inter-organizational and inter-jurisdictional coordination and the establishment of a data platform. The third set of subcomponents includes actions to achieve a climate change transformation. Transformation is the deepest form of adaptation, where the development structures are reconfigured, the political-economy regime is reformed and individual values are reconstituted (Pelling *et al.*, 2010). The process of transformation should identify roles and responsibilities between sectors and stakeholders, measures of adaptive learning, continuous monitoring, evaluation and updating for successful adaptation; identification of financing sources and advances in scientific data and its analysis focused on climate change (Tang *et al.*, 2013). The fourth set of subcomponents is composed of action to reduce vulnerability, such as building codes, protection of natural resources, programs for local incentive and public-private initiatives. The fifth set comprises effective actions for countries to be able to prepare, respond and recover extreme weather events. The promotion of early warning systems, emergency preparedness and response procedures, local hazard mitigation plans and integration of climate change into coastal zone management plans are the indicators of this subcomponent. Finally, the sixth subcomponent consists of actions to pool, transfer and share climate risks, such as reserve funds and incentive loans, financial insurance, tax credits and the development of impact fees.

### *2.2.4. Independent Variables*

Nine independent variables are measured and analyzed to explain the variation in the quality of national climate adaptation documents scores. These measurements and resources are listed in Table 2.

To select the independent variables for the regression model, we initially evaluated the correlation between the score of quality of documents (dependent variables) and each independent variable. A two-tailed hypothesis t-test was designed to measure the uncertainty associated with the correlation coefficients. The critical t-value (r=2.048) with n-2 degrees of freedom was used as a reference. If the t-test statistic value is greater than the critical value, then there is significant linear correlation, and we reject the null hypothesis. The variables with significant and highest correlation coefficients were elected for the multiple regression model.

### *2.2.5. Data treatment*

Cronbach's Alpha (Equation 4) was calculated to examine the reliability of indicators:

$$\alpha = \frac{K}{K-1}[1-(\frac{\sum S_i^2}{S_T^2})] \quad (4)$$

where $K$ is the number of component indicators, or the total number of indicators evaluated. $\sum S_i^2$ the sum of the variance of the component or all indicators (variance of each column) and $S_T^2$ is the variance of the total scores.

Cronbach's alpha above 0.75 to 0.8 suggests a high reliability level. The Cronbach's alpha scores can indicate an internal consistency of the indicators. The Table 3 lists qualitative descriptors used for value ranges to interpret alpha values calculated.

Table 2. Measurement of independent variables

| Variables | Variable Description | Scale | Data Sources |
|---|---|---|---|
| Federal risk management | Disaster preparedness and response plans and risk assessment updated over the last 5 years | 0-1<br>0 for no documents<br>0.5 for documents up to 2017<br>1 for documents after 2017. | Climate Laws of the World<br>https://climate-laws.org/<br>Platform Climate Adapt<br>https://climate-adapt.eea.europa.eu/<br>Official websites from government entities |
| Wealth | Median income per capita (2022) | Dollars<br>(natural logarithm) | World Population Review |
| Educational attainment | Percentage of population aged 25 years and over with a Bachelor's degree or higher | 0-100% | World Bank Data<br>World Population Review |
| Number of extreme climatic events | Number of severe weather events during 1980-2020 | Number of disasters | Climate Knowledge Portal |
| Population Size | Number of people per country in 2022 | Number of people (natural logarithm) | The World Bank Data |
| Number of deaths from disasters | Number of deaths from disasters during 1980-2020 | Number of deaths (natural logarithm) | Our World In Data |
| Energy consumption | Total estimated energy per capita (2022) | GigaWatts | World Population Review |
| Transport<br>emission | Amount of carbon dioxide emitted by transportation sector in 2019 | Tonnes per capita | Our World In Data |
| Greenhouse gases emission | Percentage of emissions worldwide | 0-100% | Climate Laws of the World<br>https://climate-laws.org/ |

Table 3. Reliability classification from the Cronbach's Alpha.

| Alpha Value | Reliability |
|---|---|
| $\alpha \leq 0{,}30$ | Very low |
| $0.30 < \alpha \leq 0.60$ | Low |
| $0.60 < \alpha \leq 0.75$ | Moderate |
| $0.75 < \alpha \leq 0.90$ | High |
| $\alpha > 0.90$ | Very high |

Source: Freitas & Rodrigues (2005).

