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Perception and adaptation to climate change in vulnerable regions

A. Jiménez-Bedoya[1], F. Fuentes-Gandara[2], R. Paternina-Uribe[1], J. Pinedo-Hernández[1,*]

[1] *Faculty of Basic Sciences, Department of Chemistry, Universidad de Córdoba, Cra 6 #77-305, Montería, Colombia*

[2] *Department of Natural and Exact Sciences, Universidad de la Costa, Calle 58 Nº 55-66, Barranquilla, Colombia*

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ABSTRACT

BACKGROUND AND OBJECTIVES: Understanding and implementing strategies to adapt to climate change is essential for maintaining the livelihoods and well-being of the human population. In Colombia, interest in climate change is increasing, reflected in growing attention towards adaptation and mitigation strategies. There is a lack of detailed research on this subject, especially in ecologically significant areas like the La Mojana region. The objective of this study was to evaluate the perception of different focus population groups such as fishermen, farmers and ranchers on climate change, regional adaptation strategies and implementation of public policies in the La Mojana Region of Northern Colombia, which is highly vulnerable to extreme climate phenomena. A bibliometric analysis was conducted to assess the dynamics of scientific production at both national and global levels, focusing on the perception and adaptation policies related to climate change.
METHODS: Data collection for this study involved conducting semi-structured questionnaire interviews with 420 participants from the fishing, agriculture, and livestock sectors. The aim was to gain insights into their perspectives on climate change risks and the mitigation measures they have implemented. A bibliometric analysis using the SCOPUS scientific database was conducted to explore global and Latin American publication trends related to climate change perception and adaptation policies, with a particular focus on Colombia. This analysis emphasizes the latest trends in research and the scholarly influence in the areas of climate change, public policies, and strategies for adaptation.
FINDINGS: The findings indicated that all participants observed changes in climate patterns over the past two decades, specifically in terms of irregular rainfall patterns and disruptions in traditional sowing and harvesting cycles that were once considered predictable. Focus groups' perception aligned with historical meteorological data on flood and La Niña phenomena. Priorities for government intervention include response to early emergencies, community participation, and stakeholder collaboration in future planning. Various strategies for adaptation were implemented, such as the management of communities, conservation of ecosystems, construction of resilient housing and livestock management, sustainable water management, and diversification of crops. Colombia ranks third in Latin America for scientific production on climate change perception and adaptation policies, with political context and international compliance key factors.
CONCLUSION: The study highlights how climate change affects psychological well-being through social and economic insecurity, exacerbated by the local government's lack of intervention to mitigate the vulnerability of focal groups and strengthen their adaptation and resilience capacities against climate change Colombia's significant contribution to regional scientific production on climate change perception highlights the pressing requirement for further research to explore these issues and improve adaptation strategies in the area.

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63	6	1

*Corresponding Author:
Email: *jjoaquinpinedo@correo.unicordoba.edu.co*
Phone: +57 3145311382
ORCID: 0000-0002-4288-1788

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INTRODUCTION

According to the European Commission's communication, it is crucial for individuals to recognize their fundamental role in adaptation and mitigation activities (European Commission, 2021) to effectively contribute to the co-production of climate services. The main objective of these services is to aid communities in adjusting to and confronting climate challenges through the provision of comprehensive and current data to facilitate decision-making (WMO, 2014). The Intergovernmental Panel on Climate Change (IPCC) report reiterates the critical state of global warming and presents compelling proof of climate changes resulting from human actions (IPCC, 2022). This report highlights the importance of acting quickly and decisively to reduce emissions and avoid devastating impacts on climate systems and on communities that are already experiencing their effects. With the accumulation of scientific evidence on global warming and its consequences, climate change is acknowledged as one of the most urgent and intricate challenges confronting humanity in the 21st century (Abbass *et al*., 2022; Dellmuth and Gustafsson, 2021). In recent decades, climate change has become a major concern for almost all global economic sectors, especially fishing, agriculture, and livestock. Climate change causes changes in environmental conditions, such as rising water temperatures in ecosystems, which threaten the fishing sectors by altering the productivity and distribution of organisms (Gianelli *et al*., 2023). Certain fish species may respond to environmental changes by either relocating to more favorable habitats or adapting their physical characteristics, biological processes, and reproductive strategies (Rahman *et al.,* 2021). Studies have identified a notable connection between climate change and the decrease in the size of fish, the loss of biodiversity in marine ecosystems, and the rise in mortality rates of fish species. This phenomenon also has adverse effects on the efficiency of capture fisheries (Rahman *et al.,* 2022). Climate change triggers extreme events such as droughts, tsunamis, and typhoons (Holden and Marshall, 2018). Agriculture, given its extensive scope and significant vulnerability to shifts in climate patterns, stands out as the industry most prone to the financial repercussions of climate change (Jägermeyr *et al.,* 2021). Changes in climatic events, including temperature and precipitation, have significant effects on agricultural production (Imelda and Hidayat, 2024). The influence of rising temperatures, fluctuations in precipitation, and carbon dioxide (CO_2) fertilization varies depending on the type of crop, geographic region, and degree of parameter alteration (Malhi *et al*., 2021). Studies indicate that rising temperatures negatively affect crop yields (Moore *et al*., 2021), although increased precipitation is likely to counteract or mitigate the effects of rising temperatures (Agnolucci *et al.,* 2020; Xu *et al.,* 2020). In general, tropical regions bear the brunt of climate change, primarily due to the fact that crops in these areas are adapted to a limited temperature range and are particularly susceptible to the adverse impacts of extreme heat events (Malhi *et al.,* 2021). Climate change adaptation is essential to achieve food security and sustainable agricultural development (Frimawaty *et al.,* 2023). Climate change is generating unprecedented levels of global concern, altering values, preferences, and behaviors (Imelda and Hidayat, 2024). Nonetheless, the current individual inclinations of farmers, their routine actions, and value systems play a beneficial role in influencing decision-making within agricultural practices (Haberl *et al.,* 2021). In particular, factors such as the intervention of farmer groups (Crudeli *et al.,* 2022) and basic characteristic data (e.g., main occupation, experiences, total number of family members, land ownership, and educational level) are highly useful for presenting new mitigation strategies due to the willingness of farmers to adopt programs (Wang *et al.,* 2022). Climate change-induced floods and droughts have led to severe environmental challenges in the last twenty years, impacting both livestock production and the economic well-being of ranchers (Abid *et al.,* 2016). Grazing grounds, pasture, and migration sites are vital natural resources that ranchers depend on for their livelihood (Ambelu *et al.,* 2017). The scarcity of pasture and water during drought significantly exacerbates the adverse effects on the livelihoods of ranchers. This, in turn, leads to a reduction in the production of milk and beef from cattle, thereby directly and indirectly exacerbating the issue of food insecurity (Opiyo *et al.,* 2018). Prolonged droughts and heavy rains exacerbate pastoral livelihoods by increasing the number of livestock deaths and decreasing the quality of animals (Ndiritu and Muricho, 2021). This has a detrimental impact on the livestock sector and leads to substantial

