Perception of the inhabitants of the department of Caldas, Colombia on the effects of climate change on water quality

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ABSTRACT

Climate change has direct effects on the availability and quality of water for human consumption. In order to propose actions aimed at reducing vulnerability caused by water shortages and risk management required due to extreme events, real knowledge of the community’s perception is vital. This study developed in the department of Caldas, in the Colombian Andean region, analysed the perception of the incidence of climate change particularly related to water resources. To achieve this, a survey was used with various actors based on the first National Survey of Public Perception of Climate Change. The results show that the respondents perceive that the availability and quality of water are indeed highly threatened by climate change. As actions for adaptation, they suggested the promotion of the protection of hydrographic basins and a greater control of dumping liquids into surface water sources. Finally, they requested increased opportunities to improve water governance and participation in decision-making bodies regarding climate change, which they see as a fundamental aspect to achieve a real climate empowerment that can lead to action and adaptation in the territories in emerging countries.

Key words: climate change, climate empowerment, governance, perception, water

HIGHLIGHTS

- Water quality is perceived to be affected by the effects of climate change.
- The inhabitants of the department of Caldas, Colombia observe that rainfall and temperature are increasingly variable due to climate change.
- The department of Caldas, Colombia has climatic conditions that make it vulnerable to climate change.
INTRODUCTION

One of the challenges for today’s society is climate change, defined as climate change attributed directly or indirectly to human activity which alters the composition of the atmosphere due to greenhouse gases (GHGs) (CMNUCC 1992; Jol et al. 2009). Actions, such as industrialization, deforestation and large-scale agriculture, have contributed to the increase in GHGs in the atmosphere (IPCC 2014; ONU 2020).

The climate change crisis is strictly related to the vulnerability of water sources, especially their quality and availability (Ocampo López 2011; Leveque et al. 2020). The variability of the water cycle has increased due to climate change and has caused extreme meteorological phenomena, as well as reduced the possibility of forecasting the availability of water resources and also caused a marked decrease in water quality. This, therefore, constitutes a threat to sustainable development, biodiversity and the human right to safe drinking water and basic sanitation throughout the world (IPCC 2014; ONU 2019; OMM 2020). Some of the effects of climate change by sector are displayed in Table 1, based on Bárcena et al. (2020). The populations most affected by climate change are found in coastal regions and in tropical countries where fragile and highly susceptible ecosystems abound. In these regions, extreme climatic events and the spread of infectious diseases are evident (Becerra et al. 2020; Harper et al. 2020).

Geographical location increases the degree of vulnerability of tropical countries. This is why Colombia is so vulnerable to climate change and its effects (Ocampo & Vélez 2014; Sauchyn et al. 2016). Different studies (Pabón 2003; Poveda et al. 2007; Poveda 2009; Pabón Caicedo 2012; Ocampo-López et al. 2020) have analysed long-term trends in the precipitation and temperature variables in Colombia which had an effect on surface runoff. On average, the temperature increase was 0.13°C for the period between 1971 and 2000. Increases in the average air temperature of 1.4°C for 2040 have been estimated, as have their effects on the quantity and quality of surface water sources in the country (IDEAM 2020).

Colombia has low participation in GHG emissions; however, it does present a high vulnerability to the effects of climate change due to its environmental, social and economic conditions. Therefore, seeking adaptation measures which help to counteract the adverse effects of climate change is essential. For this purpose, the National Climate Change Policy has been defined, which incorporates management of emissions into public and private decisions to promote climate-resilient and low-carbon development, reduce risks and take advantage of opportunities (Minambiente 2017). At the regional level,
this policy adopts the Comprehensive Territorial Climate Change Management Plans (PIGCCT – initials in Spanish) which are based on vulnerability analysis and GHG inventory performed by existing administrative units, which in the case of Colombia are the geographical departments. Based on this analysis, mitigation and adaptation measures and actions in the territory have been identified (Bárcena et al. 2020; Minambiente 2020).