In order to evaluate the multicollinearity between the predictors, the Variance Inflation Factor (Equation 5) was calculated, according to Thompson *et al*. (2017).

$$VIF = \frac{1}{(1 - R_{Ij}^2)} \quad (5)$$

where $R_{Ij}^2$ is the multiple correlation coefficient of the independent variables.

$VIF$ greater than 10 indicates the presence of multicollinearity. If $VIF$ is lower than 10, there is a weak collinearity. In addition, the Tolerance coefficient (Equation 6) was used to evaluate the multicollinearity better.

$$TOL = \frac{1}{VIF} \quad (6)$$

where $VIF$ is the Variance Inflation Factor.

Smaller tolerance values increase the likelihood of multicollinearity. The closer the $TOL$ is to 1, the likelihood of multicollinearity decreases. If $TOL$ approaches zero, the greater the chance of multicollinearity (Thompson *et al*., 2017).

The regression model significance was determined through an analysis of variance (ANOVA). ANOVA uses the $F$-test to assess the equality of means in three or more groups of data. The null hypothesis is that all β parameters are equal to 1. The null hypothesis is rejected when at least one of the parameters is different from zero. The significance of the β parameters was checked using the p-value in ANOVA. When p-value is lower than 0.05, the regression model is considered significant (Bedeian & Mossholder, 1994). Correlation and Regression Analysis were performed using the tool "Data Analysis" in Excel®.

## 3. RESULTS AND DISCUSSION

### 3.1. Quality of Climate Adaptation Documents

The documents selected for this study showed a medium quality in managing the risks of extreme events, since the average score was $QD_{(MEAN)}$=6.55, at a scale of 0 to 100. The minimum score was $QD_{(MIN)}$ = 2.91, corresponding to Ukraine, while the maximum score was $QD_{(MAX)}$ = 8.91, corresponding to Norway, the United Kingdom, Croatia, and Spain. Ukraine is currently in an unfortunate period of war, but its documents were elaborated before this period. The low quality of its documents is due half of indicators assessed were scored zero. Only the first two indicators scored maximum points. The mean scores for the three indicator components and the final score per country can be seen in Figure 1 and Table 4.

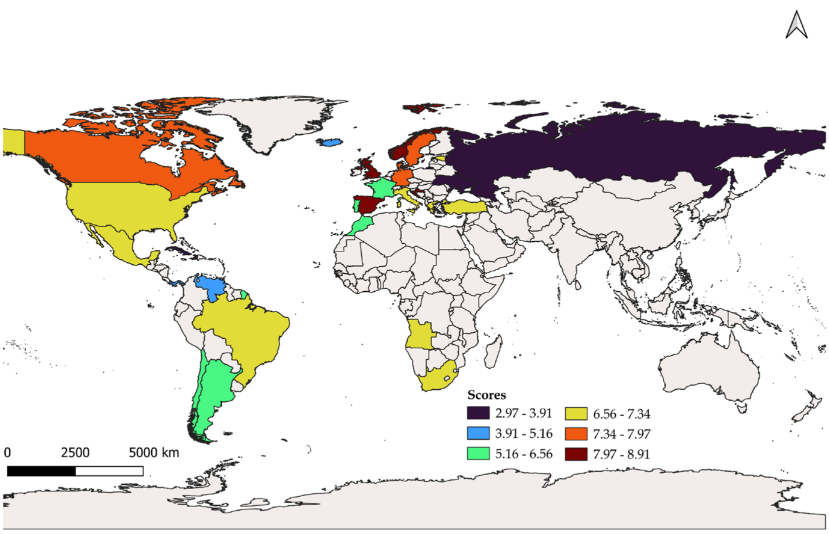


Figure 1. Map of climate adaptation document scores.