financial losses. Research demonstrates that 3.6 billion people inhabit locations that are exceedingly at risk to the consequences of climate change, compounding these obstacles. It is estimated that between 2030 and 2050, this will result in approximately 250,000 additional deaths each year, associated with increased cases of malaria, diarrhea, heat stress, and malnutrition. By 2030, the health sector costs related to the effects of climate change are projected to range between 2 and 4 billion dollars. Less developed countries and areas with inadequate healthcare infrastructure will experience the greatest impact and will need assistance in adjusting to the new challenges brought about by the climate emergency (WHO, 2023). In the context of this global reality, local communities around the world, including vulnerable regions such as La Mojana in Colombia, are increasingly affected by its consequences and find themselves at the crossroads of adaptation and resilience. In particular, the La Mojana region faces significant challenges due to their geographical location and the socioeconomic characteristics of their inhabitants that depend on agriculture, livestock and fishing. The La Mojana region is known for its ecological significance and heavy reliance on natural resources, yet it is also extremely susceptible to severe climate occurrences, including floods, droughts, and powerful storms (Marrugo-Negrete *et al.,* 2019a). This region has historically been affected by periodic flooding, but in recent decades, it has faced more pressing challenges related to climate change (Vargas *et al.,* 2018). The frequency and intensity of flooding have been heightened by extreme weather patterns, including extended droughts and subsequent heavy rainfall. This has worsened pre-existing issues and created new dangers for the well-being and economic stability of local populations. The perception of climate change is a crucial aspect to understand how local communities in La Mojana face these changes and how they respond to them as regional adaptation strategies. Sociocultural, economic and geographic factors can exert a significant influence on the way people perceive and understand climate change, which in turn has a direct impact on the adaptation strategies they adopt. Wolf *et al.* (2013) and Pröpper *et al.* (2022), propose that the way in which individuals perceive climate change is shaped by a range of cognitive frameworks, which stem from socioeconomic and cultural disparities that impact individuals' beliefs, principles, and priorities. Understanding climate variations is crucial for the long-term sustainability of the agricultural sector and ensuring adequate food supply for growing populations (Anderson *et al.,* 2020). To achieve ecological adaptation, farmers need to address the consequences of climate change in agricultural ecosystems by focusing on biodiversity conservation, soil and water preservation, and the sustainable use of natural resources (Imelda and Hidayat, 2024). The reliance of focal groups such as farmers, livestock keepers, and fishers on climatic conditions drives their awareness of climate change and the need for adaptation (Frimawaty *et al.,* 2023). Implementing adaptation and mitigation strategies yields various positive outcomes, such as increased overall income (Ahmad and Afzal, 2020), improved well-being (Rahman *et al.,* 2023), and enhanced food security (Rahman *et al.,* 2021). The community's and various focus groups' perspectives on climate variability and its impacts are shaped by psychological and socioeconomic factors, which may hinder their ability to effectively address climate change (Evans *et al.,* 2016). Various studies have highlighted the urgent need to promote communities' perception and capacity to adapt to climate change, as a complement to mitigation measures (Ayal and Filho 2017; Somboonsuke *et al.,* 2018; Ginbo *et al.,* 2021; Singh *et al.,* 2022; Yang Liu *et al.,* 2020; Abbass *et al.,* 2022; Dellmuth and Gustafsson, 2021). It is striking that, in both developed and developing countries, preparation to face climate impacts is not considered a priority issue in most global political agendas (Szpak, 2021; Hurlimann *et al.,* 2021). In Colombia, preparation to confront the impacts of climate change has not been a priority on the national political agenda, despite the country's evident vulnerability to these effects. Regions like La Mojana, which heavily rely on agriculture, livestock, and fishing, face significant challenges due to their geographical location and the socio-economic characteristics of their inhabitants. Up to this point, there has been no research conducted on the effects of climate change, the attitudes towards it, and the methods of community adaptation in the La Mojana region, despite its significance in terms of ecology and agriculture. Through a multidisciplinary approach, combining participatory methods with vulnerable

community members and literature review of scientific data in databases like SCOPUS, this study provides a comprehensive view of the challenges and opportunities faced by local communities in adapting to climate change and explores the dynamics of scientific production in the country regarding this issue. The findings of this study carry important consequences for the organization and oversight of climate change adaptation in the area and can establish a strong basis for decision-making. As the inaugural study of its type in this setting, this research can add to the current understanding of regional climate change adaptation strategies, providing insights and suggestions to improve the efficiency of adaptation efforts in comparable areas. The aim of current study is to evaluate the perception of climate change in the La Mojana region, as well as the strategies for regional adaptation and the implementation of public policies. Moreover, the aforementioned investigation was conducted by taking into consideration a thorough analysis of publication trends related to the perception of climate change and policies for adaptation on a global scale and within Latin America, with a specific emphasis on Colombia. This study has been carried out in The La Mojana region, Colombia, in 2023.

MATERIALS AND METHODS

Study area

The La Mojana region is in the northwest of Colombia (Fig. 1), with an approximate area of 5500 square kilometers (km^2), surrounded by three main rivers (Magdalena, San Jorge and Cauca) and crossed by pipes that drain the area in times of flooding. The region is typically defined by its flat topography with gentle rolling hills. In the area, the climate is warm and humid, the temperature varies between 28 and 33 degrees Celsius (°C), and the average annual precipitation fluctuates between 2350 and 2630 millimeter (mm), the rainy period being between the month of April and November, while the It dries in the month of December and ends in March. In recent years, the La Mojana floodplain has experienced numerous instances of severe flooding. The most recent flood, which occurred during the La Niña event in 2010 and 2011, came after significant floods in 2005, 2007 and 2008 (Rodríguez-Gaviria and Botero-Fernández 2013; Vargas *et al.,* 2018). Due to the flooding of a vast area, more than 200,000 people were affected, including communities traditionally dedicated to fishing, agriculture and livestock (Marrugo-Negrete *et al.,* 2019a). The region displays a considerable potential for productivity that can be leveraged through sustainable management practices in livestock, agriculture, fishing, and forestry. It holds a crucial strategic position for the country. Despite being impacted by frequent floods, droughts, environmental imbalances resulting from inappropriate land use, and mismanagement of the river basins that feed into the water delta, the area remains an asset for growth and development (Caraballo and De la Ossa, 2011; Fondo Adaptación, 2016).

