

Institutional barriers for the implementation of climate change adaptation actions in the Mexican coastal zones

Norma Patricia Muñoz-Sevilla¹, Isaac Azuz-Adeath² and Maxime Le Bail¹

¹ Centro Interdisciplinario de Investigaciones y Estudios sobre Medio Ambiente y Desarrollo, Instituto Politécnico Nacional, Mexico

² Centro de Innovación y Diseño, Colegio de Ingenieros, Centro de Enseñanza Técnica y Superior, Campus Ensenada, Mexico.

E-mail: nmunozs@ipn.mx

Abstract. This paper has as its object of study the coastal and marine areas of Mexico; specifically, it focuses on the analysis of existing barriers for the implementation of actions tending to the adaptation to climate change of these fragile and dynamic regions of the national territory. The study makes a general review of the main meetings, agreements and international entities related to the global climate that have served as the basis for the XXI Conference of the Parties, from which emanated the "Paris Agreement". After analyzing some implications of the aforementioned agreement and presenting evidence of the current situation, the main legal and normative instruments of the national marine and coastal areas are reviewed; the main risks in these areas of the national territory associated with climate change are evaluated; the main existing adaptation measures are analyzed; and, the most important socioeconomic and political barriers that exist for their correct implementation are established. Finally, some lines of action are proposed to improve the current vulnerability of the coastal areas and increase their resilience.

1. Introduction

Interest in long-term changes in climate has been the subject of scientific attention at least since the beginning of the last century [1], as well as concern for its impact on human development [2]. It is during the World Conference on Climate of 1979, when researchers of the climatic phenomenon show for the first-time signs of alarm about the effect that human activity was producing on the global climate.

This concern of the international scientific community for the climate system, prompted in 1988 the United Nations Environmental Program (UNEP) and the World Meteorological Organization (WMO) to create the Intergovernmental Panel on Climate Change (IPCC) and, years later, the United Nations Framework Convention on Climate Change (UNFCCC). This last one establishes as its main purpose: to evaluate exhaustively, objectively, openly and transparently, scientific, technical and socioeconomic information the risk of changes in the climate induced by man, its potential impacts and adaptation and mitigation options [3]-[5]. One of the main instrument of the UNFCCC, the Kyoto Protocol, seeks that the signatory countries achieve a reduction in greenhouse gas emissions.

The Conference on Environment and Development, held by the United Nations in Rio de Janeiro, Brazil, in June 1992, generated some of the global proposals and guidelines for action that have had the greatest impact on the historical development of contemporary civilization.

The UNFCCC recognizes since its appearance "that human activities have substantially increased the concentrations of greenhouse gases in the atmosphere and that this produces an increase in the global



temperature of the earth, which could adversely affect ecosystems and humanity", and clearly states as its main objective: "the stabilization of concentrations of greenhouse gases in the atmosphere at a level that allows to prevent anthropogenic interference that is dangerous for the climate system". The signatories of the UNFCCC have been holding regular meetings (COP), and the one held in Paris, France in 2015 (COP 21), resulted into the "Paris Agreement", whose 29 articles' ultima goal for the signatory countries is to stop increasing and if possible reduce the greenhouse gases concentration in the atmosphere. Other sections address the importance of national and regional strategies for communication, capacity building, risk reduction, technological development and, in particular, adaptation and mitigation measures and possible sources of financing for actions and of collaboration strategies.

Although the "Paris Agreement" has been signed by many nations, it is a political document that lacks clearly established quantifiable goals, except for subparagraph 1(a) of Article 2: "Maintain the increase in the world average temperature at maximum 2°C above the levels of the pre-industrial era and strive to limit the increase in temperature to 1.5°C above that level ". To achieve this, the document proposes in Article 4 that countries reach as soon as possible the maximum peak of greenhouse gas emissions and seek their rapid reduction to achieve a balance between emissions and reductions during the second half of this century.