Table 4. Plan component scores and total scores (by percentage).

| Country | Awareness | Analysis | Action | Whole documents |
|---|---|---|---|---|
| Canada | 0.88 | 0.75 | 0.79 | 7.97 |
| Norway | 0.88 | 1.00 | 0.88 | 8.91 |
| Russia | 0.38 | 0.25 | 0.38 | 3.59 |
| United States | 1.00 | 0.63 | 0.67 | 7.03 |
| Greece | 100 | 0.88 | 0.63 | 7.03 |
| United Kingdom | 0.63 | 0.88 | 0.94 | 8.91 |
| Mexico | 0.88 | 0.63 | 0.71 | 7.19 |
| Italy | 1.00 | 0.63 | 0.65 | 6.88 |
| Brazil | 0.88 | 0.75 | 0.69 | 7.19 |
| Denmark | 1.00 | 0.75 | 0.75 | 7.81 |
| Turkey | 0.88 | 0.63 | 0.69 | 7.03 |
| Chile | 0.88 | 0.63 | 0.54 | 5.94 |
| Croatia | 1.00 | 1.00 | 0.85 | 8.91 |
| Argentina | 0.88 | 0.63 | 0.56 | 6.09 |
| Iceland | 0.25 | 0.25 | 0.60 | 5.16 |
| Spain | 1.00 | 1.00 | 0.85 | 8.91 |
| France | 0.88 | 0.38 | 0.54 | 5.63 |
| Estonia | 1.00 | 0.88 | 0.67 | 7.34 |
| Cuba | 0.50 | 0.63 | 0.33 | 3.91 |
| Bahamas | 0.63 | 0.38 | 0.35 | 3.91 |
| Sweden | 0.88 | 0.88 | 0.71 | 7.50 |
| Morocco | 0.63 | 0.75 | 0.65 | 6.56 |
| Venezuela | 0.88 | 0.38 | 0.46 | 5.00 |
| South Africa | 0.88 | 0.88 | 0.65 | 7.03 |
| Ukraine | 0.50 | 0.38 | 0.25 | 2.97 |
| Panama | 0.50 | 0.38 | 0.42 | 4.22 |
| Germany | 0.75 | 1.00 | 0.75 | 7.81 |
| Portugal | 1.00 | 0.75 | 0.54 | 6.25 |
| Haiti | 0.38 | 0.38 | 0.33 | 3.44 |
| Angola | 0.75 | 0.38 | 0.75 | 7.03 |

Large variations were found among the countries. Norway, the United Kingdom, Croatia, Spain, Canada, Denmark, Germany, Sweden, Estonia, Mexico, and Brazil are the 10 countries with the highest quality documents. All of these countries have developed documents detailing important measures for managing the risk of extreme weather events and disasters, such as continuous monitoring, use of scientific data in decision-making process, emergency preparedness and response planning and early warning system procedures, guidelines for local hazard mitigation plans, land use and building codes. However, Norway, the United Kingdom, Croatia and Spain have developed better other indicators, such as assessment of adaptation costs, adaptive learning, tax credits, impact fees, and therefore received the highest scores.

The ten worst performers were Chile, France, Iceland, Venezuela, Panama, Cuba, the Bahamas, Russia, Haiti and Ukraine, whose documents scored below 6. All these countries developed climate adaptation documents with gaps in indicators related to emergency response, land use, and taxation. Another common feature is that many documents were extremely short. The documents for Cuba, Russia, Ukraine, France and Iceland ranged from 7 to 26 pages.

### 3.2. Indicator performance

Table 2 lists the breadth and depth scores for each indicator. The mean breadth score is 83.3%, which means that all indicators were checked in 25 countries. The breadth scores ranged from 43.3% to 100%. Four indicators were developed by all countries. These included identification of coastal hazards from climate change, risk assessment, identification of potential financing sources, and contingency and emergency preparedness and response procedures for extreme events. Assessment of adaptation costs showed the lower breadth, verified in 13 of the 30 countries.

This depth score shows that, among the countries whose documents identified any of the indicators, 54.5% to 96.5% received the maximum possible score. This is the case for the first indicator "Extreme events from climate change", whose total score was 56 in 58 and achieved the maximum depth score. The indicator "Development of local all-hazard mitigation plans" was found in 22 national documents and received 24 out of 44 possible points.