In the department of Caldas, the PIGCCT was adopted to advance climate change management. The geographical location, the biophysical conditions and the socioeconomic dynamics make this territory vulnerable to climate change. Caldas is in the Colombian Andean region. Most of its towns and villages form part of the coffee-growing region declared by UNESCO to be a Cultural Heritage of Humanity (UNESCO 2009). Caldas is characterized by a marked altitudinal gradient which ranges from 5,286 meters above sea level (masl) in the Los Nevados National Natural Park down to 170 masl in the town of La Dorada located in the valley of the Rio Grande de La Magdalena, the main Colombian river. This area is made up of different strategic ecosystems, such as glaciers, wetlands, high Andean forest and tropical dry forest (Poveda et al. 2011). The region is extraordinarily biologically diverse. The avifauna is especially noteworthy having 50% of all the species reported at the national level and there are several different Important Areas for the Conservation of Birds and avitourism (Matallana Tobón 2017; Corpocaldas 2019). The Florence National Natural Park is in Caldas and has an average annual rainfall that reaches 8,000 mm and an average temperature of 19°C. The humid tropical forest with its climatic characteristics houses the greatest diversity of amphibians in the country with a high degree of endemism. It is a park of strategic importance, hydrologically speaking, because of the Magdalena river basins. All these characteristics make the department of Caldas a key hotspot for identifying signs of climate change (Pabón-Caicedo 2002).

### Table 1 | Potential impact and risks of climate change in Latin America

| Threatened sector               | Key risks                                                                 | Climate drivers                                                                 |
|---------------------------------|---------------------------------------------------------------------------|---------------------------------------------------------------------------------|
| Agricultural                    | Decrease in production and in the quality of food and income; price increases. | • Rising temperatures and extreme episodes.                                     |
|                                 |                                                                           | • Erratic precipitation and extreme episodes.                                   |
|                                 |                                                                           | • Fertilization due to increases in the concentration of CO2.                  |
| Water resources                 | Less water availability in semi-arid regions and those dependent on the melting of glaciers; floods in rural and urban areas related to extreme rainfall. | • Tendency to increase in temperature.                                          |
|                                 |                                                                           | • Tendency to suffer droughts.                                                  |
|                                 |                                                                           | • Covered with snow.                                                           |
|                                 |                                                                           | • Increased rainfall.                                                          |
| Biodiversity and forests        | Disappearance of forests, coral bleaching and loss of biodiversity and ecosystem services. | • Increase in deforestation.                                                   |
|                                 |                                                                           | • Fertilization due to increases in the concentration of CO2.                  |
|                                 |                                                                           | • Tendency to increase temperature.                                             |
|                                 |                                                                           | • Acidification of the oceans.                                                  |
| Health                          | Spread of vector-borne diseases at higher altitudes and latitudes than in their original distribution. | • Temperature increase.                                                        |
|                                 |                                                                           | • Increased rainfall.                                                           |
| Tourism                         | Loss of infrastructure, rise in sea level, appearance of invasive species and extreme phenomena in coastal areas. | • Sea level rises.                                                             |
|                                 |                                                                           | • Extreme temperatures.                                                        |
|                                 |                                                                           | • Extreme rainfall and flooding.                                                |
| Socioeconomic factors           | Decrease in the income of vulnerable populations, mainly agricultural, and increase in income inequality. Deterioration of the habitability conditions and quality of life of displaced populations or people living in poverty. | • Increase in temperature and extreme episodes.                                 |
|                                 |                                                                           | • Tendency to suffer droughts.                                                  |
|                                 |                                                                           | • Erratic precipitation or precipitation outside the parameters of crop physiology. |

Source: adapted from Bárcena et al. (2020).
In an area of 7,888 km² live 923,472 people, with 75.4% concentrated in urban areas. However, the geographical department is still agricultural and the majority of its territory is rural. The department has a high aging index (67.1%), one of the highest in the country, although the youth index is also significant at 23.74% (DANE 2019). This territory has 55,801 indigenous inhabitants, comprising 6% of the population, with the Emberá, Emberá Chami and Caña mamó being the largest ethnic groups present, distributed in reservations, partialities and settlements. Also, 2% of the population are Afro-descendants and are distributed in 29 organizations.

This population diversity makes the community-based adaptation approach one of the guidelines of the National Climate Change Adaptation Plan which seeks to empower the most vulnerable communities to address the effects of climate change in the short, medium and long term (DNP 2016). Working with this adaptation approach, understanding the perception of the inhabitants regarding their vulnerability to climate change and its effects on their territories, ecosystems and resources is a necessity. This perception forms the first step in defining adaptation measures based on local priorities, needs, knowledge and capacities. Perception exercises have been prioritized at the national level as essential in reducing the vulnerability of communities (DNP 2016), because ‘adaptation is specific to the place and context, and there is no single method to reduce risks that are appropriate for all situations’ (IPCC 2015).