Interview questionnaire and literature review

The study employed a mixed methodology that combined semi-structured interviews and questionnaires focused on stakeholders related to fishing, agriculture, and livestock, as described by Geilfus (2008). The semi-structured interviews aimed to gather comprehensive data through the identification of key informants within the research area. This technique allowed for the adaptation of questions according to the specific context of each interviewee, which is crucial for obtaining broad and contextualized perspectives on the perception of risk associated with climate change and the adaptation actions implemented. The hypothesis posited that a majority of the populace holds a strong perception regarding the impacts of climate change on fishing, agriculture, and livestock. The number of people to be surveyed was determined for simple random sampling, using Eq. 1 (López, 2004):

$$n = \frac{N*\left(k*0,5\right)^2}{1+\left(e^2*\left(N-1\right)\right)} \quad (1)$$

Where, N is the population size of rural inhabitants, k is the confidence level, 90 percent (%) (1.645), and e^2 is the precision or error, 10% (0.01).

The interview questionnaire focused on the knowledge and understanding of 420 participants made up of fishing, agriculture and livestock focus groups. The questionnaire was developed with a concentration on multiple crucial elements associated with climate change in the study region. The aim was to understand the current perception of

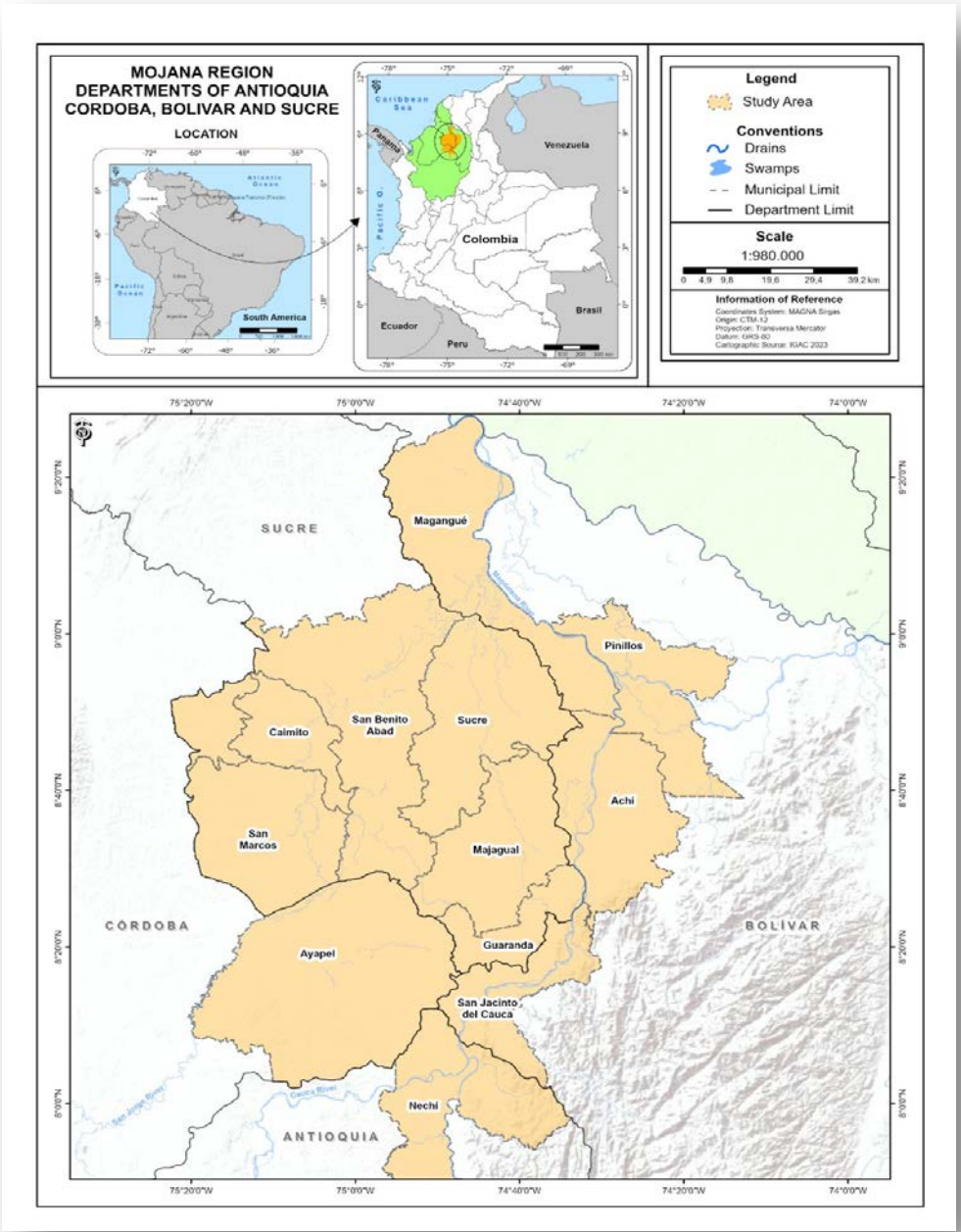


Fig. 1: Geographic location of the study area in La Mojana Region, Colombia

the risk associated with climate change, as well as the actions implemented to adapt to it. The effectiveness of the adaptation measures implemented was assessed, while also examining the viewpoints on policies, regulations, and guidelines pertaining to this critical matter. The study delved into the examination of the short and long-term strategies implemented, the constraints posed by resource limitations, and

Table 1: Sociodemographic and other characteristics of volunteers

Characteristics	Categories	N°			
		M	F	Total	%
Sex		220	200	420	100
Age	18-30	40	14	54	12.9
	30-40	124	22	146	34.8
	40 -50	108	72	180	42.9
	>50	24	16	40	9.5
Educational level	None	10	8	18	4.3
	Primary	192	106	298	71.0
	Secondary	64	30	94	22.4
	University	6	4	10	2.4
Residence in the area	Ages	>15	>15	210	100
Economic activity	Agriculture	130	10	140	33.3
	Fishing	170	8	178	42.4
	Livestock	90	12	102	24.3
Own means of transportation	Motorcycle	240	24	264	63
	Self-moving	130	26	156	37
Characteristics					
Homeownership	Urban				15
	Rural				85
Public services	Sewer				15
	Latrine				85

N° represents the total number of people, M indicates the number of male individuals, and F indicates the number of female individuals.

the crucial factors pinpointed for attaining effective adaptation to climate change. The response options of the questionnaire focused primarily on “Yes” or “No” responses, supplemented by “which” or “what” options to provide the researcher with an overview of the participants’ views. Semi-structured interview inquiries were posed, focusing on the “how” and “why” aspects, in order to gain an in-depth understanding of the participants’ perspectives and the rationale behind them; with a particular emphasis on maintaining confidentiality and removing any personal details of the participants. In this study, a bibliometric analysis was conducted on the output of perception documents and adaptation policies to climate change by country in the SCOPUS scientific database. The search keywords used were: “climate change”, “perceptions”, “adaptation”, “climate change risk”, “climate response”, “policy”, “strategy”. The analysis of publication data from various countries over time was employed to uncover the global and Latin American scientific output distribution, with a specific focus on Colombia. This examination aimed to illustrate the prevailing research trends and academic influence pertaining to climate change, public policies and adaptation.