In the "Awareness" component, more than 90% of the documents recognized extreme events from climate change. Seven countries did not cite climate change evidences from IPCC reports in their documents. Although 90% of the countries mentioned climate resilience as an objective in their documents, the depth was moderate ($DS$ = 68.5%). 75% of the countries have achieved the highest level for this component and four countries did not reach 50% of the maximum score: Venezuela, Iceland, Haiti and Russia. Portugal, Estonia, Croatia, Denmark, Italy, the United States and Greece fully developed this component, scoring 100%. Despite the resilience goals not being consolidated in the documents analyzed, resilience plans have already been developed by the member states of the European Union. These plans follow the "NextGenerationEU" regulation, which aims to rebuild Europe after the pandemic crisis through green and digital transition (Pilati, 2021). The United States has also supported developing municipal resilience plans, with a total investment of $1 billion (Woodruff *et al.*, 2022). Resilience plans have presented a more integrated and participatory approach than adaptation plans, although local adaptation plans present a more robust assessment of local impacts (Woodruff *et al.*, 2022).

The mean depth and breadth scores for the "Analysis" component were around 80% for all countries. Russia, Iceland, France, Bahamas, Ukraine, Panama, Haiti and Angola also did not reach 50% of the score in this component. Most documents provide a good level of depth ($DS$ = 66.7%) in identifying coastal hazards from climate change, but without contextualizing the geographical characteristics of the country. With regard to the assessment of vulnerability, 28 out of 30 countries carried it out with a high level of depth ($DS$ = 83.3%). In contrast to the other indicators, the assessment of adaptation costs had a low breadth ($BS$ = 43.3%), being developed by only thirteen countries. However, these countries reported a detailed analysis with significant depth ($DS$ = 84.6%). Norway, Croatia, Spain, and Germany produced good assessment documents, addressing their hazards, risks, and vulnerabilities according to their geographical and socio-economic characteristics, and developing a detailed assessment of adaptation costs. Nonetheless, the assessment of adaptation costs is a difficult tool to implement. There are gaps in the scope and depth of the many analyses, such as the costing of measures, and the treatment of uncertainty. This reflects the difficulty of measuring costs, which tend to be underestimated (Fankhauser, 2010). There is also a lack of knowledge on how to measure and assess adaptive capacity and practical barriers to adaptation. Little is known about how to adequately evaluate the aggregate costs of adaptation, but implementation has become more difficult (Fankhauser, 2017).

The "Action" component was rated the lowest among the countries, which together reached 62% of the maximum score. The top 4 scoring countries were Norway, the United Kingdom, Croatia, Spain, and Germany, with scores ranging from 75% to 94%. The lowest scoring countries ranged from 25% for Ukraine, 33% for Cuba and Haiti, 35% for the Bahamas, 38% for Russia, 42% for Panama, and 46% for Venezuela. Given that this component includes proposals, guidance, and actions to achieve climate resilience, it is worrying that highly vulnerable countries have not sufficiently developed this part of the planning. Cuba, Haiti, Panama, and Venezuela are part of the climate-vulnerable Latin America that still has a deficit in implementing adaptation measures and disaster management strategies (Nagy *et al.*, 2019; Stennet-Brown *et al.*, 2019).

In the "exposure reduction" subcomponent, land acquisition programs ($BS$ = 60%; $DS$ = 61.1%) and shoreline regulations ($BS$ = 56.7%; $DS$ = 67.6%) received moderate attention. These two issues are sensitive because they may involve removing people from their homes. The intensification of hazard risks due to climate change has increased the need for resettlement policies, which can be a violation if it destroys the livelihood and network