The difficulty of this task is that there is no scientific evidence showing an improvement in global climate conditions or that they can be optimistic about the reduction of greenhouse gas emissions into the atmosphere. Figure 1 shows the historical concentration of CO₂ in the atmosphere recorded in the observatory of Mauna Loa [6]. From the 18th century to some recent relevant events.

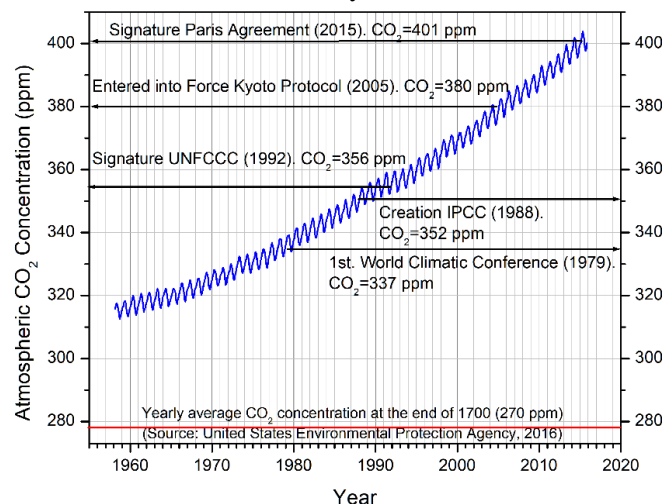


Figure 1. Atmospheric CO₂ concentration recorded by the Mauna Loa observatory (based on data from: Tans, P. and R. Keeling, 2016, NOAA / ESRL and Scripps Institution of Oceanography).

Because reliable records of the global temperature of the planet began after 1880 and that the IPCC establishes there is a low level of confidence existing in the measurements of temperatures previous to the year 1880 and during the industrial revolution [7], there would be no precise data of the maximum permissible global temperature not be exceeded. Despite this lack of definition and the non-technical nature of the "Paris Agreement", greenhouse gases emitted into the atmosphere continue to increase; and it is clear that the human being is affecting the global climate system and having an impact on natural and human systems.

Some of the most important impacts of climate change that are particularly important for this study, which focuses on the coastal states of Mexico, are: an increase in atmospheric temperature and upper layers of the oceans, an accelerated rise in the average sea level, occurrence with greater frequency and intensity of extreme weather events, acidification of the ocean, changes in natural biogeochemical cycles, increase in the incidence and spread of diseases caused by vectors, alterations in agroclimatic systems and fishing.

2. Case study

Mexico has a territorial area of approximately 1.96 million km², a maritime area of 3.15 million km² (61.5% of the national territory) and 11,122 km of coastline, shared by 17 coastal states and around 155 municipalities with seafront. The latitudinal extension of the country, its physiography and its opening to the Pacific Ocean, the Gulf of Cortés, the Gulf of Mexico and the Caribbean Sea, has allowed the existence of a varied and rich biological and landscape diversity.

According to the last census in 2010, the total population of the coastal states was 51.9 million people (46% of the national total), of which 17.5 million lived in municipalities with seafront. Between the years 2005 and 2010, 94% of the existing coastal municipalities reported an increase in their population, while only 6% had a decrease in it. This trend of population and urban growth in the coastal areas of Mexico will continue to increase the pressure and deterioration of coastal and marine spaces and resources; generating great challenges in terms of creation and maintenance of infrastructure, services, transportation and communication networks and, finally, increasing the risk and vulnerability to the phenomena related to climate change.

The 2013 National Inventory of Greenhouse Gases shows that mobile sources, electric power generation and industrial processes contribute with 416 Mt of CO₂e of emissions to the atmosphere, which represents 62.5% of the total national. The coastal states house approximately 40% of the national vehicle fleet, 53% of the national manufacturing companies, and 63% of the national energy total is generated there, which makes them key CO₂e generators. Additionally, it is important to consider the 75,000 marine fishing vessels that operate on the Mexican coast, of which 68,245 have a capacity lower than one ton and, therefore, regularly lack of an adequate preventive maintenance (from the emission perspective). SEMARNAT [8] reported for 2008 that 48% of CO emissions from fixed sources, 55% from mobile sources and 67% from area sources, were generated in coastal states.