RESULTS AND DISCUSSION

Socio-demographic background

The sociodemographic and other general characteristics of the participating population are shown in Table 1. The study involved 420 individuals with an age range of 18 to 62 years (average age of 38 ± 1.5 years). The gender distribution was relatively equal, with men accounting for 52.4 percent and women for 47.6 percent of the participants. 80% are households headed by men, within this 95% of household heads present marital status as common-law union. All residents in the study area have lived there for more than 15 years, with some individuals being native to the area and also working there. Urban areas house 15% of the population, while the remaining 85% in rural areas, associated with townships or villages. 53% of people live on their own property or home and 47% rent it. In relation to public services, 15% of the population has sewage service with conventional bathroom sanitary facilities, while the other 85% have latrine facilities.

The electric energy service covers 100% of the population, unlike the aqueduct or supply service that covers 81% through water supply from groundwater wellsPublic transportation is not available in the

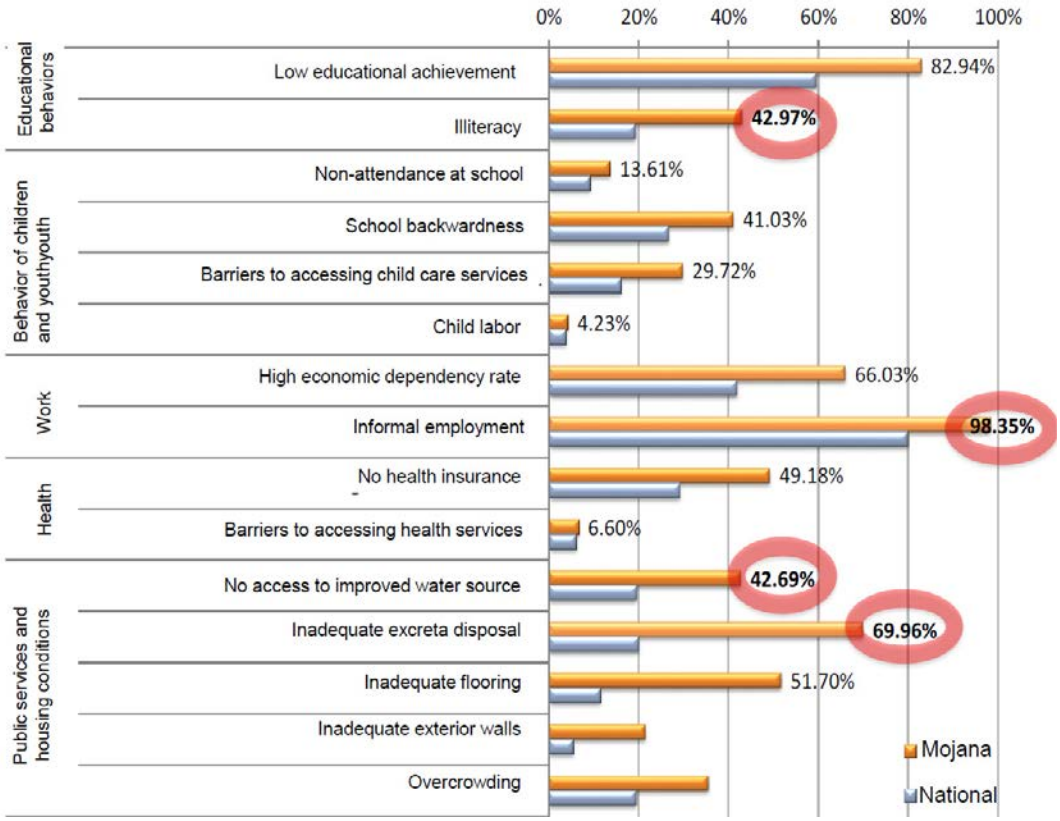


Fig. 2: Multidimensional poverty index for La Mojana in 2016 (Fondo Adaptación, 2016)

area, leading to 63% of the population owning their own means of transportation, such as motorcycles or other vehicles, making up 37%. In terms of education, 71% have completed primary school, 22.4% have finished secondary school, 2.4% have attended university, and a mere 4.3% of individuals lack any formal education. 98% of the respondents stated that they are aware of the concept of climate change and its causes. Regarding the educational level of household heads, 46% (M: 176, F: 18) have primary education, and 16.6% have secondary school levels (M:64, F:6). The primary economic activities of interest include agriculture, livestock, and fishing. In this sense, in relation to socioeconomic aspects, the Multidimensional Poverty Index (MPI) shows that 83.8% of the population of La Mojana was poor in 2005, compared to 49.6% of the national average (Departamento Administrativo Nacional de Estadística de Colombia (DANE), 2005). However, by 2016, the entire population of La Mojana was living in poverty, presenting a more severe situation than the national average (Fondo Adaptación, 2016). (Fig. 2). Labor informality in La Mojana is practically 100%, which translates into very low access to social security (health service and pensions), in addition to the non-generation of taxes at the local level and, in a broader sense, the existence of an informal culture whose limits, in many cases, are blurred by illegality. There is a dearth of recent reports providing information on the current situation in the Mojana region. However, it is unlikely that there have been substantial changes, given that the four departments of Antioquia, Bolívar, Córdoba, and Sucre, where La Mojana is situated, exhibit multidimensional poverty rates surpassing the national average of 12.1%. The multidimensional poverty values for these departments are 15.3%, 18.4%, 21.4% and 23.1%, respectively (DANE, 2023).

Perceptions of impacts of climate variability

All participants (100%) share the common belief

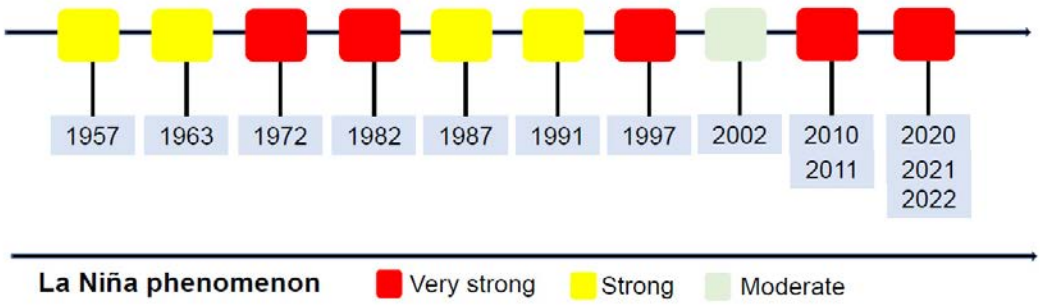


Fig. 3: Historical record of the La Niña phenomenon in the Mojana region, Colombia