Table 5. Indicator breadth and depth scores

| Components and subcomponents | | Indicators | Breadth (%) | Depth (%) |
|---|---|---|---|---|
| AWARENESS | | A01. Extreme events from climate change | 96.6 | 96.6 |
| | | A02. Uncertainty of climate change | 86.7 | 94.2 |
| | | A03. Climate change evidence identified by IPCC assessment report | 80 | 91.7 |
| | | A04. Goal for building coastal resilience | 93.3 | 69.9 |
| ANALYSIS | | B01. Identification of coastal hazards from climate change | 100 | 66.7 |
| | | B02. Vulnerability assessment | 93.3 | 83.9 |
| | | B03. Risk assessment | 100 | 80 |
| | | B04. Assessment of adaptation costs | 43.3 | 84.6 |
| ACTION | Reduce exposure | C01. Land use and development regulations | 86.7 | 76.9 |
| | | C02. Property acquisition programs | 60 | 61.1 |
| | | C03. Shoreline regulations and requirements | 56.7 | 67.6 |
| | | C04. Defensive infrastructure and critical facilities policies | 96.7 | 82.8 |
| | Increase resilience to changing risks | C05. Public awareness, education to climate change and hazards | 96.7 | 91.4 |
| | | C06. Incorporation of risk management into economic development decision-making processes | 96.7 | 86.2 |
| | | C07. Enhancement inter-organizational, cross-jurisdictional coordination | 83.3 | 62.0 |
| | | C08. Establishment of environmental stewardship and sustainability platform | 86.7 | 80.8 |
| | Transformation | C09. Identification of roles and responsibilities among sectors and stakeholders | 93.3 | 62.5 |
| | | C10. Adaptive learning, continuous monitor, evaluate and update | 100 | 83.3 |
| | | C11. Identification of potential financing sources | 93.3 | 80.4 |
| | | C12. Advancing science data and analysis for climate change | 83.3 | 80 |
| | Reduce vulnerability | C13. Building codes and design standards | 83.3 | 80 |
| | | C14. Natural resource protection | 96.7 | 84.5 |
| | | C15. Local incentive programs | 73.3 | 68.2 |
| | | C16. Public-private sector initiatives | 96.7 | 74.1 |
| | Prepare, respond, recover effectively | C17. Promotion of early warning and communication | 83.3 | 78 |
| | | C018. Emergency preparedness and response procedures for extreme events | 100 | 76.7 |
| | | C19. Development of local all-hazard mitigation plans | 73.3 | 54.5 |
| | | C20. Integration of climate change into coastal zone management plans | 63.3 | 68.4 |
| | Pool, transfer, and share risks | C21. Mutual and reserve funds/incentive loans | 90 | 90.7 |
| | | C22. Financial insurance | 76.7 | 69.6 |
| | | C23. Tax credits | 80 | 72.9 |
| | | C24. Development impact fees | 50 | 66.7 |

of communities exposed to risks without replacing them. Many countries don't have the legislation, institutions, and qualified professionals to carry out this process in a humane and fair manner. There is no clear internationally accepted definition of uninhabitability and under what conditions resettlement may be the best option (Oliver-Smith, 2021).

In the subcomponent "Increase resilience to changing risks", the enhancement of inter-organizational and cross-jurisdictional coordination had great breadth but moderate depth ($BS$ = 83.3%; $DS$ = 62.5%). The role of regional international organizations in the implementation of disaster-related adaptation measures was weakly mentioned in the documents. Regional organizations are important sources of technical and financial assistance in areas such as food security, water resources management, and coastal management. Increased coordination tends to reduce rivalries and competition for access to international funding sources (Gilfillan *et al.*, 2020).

In the transformation subcomponent, most countries identified the roles and responsibilities between sectors and stakeholders but did not provide a more detailed description ($BS$ = 93.3%; $DS$ = 62.5%), especially with regard to climate disasters. The documents were limited to mentioning coordination and relationships between different spheres of government (local, state and federal), but the responsibilities of each level for managing extreme weather events were poorly developed. Half of the countries have described procedures for adaptive learning, continuous learning, evaluation and updating in relation to extreme climate events, with medium to high depth ($BS$ = 50%; $PPI$ = 63.3%). Adaptive capacity is a fundamental requirement for the success of adaptation measures. Lack of knowledge has been identified as one of the constraints in the adaptation process. The production and sharing of knowledge are a strong determinant in this process (Williams *et al.*, 2015). The low breadth and moderate depth of this indicator may indicate that this key condition has not been prioritized in planning processes. Multi-stakeholder integration is essential for the development of a knowledge culture, which leads to the civil society participation in decision-making processes related to planning and implementation of disaster preparedness and response (Butler *et al.*, 2015).