The natural and human systems present in the coastal areas of Mexico are especially sensitive to the impacts of climate change. These areas are intrinsically dynamic spaces for which strategies that favour their sustainable development must be sought. In this sense, this paper will address the following issues: first, it will analyze the relevant legal and regulatory instruments for the coastal and marine areas; then, it will analyze the main risks associated with climate change and variability and, finally, it will review existing and necessary adaptation measures and analyze the main barriers to the implementation of climate change adaptation actions.

3. Legal instruments for climate change and coastal zones

The National Policy for Seas and Coasts of Mexico establishes the need for coastal municipalities to count with an "Atlas of Risk" in which particular attention must be paid to the effects and impacts of climate change (section 1.4.1). On the other hand, strategy 1.5 proposes "to promote the elaboration, conclusion and execution of the Climate Change State Programs for the 17 coastal states". This policy for seas and coasts is contemporary with the General Law of Climate Change [9], which had as main antecedents the creation of the Inter-Ministerial Commission on Climate Change, the appearance of the National Strategy for Climate Change and the National Climate Change Program 2008-2012, published in 2009.

The General Law of Climate Change (LGCC), in addition to creating the National Institute of Ecology and Climate Change (INECC) and the National Council on Climate Change, establishes among its general provisions the elaboration and application of public policies for the adaptation to climate change and for the mitigation of emissions of gases and compounds of greenhouse effect. It defines the attributions of the federation, states and municipalities in the matter of climate change; the principles of the National Climate Change Policy and its evaluation mechanisms, as well as the guiding principles of the National Policies for Adaptation and Mitigation of Climate Change. It also specifies the guidelines of the National Climate Change System, of the CICC, of the National Council on Climate Change and creates the following planning instruments: the National Climate Change Strategy 10-20-40, the Special Program on Climate Change and the Climate Change State Programs as the main normative instrument of government actions on climate change, the LGCC is a solid, coherent instrument with the necessary instruments for the country to adequately address the challenges posed by climate change.

From the perspective of the environmental sector, the Climate Change Strategy for Natural Protected Areas [10] and the recent appearance of the Strategy towards 2040 [11], highlight the importance and commitment of these ecological policy instruments [12] with the conservation of the ecosystems and the environmental services that they provide, as a substantive axis in mitigating the impacts of climate change. For this purpose, it establishes as part of its vision for the Natural Protected Areas (NPAs) and the Priority Regions for Conservation (CPRs): "Contribute to increase the resilience of human communities, ecosystems and their environmental services, as well as to the mitigation of climate change in the NPA, CPR and other conservation modalities". It should be remembered that approximately 1.6% of the country's marine territory is part of the ANP network and that 70 marine and coastal RPCs have been identified, delimited and characterized [13].

To implement climate change adaptation and mitigation actions, different state (PEACC) and municipal (PACMUN) level action plans and programs for climate change action have been developed. According to the 5th National Communication to the UNFCCC [14], there were 8 PEACC completed in the country, of which 3 belonged to coastal states, 23 were in development (13 coastal) and 1 in planning corresponding to the state of Colima. After 2012, only Morelos has decreed its PEAAC (non-coastal state). Regarding the PACMUN in the reference year, only 16 of the 156 coastal municipalities had the official document.

4. Climate change and risk in the Mexican coastal zones

Mexico's coastal and marine zones are highly vulnerable to the direct impacts and side effects of climate change. In the opinion of the authors, the adaptation and mitigation measures at the local level (coastal States and Municipalities) have not been developed and implemented with the adequate urgency, mainly due to the lack of economic resources, human capacities and sensitivity of the decision makers to the phenomenon of climate change.