that climate change has led to the unpredictability of the rainy and dry seasons, as well as the sowing-harvesting cycle, which were previously predictable over a span of 20 to 30 years, irrespective of the climatic conditions in the region. Additionally, the individuals have observed that unforeseeable transformations have been notably encountered in the past few decades, including: decline in agricultural, livestock, and fishing outputs, elevated production expenses, shift in employment from agricultural to non-agricultural sector, consequences of drought occurrences (El Niño Phenomenon), and excessive flooding since 2005 resulting in damages to various sectors of the region's economy, as well as health issues for the population. These flood events reported by the focus groups are consistent with metrological findings related to major floods in 2005, 2007 and 2008 followed by a La Niña event during the second half of 2010 (Rodríguez-Gaviria and Botero-Fernández, 2013; Vargas *et al.,* 2018). In addition to the three-part occurrence of La Niña, covering consecutive winters in the northern hemisphere from the latter part of 2020 to the latter part of 2022 (WMO, 2022) (Fig. 3). As a result of this phenomenon, there were overflows and breaks in the left marginal dam of the Cauca River that currently remains and which contributes to exceeding the storage capacity of the swamps and, therefore, producing the largest flood recorded in the subregion of La Mojana, at the level of the sector known as Cara de gato by Instituto de Hidrología, Meteorología y Estudios Ambientales (IDEAM, 2022).

Fig. 3 illustrates the influence on the primary livelihood resources of the population (agriculture, livestock, and fishing). It depicts the farmers' perception of the adverse effects of climate variability, particularly the impacts of flooding or drought on rice production (higher crop yield). These effects include crop losses, the decline of local rice varieties due to the introduction of new rice varieties adapted to climate variability, the loss or alteration of traditional or reference planting methods, reduced labor force due to migration to non-agricultural areas, decreased agricultural land productivity, higher food prices, and increased. Within the field of fisheries, it is highlighted that the primary issue stemming from climate variability is the deterioration of water quality. This degradation not only poses a threat to fishing activities but also to human health, leading to a decline in fish populations and a loss of biodiversity within aquatic ecosystems and fishing grounds. In summary, the perception of the groups that participated shows that they identify climate change or variability as something that has been happening for a long time and that its negative impacts occur year after year, increasing poverty levels. The Mojana region is frequently affected by mercury contamination in various environmental components, while high-risk impacts include fluctuations in precipitation, prolonged drought, and an increase in severe weather events. It is crucial to emphasize the significance of these issues (Pinedo *et al.,* 2015; Marrugo-Negrete *et al.,* 2015, 2019ab, 2020; Calao-Ramos *et al.,* 2023; De la Ossa *et al.,* 2023). Addressing this issue required understanding the residents' perception of whether they believe this problem is part of climate change. According to 75% of the population, this issue is not related to climate change, but is rather the result of poor mining practices. The remaining 25% indicate a direct relationship, as flooding events resulting from

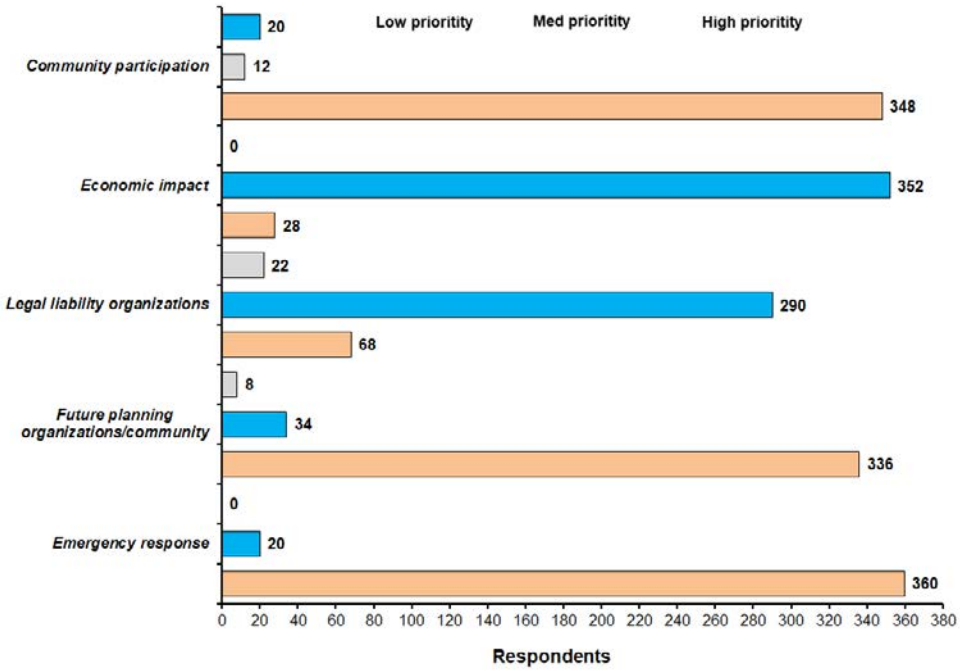


Fig. 4: Adaptation priorities by communities in the Mojana Region

climate variability can exacerbate the effects of this contamination due to transportation and deposition processes in the area. It is widely recognized that both matters are significant from an environmental standpoint, and it is crucial to take into account that people's understanding may differ based on their knowledge, background, and information accessibility. Education in these characteristic areas of vulnerability is crucial for the processes of implementation and adaptation of public policies. This potential facilitates dialogue and cooperation processes between the community and other actors, including government agencies, on climate change issues such as risk assessments, vulnerability and the design of crucial adaptation and conservation policies and the sudden and unexpected changes that arise in the study area. Participants acknowledged the significance of conducting additional research at the policy level to explore the integration of adaptation and mitigation measures within local governments. This document does not delve into the investigation of the relationship between pollution, public policies, and participants' perceptions, recognizing it as a limitation of the study.

Regional climate change adaptation practice

To understand the preparation of the participants towards climate change, questions were asked about what would be the adaptation priorities that the local or national government should provide. The primary focus was on addressing immediate emergencies first, then engaging the community and planning for the future (Fig. 4). Local and national administrative entities are well aware of the risks associated with climate change in the La Mojana region, thus considering it as a certainty rather than an uncertainty based on weather patterns. Although efforts have been made to adapt, the impact is not clear. For instance, in emergency care meeting points, 65% of the attendees report that local communities lack river transportation and proper equipment for handling emergency situations. According to participants, it is important, to address the risk of climate change as a single unit that addresses the mitigation plan, adaptation, execution policies and implementation indicators with active participation of the entire population throughout the study area and relevant organizations. The stakeholders understand that the process of adaptation is a long-term endeavor, with

the primary obstacle being the financial constraints imposed by short-term political agendas. This significant barrier hinders both the execution of plans and decision-making. The participants have indicated these two characteristics with medium priority, which is intriguing given that the economic factor is typically the primary variable variable in any process. Perhaps, as some participants indicated in a general way "for money, if it is necessary to fight corruption and that talk was lost, an example of this is that to date the flood phenomenon with the greatest impact in the history of La Mojana through the breakup of the Cauca River in the Cara Gato sector since 2022 and that to date has not has been able to be solved, why will it be?, a response that correlates with the average priority indicated by the participants for the legal responsibility of government organizations, especially the National Risk Management Unit, has not demonstrated that there are currently notable legal links to address the risk of climate change in the region; making known how tired the community is to the point of reaching the point where the communities affected by the floods agreed to an indefinite sit-in by blocking national roads and to which they respond to the authorities: " The community's frustration has led to protests, including blocking national roads until infrastructure improvements are made visible to the affected communities. The authorities' agreements and promises have led to disappointment, and the road will remain blocked until tangible progress is made." (Infobae, 2023).