Considering that extreme weather events can cause irreparable material and human damage, investing in early warning systems (EWS) is one of the main ways to prepare for and respond to emergencies (Zommers & Singh, 2014). In this regard, 24 out of 30 countries presented and described procedures for these systems ($BS$ = 83.3%; $DS$ = 78%). Since the Indian Ocean tsunami in 2004, the number of publications on EWS and disaster management has increased, although there are still limitations in their performance, which ignores power relations and the need for a pluralistic knowledge approach (Hermans *et al*. 2022). Within the "prepare, response and recovery effectively" subcomponent, the development of local hazard mitigation plans also had a high breadth but low depth ($BS$ = 73.3%; $DS$ = 54,5%). Planning at the local level is essential to identify and manage hazards, risks, and vulnerabilities with spatial specificity. In this sense, it is necessary for all national jurisdictions to require local hazard mitigation plans, integrated into local climate plans, in order to access national funds and to prepare for and respond to climate change-related disasters (Stults, 2017; Wickham *et al.*, 2019). Still regarding disaster preparedness and response, coastal countries need to have integrated coastal management and climate adaptation plans, mainly due to the greater vulnerability of these areas to extreme weather events (Frazão Santos *et al.*, 2020). However, only 18 countries have developed documents indicating this integration and only 7 have detailed it ($BS$ = 63.3%; $DS$ = 68.4%). The low level of operationalization of this integration has been identified as a major challenge (Frazão Santos *et al.*, 2020).

In the subcomponent "pool, transfer and share risks", the development of impact fees was presented by half of the countries and detailed by only 5 ($BS$ = 50%; $DS$ = 66.7%). The development of emission impact fees is an important tool for internalizing the costs of climate change. It should be developed based on a cost analysis of greenhouse gas emissions by economic activities and households (Jepson, 2011). The formulation of these taxes, especially in households, needs to be done with public participation and support (Jepson, 2011). Another important application is the taxation of emissions through Pigouvian taxes. For example, in Sweden and Uruguay, economic activities must pay a tax of $130 and $137 per ton of carbon emitted, respectively (World Bank, 2022).

### 3.3. Cronbach's alpha Coefficient

The components ranged from low to high reliability, indicating differences in the internal consistency of each component separately. "Awareness" component coefficient was the lowest ($\alpha$ = 0.59) and with the smallest variance, resulting in low consistency. The "Analysis" component obtained moderate reliability ($\alpha$ = 0.72). The "Actions" component ($\alpha$ = 0.89) and the total of the indicators ($\alpha$ = 0.92) were considered to have high and very high reliability, respectively (Table 6). Overall, the reliability of the indicators is very good, but the low variances for the “Awareness” and “Analysis” components suggest the need for the selection of indicators for these components.

### 3.4. Correlation and Regression

Two independent variables were statistically significant with the document scores, and they were selected for the regression model, as seen in Table 7.

Among the nine independent variables, “Wealth” and “Educational attainment” were statistically significant and had the highest correlation values for selection in the regression model. The results of the $VIF$ and $TOL$ multicollinearity tests are shown in Table 8.

The variables selected for the regression model had $VIF$ values less than 10, indicating weak collinearity. However, the $TOL$ estimator had a value of 0.49, slightly closer to 0 than to 1. Based on the above tests, we decided to perform a multiple regression with the tested variables that were significant (Wealth and Educational attainment).

In the multiple regression analysis, the coefficient of determination (r2) was 0.20, which means that the selected variables explain about 20% of the variation in the document scores. The F-test in one-way ANOVA was less than 0.05, which shows that the linear regression model is significant. However, the parameters β1 and β2, both parameters showed a p-value above 0.05 and therefore not significant. The low value of the coefficient of determination suggests that new explanatory variables should be selected and tested to explain the variation in document quality. Residuals are randomly scattered and are normally distributed. Tables 9 and 10 show the values of the regression model developed for this study.