The following list shows some of the most important climate change impacts in Mexico's coastal and marine zones:

1. Increase in the atmospheric temperature and in the upper layers of the ocean: a) the coastal states of Mexico are the main agricultural (66%), bovine (66%) and fishing (98%) producers of the country. Global warming, climatic variability, droughts and heat waves impact the food system, while in the oceanic part capture zones are shifting; b) the thermal expansion of the oceans and the increase of fresh water from the melting of glaciers and rain, have produced an accelerated rise in sea level, which puts at risk low-level-living and floodable coastal areas; c) the increase in the temperature of the surface layers of the ocean leads to an increase in the intensity and frequency of tropical systems (torrential rains, floods, landslides, intense winds, coastal erosion, etc.) also affecting public infrastructure, private companies and putting human lives at risk; d) the synergistic and often non-linear effect produced by the interaction of these phenomena can substantially increase the vulnerability of coastal areas through an intensification of the erosive processes on sandy beaches. This combination of phenomena can also affect the water quality and availability by increasing the salinization in groundwater reservoirs, and e) the increase in evaporation, cloudiness and rainfall, as a consequence of the increase in temperatures, favors the appearance, faster propagation and expansion to new areas of vectors transmitting diseases in humans (e.g. dengue) and associated gastrointestinal diseases due to the decomposition or deficient conservation of food, as well as agricultural pests.
2. Increase in the CO₂ levels in the atmosphere: a) the increase in atmospheric CO₂ levels favors a greater uptake of this compound by the ocean, decreasing its hydrogen potential (pH) and producing its acidification. The impact on the biogeochemical cycles of these and other processes associated with climate change are still under discussion, and b) ocean acidification has severe impacts on marine and coastal ecosystems. Sea level rise, ocean acidification, climatic variability (e.g. *El Niño* phenomenon) and changes in sea temperatures have led to the "whitening" of coral reefs at unprecedented levels in history [15]. Marine animals provided with calcareous shells are taking longer to reach their historical sizes. Microorganisms and

algae - important to the medical industry - are being affected by the acidification of the oceans and coastal bodies of water.

More information on climate change impacts on the Mexican coastal and marine zones is afforded by Muñoz-Sevilla y Le Bail [16], Escobar Briones [17], Azuz-Adeath [18], Aguilar et al. [19], Agüero [20] and Yañez-Arancibia [21].

In summary, it can be said with high confidence that the main recipients of the effects associated with climate change will be the coastal states of the country and, in particular, the municipalities with coastal fronts that depend on the services and functions of the marine and coastal natural ecosystems, as well as the infrastructure and services derived from the use of these valuable areas.

5. Adaptation measures and actions

The National Strategy for Climate Change Vision 10-20-40 proposes 3 strategic axes for adaptation: 1) to reduce vulnerability and increase the resilience of the social sector in the face of the effects of climate change; 2) to reduce vulnerability and increase the resilience of strategic infrastructure and productive sectors in the face of the effects of climate change, and 3) to conserve and use ecosystems sustainably and maintain the environmental services they provide.

41 lines of action emerge from these strategic axes, of which many have a clear impact on the coastal areas where a large part of the strategic (e.g. energy, communications and transport, military) and productive infrastructure (e.g. tourism, port, livestock and agriculture) is located.

However, despite the clear lines of action proposed, the country lacks the economic capacity to adequately address the problem of climate change and particularly to implement effective long-term adaptation measures.

To mitigate the impacts of climate change in coastal zones, at least the following requirements must be met: a) to establish mandatory vehicle verification mechanisms in all states and municipalities of the country in parallel with a development of public transport, b) to encourage the transition to low carbon economies at the municipal level, evaluating energy efficiency and implementing the use of clean energy, starting with government facilities, industries and public services (e.g. public lighting generated by wind or solar energy), and c) to maintain and seek to restore the natural vegetation percentage of the coastal municipalities.

To adapt to climate change in the coastal areas of the country, there are not many alternatives, but we could mention: a) the relocation of settlements and infrastructure located in risk areas, b) the modifications to the "traditional" types of crops, adapting new products or seasonality to changes in climatic conditions, c) the implementation of engineering measures to protect from the impacts of climate change (e.g., protection infrastructure for coastal areas, elevation of facilities of economic or strategic importance, communication routes and infrastructure of services), and d) the technological innovation to create large-scale infrastructure that "sequesters" carbon from the atmosphere and oceans.