It is important to highlight that a minority of participants (fewer than 40) express doubt concerning the dangers associated with climate change. It is contended by some individuals that the complexity of defining the uncertainty related to the climate phenomenon stems from its susceptibility to a multitude of variables beyond human influence. Therefore, in this study, which originally focused solely on the community's viewpoint on climate change, it emerged to explore the adaptation strategies that the communities have adopted. Some adaptation practices to climate change implemented by communities in the Mojana region can be highlighted, such as: 1) Community risk management, where communities have established community risk management systems to address extreme weather events. This involves prior planning and preparation, identification and communication of early warnings. 2) Sustainable water management, involves the implementation of various practices by communities, including the development of effective irrigation systems, the collection and retention of rainwater, and the protection of water sources. These strategies enable a more effective and sustainable utilization of water resources, particularly in times of water scarcity. 3) Agroecology and crop diversification are agricultural practices that enhance the adaptability of farming systems to evolving climate patterns, thereby diminishing reliance on a sole crop and bolstering food security. 4) Conservation and restoration of ecosystems that play a crucial role in climate change mitigation and flood protection. 5) Enhancing the abilities and expertise of local communities enables them to comprehend climate-related threats, formulate adaptation plans, and make well-informed choices regarding the conservation of their environmental assets. 6) Strengthening local culture, rural communities have valued and promoted their local culture as part of their adaptation strategy to climate change, including the revitalization of traditional natural resource management practices, knowledge and use of local medicinal plants, and the promotion of indigenous and traditional knowledge systems in decision-making. 7) The development of durable residences, embracing construction techniques that can withstand the impacts of climate change. This involves using appropriate construction materials and techniques to withstand extreme weather events, such as flooding and high winds. 8) Strengthening the resilience of livestock, which involves enhancing grazing methods, diversifying livestock feeding, and managing natural resources utilized by the livestock sector. 9) Promotion of sustainable fishing practices, adopting the promotion of responsible fishing, the use of selective fishing gear and the protection of species reproduction areas. It is crucial to emphasize that the aforementioned explanations are of a general nature and are implemented as strategies for adapting to climate change in the La Mojana region, which comprises several municipalities. Each situation is unique per municipality of interest and requires a detailed and specific analysis to fully understand the challenges and barriers in the implementation of adaptation policies. It should be noted that experience has played a fundamental role in economic activities such as agriculture, livestock and fishing, where the

average experience is 25 years, which results in the greater the experience, the greater the adaptation to climate variability. Individuals with advanced educational backgrounds demonstrate a heightened capacity to respond to climate change. This implies that education, alongside experience, has a crucial impact on their ability to interpret and comprehend climate-related information effectively. As a result, individuals with higher levels of education are more adept at identifying potential solutions to climate change impacts and implementing appropriate adaptation measures. Similar results were reported in southern Ethiopia by Belay *et al.* (2022), East Africa and South Asia by Aryal *et al.* (2020) and South Africa by Abegunde *et al.* (2020), respectively, indicating that literacy levels significantly contribute to knowledge, understanding and adaptation to climate change. The research indicated that small-scale producers who possessed advanced literacy skills demonstrated a more profound comprehension of climate change, enabling them to effectively mitigate its effects. Education can increase the adoption of adaptive agricultural practices by up to 30% and is a crucial determinant for adopting climate-smart practices, with an influence ranging from 20% to 40%. These findings highlight the importance of education in strengthening the resilience of farming, livestock-raising, and fishing communities against climate change challenges. The findings regarding adaptation strategies in La Mojana underscore the critical necessity for more robust policies and sufficient financial resources to bolster these efforts. They identify evidence-based strategies that are essential for advancing climate adaptation, emphasizing early preparedness and rapid response as crucial to reducing vulnerability to extreme events and promoting community resilience (IPCC, 2021). For its efficacy in enhancing the local ability to respond to natural disasters, consequently reducing their negative consequences (International Federation of Red Cross and Red Crescent Societies (IFRC, 2014). The lack of adequate resources and insufficient institutional response are critical barriers that limit the effectiveness of these strategies at the local and national levels, as evidenced by recent research (United Nations Environment Programme (UNEP), 2019). Addressing these challenges requires strengthening adaptation policies through the integration of science-based strategies and the prioritization of financial resources. This involves fostering community engagement in the design and execution of adaptation initiatives, in addition to instructing communities in sustainable and resilient techniques. Enhancing collaboration among governmental bodies and various organizations is essential in order to guarantee a successful and unified approach towards addressing climate change. These actions will not only enhance La Mojana's capacity to face climate challenges but also establish a solid framework for future interventions and public policies, ensuring sustainable and resilient development in the region.

Implementation of public policies

In Colombia, addressing both mitigation and adaptation to the effects of climate change are key focal points within the country's environmental policy agenda.The main public policy tools on climate change are: Law 1931 of 2018, which establishes guidelines for the management of climate change; the national climate change policy; the low carbon development strategy; the national climate change adaptation plan; the national REDD+ (Reducing emissions from deforestation and forest degradation) strategy; the financial strategy to reduce the fiscal vulnerability of the state in the event of a natural disaster; the national climate change system and the national development plan 2018 – 2022: pact for Colombia, pact for equity. It can be deduced that in the region of La Mojana, which is known for its recurring issues related to climate variability, the National Plan for Adaptation to Climate Change (PNACC) has not effectively produced the desired outcomes, despite its intended purpose of diminishing the country's vulnerability and enhancing its ability to address the challenges posed by climate change. In that sense, taking as a reference the perception of the population in the study area regarding the implementation of public policies where in summary it is indicated that a holistic plan for adaptation to climate change is not carried out and the adaptation works are implemented in fragments in a large proportion with unwanted results; leading to a lack of policy evaluation and a monitoring plan to follow. In other words, while there exist crucial planning and policy tools, the key to achieving success lies in the execution and assessment of these tools. Without proper implementation and evaluation, these tools will merely exist in theory, confined