Table 6. Cronbach’s alpha Coefficient for the indicators

| Components | Number of indicators | $\sum S_i^2$ | $S_T^2$ | Cronbach’s alpha index | Reliability |
|---|---|---|---|---|---|
| Awareness | 4 | 1.73 | 3.10 | 0.59 | Low |
| Analysis | 4 | 1.69 | 3.63 | 0.71 | Moderate |
| Action | 24 | 10.32 | 74.15 | 0.89 | High |
| All indicators | 32 | 13.75 | 123.13 | 0.92 | Very high |

Table 7. Correlation between document scores and independent variables

| Independent variable | Coefficient of correlation (r) | Student’s t-test (Critical Value = 2,048) | p-value |
|---|---|---|---|
| Federal risk management | 0.27 | 1.48 | 0.45 |
| Wealth | 0.39 | 2.26 | 0.03 |
| Educational attainment | 0.42 | 2.43 | 0.02 |
| Number of extreme climatic events | 0.17 | 0.92 | 0.34 |
| Population Size | -0.20 | 1.10 | 0.28 |
| Number of deaths from disasters | -0.22 | 1.21 | 0.24 |
| Energy consumption | 0.12 | 0.62 | 0.54 |
| Transport emission | 0.33 | 1.86 | 0.09 |
| Greenhouse gases emission | 0.02 | 0.13 | 0.90 |

Table 8. Multicollinearity test for the selected variables for regression model

| Isolated variable | VIF | TOL |
|---|---|---|
| Wealth | 2.05 | 0.49 |
| Educational attainment | 2.05 | 0.49 |

Table 9. Regression Model Parameters

| Parameters | Value |
|---|---|
| Coefficient of determination | 0.1924 |
| F-test (ANOVA) | 0.0544 |

Table 10. P-value of the parameters β in the Regression Models

| Predictor Variable | P-value |
|---|---|
| Wealth (β1) | 0.445 |
| Educational attainment (β2) | 0.267 |

## 4. CONCLUSIONS

Climate adaptation documents include strategies, plans, reports, and risk analyses designed to reduce climate vulnerability and to integrate with other related national programs, activities, and policies. In coastal areas, the impact of extreme weather events tends to be greater due to their geographical vulnerability and ability to affect large numbers of people and economic activities.

The climate adaptation documents in this study presented good contents, as the average obtained was M=6.44 (above 6). Twelve of the thirty countries evaluated scored below the average (Russia, Chile, Argentina, Iceland, France, Cuba, Bahamas, Venezuela, Ukraine, Panama, and Haiti).

In the "Awareness" component, which consists of four indicators, the inclusion of IPCC data and climate resilience targets is fundamental to contextualize climate adaptation strategies and plans. These indicators have been reasonably developed by most countries. The definition of climate resilience targets was not developed in detail in the adaptation documents. In most countries, the issue was briefly mentioned.

Similarly, an assessment of the country's risks, hazards, and vulnerabilities, as well as a study of the costs of adaptation, are key factors for a successful adaptation process. Within the "Analysis" component, the identification of coastal hazards was carried out in little depth by most of the countries in the study, without detail and contextualization with their geographical, meteorological, and climatic peculiarities. The analysis of adaptation costs is a difficult process and was performed by less than half of the countries.

The "Action" component, with 24 indicators, was the least developed in this study. 19 out of 30 countries developed the subcomponents "reduce exposure and vulnerability", "increase resilience", " transformation", "prepare, respond and recover effectively" and "pool, transfer and share risks" above average. This result indicates the need to review the documents for improvements. The indicator "local hazard mitigation plan" was poorly developed by 16 countries. Adaptive learning policies were also underdeveloped and represent barriers to climate adaptation. Many of the worst performing countries in this component are part of the Caribbean, an area highly vulnerable to climate change. It is imperative that these countries improve their planning and, above all, implement the measures necessary for good climate adaptation.

The quality of the selected indicators developed by Tang *et al.* (2010; 2013) showed low to very high reliability based on Cronbach's alpha coefficient. A revision of the "Awareness" component could increase the internal consistency of the indicators. In addition, the selection of new indicators could enhance the consistency of the method. Indicators that could potentially be tested include an achievement of goals from disaster risk management frameworks and document release dates.

Finally, the regression model is significant, and the residuals are randomly scattered and normally distributed. However, the coefficient of determination is low, indicating that wealth and education attainment explain 20% of the variation in the document scores. Some additional independent variables should be selected and tested to further identify the relationship between planning content and influencing factors.

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