Regardless of the selected adaptation option, the economic cost is very high and an important long-term planning is required. To the extent that this issue is not urgently addressed, Mexico's coastal zones will continue to degrade and suffer the incremental and uninterrupted impacts from climate change.

6. Barriers for the implementation of adaptation measures

From the local level (coastal towns), the main barriers to the implementation of adaptation actions to face climate change are: lack of economic resources; lack of long-term vision or regulatory instruments for long-term projects; technical capacities and planning often limited; prioritization of what is urgent and important; ignorance of the phenomenon of climate change; scarce social participation in decision-making; disengagement between government agencies and sectors of plans and programs; lack of instances to formalize mutually beneficial associations with the private sector, academic and international organizations, and often political differences associated with the partisan origin of the mayors and state governors.

In the case of coastal states, it is important to note that the State Development Plans (PEDs) of all coastal states include elements related to the importance of climate change. However, in this State strategic planning instruments, there are few concrete strategies to contribute to mitigation or adaptation. Within the specific measures identified, one can generally speak of the following: a) to use clean energy and resilient infrastructure, b) to establish adaptation and mitigation measures for climate change for the use of natural resources, cultivation areas and the reduction of the impact of natural disasters, c) to make proposals for social awareness, technical training, scientific research and the use of geographic information systems as support elements for decision making, and d) to make proposals in the legal field such as: the creation of the State Councils on Climate Change, initiatives on the Law on State Climate Change and preparation of State Programs of Action in the face of Climate Change. However, despite the existence of this type of proposal in the State PEDs, in most cases no concrete instruments are presented to make them operational, nor there is talk of the need to clearly establish integral strategies and programs, binding with other sectors (e.g. business, academic, social) to address climate change issues.

7. Conclusions

To achieve the objectives set out in the "Paris Agreement" regarding the maximum desirable increase in global temperature, there are few options available: to stop increasing and, if possible, to reduce greenhouse gas emissions.

In Mexico, the main generating sectors of this type of gases have been identified and quantified; legal and normative instruments have been established; high-level technical and consultative bodies have been created related to the knowledge of the phenomenon, which have created technically very well elaborated strategies and programs.

The marine and coastal areas of Mexico are undoubtedly the most vulnerable regions of the country and with the greatest risk to the current and potential effects of climate change. Additionally, these regions have high rates of population growth, which implies, among others, a greater demand for energy, means of transport, generation of waste and, in general, sources of greenhouse gas production. On the other hand, considering the importance of the agricultural, livestock, energy and manufacturing sectors (main GHG generators) of the coastal states in the national context, it is clear that the coastal and marine zones of Mexico should be one of the spaces of greater attention in the policies of adaptation and mitigation to climate change.

However, the adoption and implementation of many policies and actions at the regional and local level, in addition to the lack of economic, human and technical resources and official municipal management times (3 year-terms), the lack of long-term vision in local planning and development instruments make coastal municipalities the weakest link in the structure of national attention to climate change.

The costs of adapting to climate change in the coastal areas of the country are high but, in the mid-term, the costs generated by the losses could be greater. Mitigation actions may be less costly from the economic point of view but carry political risks for the governors and decision makers. However, in the long term, the only option to achieve the sustainability of the coastal and marine areas of the country in the context of climate change is to take intelligent and effective measures based on scientific and technical knowledge.