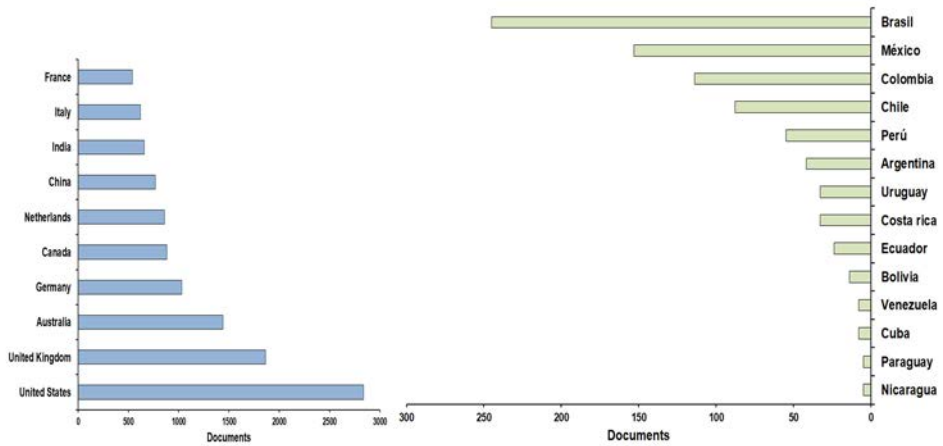


Fig. 5: Documents by country. a) World Cup, b) Latin America

to documents that merely echo the sentiments of certain individuals who believe that "paper holds everything." This sentiment is further reinforced by the observation that "if a problem has persisted for over two decades, why has it not been resolved?" This highlights the importance of conveying to the population that the PNACC is an ongoing process that encourages feedback. The Ministerio de Ambiente y Desarrollo Sostenible website is consistently updated with information regarding the threat of climate change and the lessons learned from different countries and their adaptation strategies, reflecting the ongoing generation of new information in this area (MADS, 2016). It should be noted that local government authorities with direct transition to the state when large-scale climate phenomena occur face various challenges to manage and adapt to the risks of climate change that arise depending on the weather in the La Mojana region. The obstacles encompass uncertainty in decision-making, handling community reactions and legal obligations, the viability of enforcing development limitations in at-risk zones, along with the necessity to establish suitable early emergency protocols, which were identified as a top priority in interviews. Subsequently, informed planning decisions are made in response to the climate fluctuations in the region, causing participants to display increased concern. Despite the consensus on the importance of community involvement in climate preparedness, the lasting impacts of climate change on community well-being have not been adequately communicated, resulting in a lack of sustained action and the implementation of investigative measures. In summary, although government policies and interventions have the potential to significantly support adaptation efforts in vulnerable regions, their impact is constrained by inadequate implementation and assessment, leading to inadequate support and, at times, obstruction of adaptation endeavors. The number of publications is an important indicator that is used to evaluate the development trend in a particular field and where the number of documents from a given country on this topic can reflect the research pattern of the country to a certain extent. Fig. 5a depicts the bibliometric analysis of climate change adaptation policies across different countries, utilizing data obtained from the scientific database SCOPUS. From the diagram it can be seen that articles on climate change adaptation policies are mainly concentrated in countries such as the USA, the United Kingdom, Australia, Germany, Canada, the Netherlands and other countries. Colombia is not included in this ranking, as it is ranked third among Latin American nations (Fig. 5b), trailing behind Brazil and Mexico, which are typically regarded as the prominent countries in various research endeavors. There is a lack of research processes in the area of interest with respect to international standards, which is possibly due to the fact that it does not face greater pressure on reducing emissions and the impact of climate change like developed countries; where according

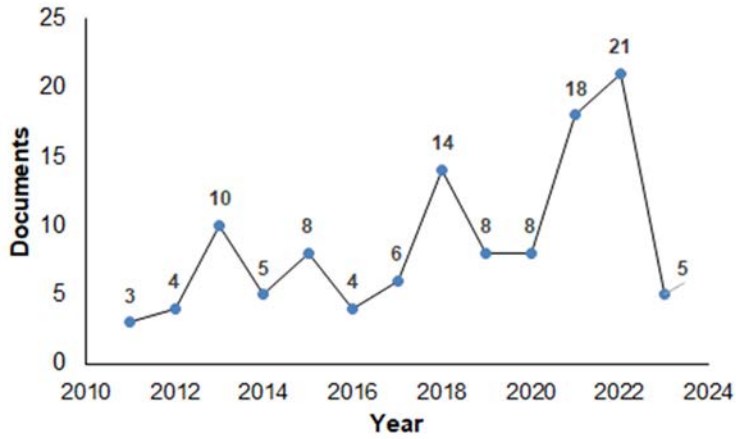


Fig. 6: Annual production of articles over the years in Colombia

to the report by Thomas and Twyman (2005) in developed countries assuming greater responsibility in reducing emissions due to the socioeconomic level of a large proportion compared to underdeveloped countries has caused the number of publications to have a significant increase.

In Fig. 6, it is evident that despite the implementation of the Kyoto Protocol in 2000, there has been no substantial increase in research related to Colombia in this field. This could be attributed to the emphasis on studying climate change and global warming to mitigate emissions rather than focusing on public adoption policies. However, there has been an increase in publication records since 2011, possibly influenced by the endorsement of the Bali Road Map in 2007, which may have shifted the paradigm towards the importance of adapting to climate change, an area that had previously not received adequate. The endorsement of the Copenhagen agreement since 2009, with its primary emphasis on action and collaboration for climate change adaptation, particularly in less developed nations, may have led to a rise in the volume of literature over time, linked to the perception, consciousness, and significance of climate change, particularly in 2018. This increase could be attributed to the favorable political and regulatory environment in Colombia, where a robust political and regulatory structure has been established to address climate change, including the enactment of Law 1931 of 2018, which outlines the framework for climate change adaptation and mitigation in the country. The presence of a supportive framework may have motivated researchers to concentrate on adaptation policies and produce publications on the subject. The above is in accordance with the reports made by Guardela (2020) in his work titled "Evolution of climate change policy in Colombia" in which within the Colombian context he identifies three periods. From 1994 to 2010, the country primarily focused on an economic approach to climate change, aiming to capitalize on the mechanisms outlined in international agreements and conferences to develop projects with economic advantages. A second period from 2010 to 2014, where the government faced a severe winter caused by the "La Niña" phenomenon, which significantly affected the country towards the end of 2010. The country's approach to climate change underwent a transformation following the event, placing increased emphasis on adaptation and risk management in light of the impacts and disasters experienced. Finally, a third period that covers the years 2014 to 2018 and coincides with the Santos government and its Development Plan "All for a New Country", where Colombia assumed the responsibility of complying with new international commitments, such as the Paris Convention and the Sustainable Development Goals. The establishment of the National Climate Change Policy in late 2017 and the enactment of Law 1931 of 2018 marked significant milestones in setting forth regulations for addressing climate change and its effects within the nation. Something curious regarding the publication

dynamics is that the largest number of publications occurred between the years 2020 and 2022 consistent with the Covid19 pandemic, which may be associated with different possible hypotheses; 1) Research opportunities in times of restrictions: The COVID-19 pandemic led to limitations and lockdowns that impacted numerous activities and projects. In this context, researchers may have found opportunities to dedicate more time to research and writing scientific publications, which may have contributed to the increase in the number of publications on climate change adaptation policies. 2) Greater awareness and government commitment: The Colombian government has been strengthening its commitment to climate change mitigation and adaptation in recent years. There has potentially been a rise in the production and distribution of scientific information within this domain due to heightened attention and backing from the government. 3) Enhanced emphasis on sustainability and adaptability: The significance of tackling worldwide issues like climate change, public health, and sustainability has been underscored by the COVID-19 pandemic. This has generated greater interest in research and publications related to climate change adaptation policies, as the need to strengthen the resilience of communities and systems in the face of future crises is recognized. 4) Need for information and guidance: The relevance of adapting to climate change in Colombia has grown significantly as a result of the observed impacts of climate change in various parts of the nation. This has led to a heightened need for information and direction on adaptation strategies, consequently leading to a rise in the number of scientific publications on the subject.

CONCLUSION

This study represents a notable progress in emphasizing the heightened vulnerability of rural communities, small-scale farmers, ranchers, and fishermen in the La Mojana region to the adverse effects of climate change. These groups are consistently disadvantaged by resource constraints, limited responses to early crises, and the lack of access to relevant adaptation and mitigation measures. It underscores the urgent need for integrated adaptation and mitigation measures. It is crucial to note the significant lack of research on the perception and adaptation to climate change in these vulnerable communities in Colombia. It has been observed that individuals living in rural areas are not adequately equipped to deal with the problem, and the consequences of climate change can result in substantial losses that may lead to economic insolvency and hinder the ability to bounce back, primarily due to the absence of state or private financial support, thereby exacerbating poverty levels. Climate inconsistency or variability is the main perception of the participants in the La Mojana region, considering that they are not only victims of climate variability and extremes, but also active observers. The general populace recommends that officials implement timely measures to incorporate both adaptation and mitigation efforts in order to address and anticipate recurring climate hazards annually. Several barriers were identified to develop a robust implementation, monitoring and evaluation plan, including lack of human resources, lack of leadership and competing priorities, lack of financial resources with a sense of who will bear costs and how progress can be monitored, as well as the political cycle that plays a fundamental role in the adaptation policy process. It is evident that despite the inclusion of climate change adaptation plans in the policy documents of local and national government authorities, the effectiveness of these policies in facilitating successful adaptation remains uncertain. This uncertainty stems from a lack of understanding within communities regarding the implementation, evaluation, and monitoring of these adaptation measures. It is essential to address this knowledge gap and promote greater clarity and active participation of communities to ensure success in the fight against climate change and building a more resilient society in the face of its impacts. The findings of this research align with the findings of the latest IPCC 2022 report, emphasizing the necessity to enhance studies on perception, execution, and funding for adaptation strategies. This is particularly crucial given the increasing global significance of this matter, especially in the Colombian Caribbean region where the populace has lost faith in or grown weary of government policies. In conclusion, it is essential to examine the climate change adaptation policies and practices in the Mojana region of Colombia is crucial to address the current and future challenges of climate change. By analyzing these policies and practices, the region can progress towards the implementation of more efficient and enduring strategies, which will foster resilience and sustainable development, while

also providing a model for other climate change-affected areas. It is crucial to acknowledge that climate change has a profound impact not only on the environment but also on the mental health of individuals throughout the entire supply chain. Those who are most at risk include small-scale fishers, farmers, and livestock ranchers, as they have limited access to resources. This highlights the urgent need for comprehensive strategies that address both the environmental and social dimensions of climate change impacts to ensure the well-being of affected communities.

AUTHOR CONTRIBUTIONS

J. Pinedo Hernández, the corresponding author, contributed to the data analysis, prepared most of the tables and figures and manuscript writing, supervision and interpretation of the results. A. Jiménez-Bedoya contributed to the consolidation of the research proposal and critically reviewed the manuscript. R. Paternina Uribe, participated in the supervision, interpretation of the results, and manuscript preparation F. Fuentes Gandara, participated in the supervision, interpretation of the results, and manuscript preparation.

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CONFLICT OF INTEREST

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the ethical issues including plagiarism, informed consent, misconduct, data fabrication and, or falsification, double publication and, or submission, and redundancy have been completely witnessed by the authors.

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ABBREVIATIONS

%	Percent
°C	Degrees Celsius
CO_2	Carbon dioxide
DANE	Departamento Administrativo Nacional de Estadística de Colombia
Eq.	Equation
F	Number of female individuals
Fig.	Figure
IDEAM	Instituto de Hidrología, Meteorología y Estudios Ambientales
IFRC	International Federation of Red Cross and Red Crescent Societies
IPCC	Intergovernmental Panel on Climate Change
km^2	Square kilometer
M	Number of male individuals
MADS	Ministerio de Ambiente y Desarrollo Sostenible
MPI	Multidimensional poverty index
mm	Millimeter
N	Number of individuals
PNACC	National Plan for Adaptation to Climate Change
REDD+	Reducing emissions from deforestation and forest degradation

UNEP	United Nations Environment Programme
WHO	World Health Organization
WMO	World Meteorological Organization

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AUTHOR (S) BIOSKETCHES

Jiménez-Bedoya, A., M.Sc., Assistant Professor, Faculty of Basic Sciences, Universidad de Córdoba, Montería, Colombia.
- Email: *albamilenajimenez217@gmail.com*
- ORCID: 0000-0002-7287-1054
- Web of Science ResearcherID: NA
- Scopus Author ID: NA
- Homepage: https://scienti.minciencias.gov.co/cvlac/visualizador/generarCurriculoCv.do?cod_rh=0001751855

Fuentes-Gandara, F., Ph.D., Professor, Department of Natural and Exact Sciences, Universidad de la Costa, Barranquilla, Colombia.
- Email: *fabioar20@hotmail.com*
- ORCID: 0000-0002-0681-0544
- Web of Science ResearcherID: GXV-7697-2022
- Scopus Author ID: 57192062455
- Homepage: https://www.researchgate.net/profile/Fabio-Fuentes

Paternina-Uribe, R., M.Sc., Assistant Professor, Faculty of Basic Sciences, Department of Chemistry, Universidad de Córdoba, Montería, Colombia.
- Email: *rpaternina@correo.unicordoba.edu.co*
- ORCID: 0000-0002-1994-0225
- Web of Science ResearcherID: IGY-7758-2023
- Scopus Author ID: 57219385071
- Homepage: https://www.researchgate.net/profile/Roberth-Paternina-2

Pinedo-Hernández, J., M.Sc., Assistant Professor, Faculty of Basic Sciences, Department of Chemistry, Universidad de Córdoba, Montería, Colombia.
- Email: *jjoaquinpinedo@correo.unicordoba.edu.co*
- ORCID: 0000-0002-4288-1788
- Web of Science ResearcherID: AAV-2548-2021
- Scopus Author ID: 55780076200
- Homepage: https://www.researchgate.net/profile/Jose-Pinedo-2

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