8. References

- [1] Ward R D (1906). Changes of Climate. *Popular Science Monthly*, Vol. **LXIX**, October, p. 458-470.
- [2] Huntington E (1917). Changes of Climate and History. *American Historical Review*, Vol. **XVIII**, No. 2, January, p. 213-232.
- [3] IPCC (2014). *Climate Change 2014: Synthesis Report*. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.
- [4] Hartmann D L *et al.* (2013). Observations: Atmosphere and Surface. In: *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of*

- the Intergovernmental Panel on Climate Change* [Stocker, T.F., *et al.* (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA
- [5] Wong P P *et al.* (2014). Coastal systems and low-lying areas. In: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Field, C.B., *et al.* (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 361-409.
 - [6] EO/NOAA (2016). Earth Observatory, National Oceanic and Atmospheric Administration (EO/NOAA). Visited on November 2017 at: <http://earthobservatory.nasa.gov/Features/WorldOfChange/decadaltemp.php>
 - [7] Floud R and McCloskey D (1981). The industrial revolution 1780-1860: a survey. In: *The economic history of Britain since 1700*. Cambridge University Press, pp. 103-127.
 - [8] SEMARNAT (2014). *El Ambiente en Números. Selección de estadísticas ambientales para consulta rápida*. Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT), 59 pp.
 - [9] DOF México (2012). Ley General de Cambio Climático. *Diario Oficial de la Federación* del 06-06-2012.
 - [10] CONANP (2010). *Estrategia de Cambio Climático para Áreas Protegidas*. Comisión Nacional de Áreas Naturales Protegidas (CONANP), Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT), México, 23 pp.
 - [11] CONANP (2014). *Estrategia hacia 2040: una orientación para la conservación de las áreas naturales protegidas de México*. Comisión Nacional de Áreas Naturales Protegidas (CONANP), Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT), México, 80 pp.
 - [12] DOF México (2015). Ley General del Equilibrio Ecológico y Protección al Ambiente. *Diario Oficial de la Federación* 28-01-1998 (original). *Diario Oficial de la Federación* 09-01-2015 (texto vigente).
 - [13] Arriaga Cabrera L *et al.* (Coords) (1998). *Regiones marinas prioritarias de México*. Comisión Nacional para el Conocimiento y uso de la Biodiversidad. México. Azuz-Adeath I (2012). The role of global oscillations and teleconnections within atmosphere and ocean in regional coastal management. *Ocean & Coastal Management* **69**, p. 78-91.
 - [14] SEMARNAT-INECC (2012). *Quinta Comunicación Nacional ante la Convención Marco de las Naciones Unidas sobre el Cambio Climático*. Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT) e Instituto Nacional de Ecología y Cambio Climático (INECC), 400 pp.
 - [15] Normile D (2016). El Niño's warmth devastating reefs worldwide. *Science*, Vol. **352**, Issue 6281, pp. 15-16.
 - [16] Muñoz-Sevilla N P and Le Bail M (2015). Sistemas costeros y zonas inundables. In: Ortiz Espejel B, Muñoz-Sevilla N P and Le Bail M (Coords). (2015). *Reporte Mexicano de Cambio Climático. Volumen 2: Impactos, Vulnerabilidad y Adaptación*. Universidad Nacional Autónoma De México/Programa de Investigación en Cambio Climático. ISBN Volumen: 978-607-02-7370-4
 - [17] Escobar-Briones E (2015). Sistemas Oceánicos. In: Ortiz Espejel B, Muñoz-Sevilla N P and Le Bail M (Coords) (2015). *Reporte Mexicano de Cambio Climático. Volumen 2: Impactos, Vulnerabilidad y Adaptación*. Universidad Nacional Autónoma De México/Programa de Investigación en Cambio Climático. ISBN Volumen: 978-607-02-7370-4
 - [18] Azuz-Adeath I (2012). The role of global oscillations and teleconnections within atmosphere and ocean in regional coastal management. *Ocean & Coastal Management* **69**. Pp 78-91.
 - [19] Aguilar A, Sánchez A and Martínez B (2012). Economic Impacts of Climate Change on Two Mexican Coastal Fisheries: Implications to Food Security. *Economics E-Journal*, No. **64**. 20 pp.
 - [20] Agüero J M (2014). Long-Term Effect of Climate Change on Health: Evidence from heat waves in Mexico. Inter-American Development Bank (IDB), *IDB Working Papers Series* No. **481**, 26 pp.
 - [21] Yañez-Arancibia A (2015). *Cambio Climático. Adaptación y Mitigación hacia agendas siglo XXI*. AGT Editor, S.A., 254 pp.