In Colombia, the Third National Communication on Climate Change (TCNCC – initials in Spanish) carried out the first national survey of public perception of climate change in 2016. The respondents perceived that climate change has had a direct influence on water sources and on the availability of water resources and reported the decrease in access to water as one of its main effects (IDEAM et al. 2016).

For Caldas, the community perception exercise was carried out in different workshops in the six sub-regions of the department. The National Study of Social Perception guidelines created by the TCNCC were used. This study presents the results of this perception exercise in relation to the knowledge of climate change, the change in climate variables, the threat and the impacts of climate change. The methodology is detailed below and the perception results are presented, with an emphasis on the effects of climate change on the availability and quality of water in the region.

**MATERIALS AND METHODS**

This study was carried out within the Department of Caldas’ PIGCCT framework and also within the framework of the call for young researchers made by the Ministry of Sciences of Environmental Health (Minciencias en Salud Ambiental).

The research was both qualitative and quantitative, with a cross-sectional exploratory, descriptive and interpretative approach. The study was carried out to determine society’s perception and especially the point of view of institutional actors, community leaders and experts on the effects of climate change on the department of Caldas’ water resources.

Caldas is one of the 32 departments which make up the Republic of Colombia, it has an area of 7,888 km². Its physical geography is Andean, lying between the Western and Central mountain ranges (see Figure 1). It is divided into 27 towns which are distributed in the six subregions (DNP & PNUD 2009). The department has a population of 923,472 inhabitants, which represents 2.1% of the total national population. Of the total population, 48.5% are male and 51.5% are female. Manizales, the capital of the department, is home to 45.4% of the population, followed by La Dorada (8%), Villamaría (6%), Riosucio (6%) and Chinchiná (5%) (DANE 2019).

The six subregions of the department are Alto Occidente, Occidente Prospero, Centro Sur, Magdalena Caldense, Alto Oriente and Norte. All the thermal floors can be found in this department, from the hot valleys of the Magdalena River and the Cauca River to the perpetual snows of Nevado del Ruiz (Gobierno de Caldas 2017).

As reported by the Autonomous Regional Corporation of Caldas – Corpocaldas (2019), which is the environmental authority in the department, the communities are highly vulnerable and are exposed to hydrometeorological events and socio-natural threats, such as erosive processes and landslides; mass movements; flash floods, flooding and forest fires. The recurrence of extreme climatic events is of great concern due to the abundant rain precipitation which ranges from 1,200 to 8,000 mm.

A survey was designed to ascertain the perception of climate risk in the different communities, based on the first National Survey of Social Perception carried out by the TCNCC. The survey consisted of the following questions about the water resource dimension:

- What is your level of information on climate change?
  - Very informed.
Informed.

Little Informed.

Not Informed.

• Means by which you obtained information on climate change:
  o Television.
  o Radio.
  o Newspapers.
  o Internet.
  o Specialized channels.

• Perception of the variation in temperature in your town or village in the last decade:
  o Warmer.
  o Cooler.
  o Very variable.
  o Has stayed the same.

• Perception of the amount of rain in your municipality in the last decade
  o Has increased.
  o Has decreased.
  o Very variable.
  o Has stayed the same.

• What is the threat of climate change to the availability of water? Consider your assessment on the following scale:
  o Not threatened.
  o A little threatened.

Figure 1 | Geographical location of the department of Caldas, source: IGAC. Atlas of Colombia (1999); DANE Geoportal. Map of Caldas (2018).
What is your perception of the main impacts of climate change in Caldas? Mark the 5 (five) most important with an X

- Increase in food prices.
- Periods of extreme heat or cold.
- Unexpected temperature changes.
- Droughts.
- Increase in the cost of the domestic electricity service.
- Forest fires.
- Loss of fauna and flora.
- Water rationing.
- Severe rains or heavy storms.
- Increased incidence of tropical diseases (such as Zika, Dengue fever, Yellow Fever, Chikungunya).
- Soil erosion.
- Flooding.
- Landslides.
- Migratory movements of human beings.
- Increase in the number of earthquakes.

What actions of mitigation and adaptation do you propose for your town or village?

**Sampling:** The survey was carried out by those attending the sub-regional workshops on Climate Change, which included the participation of community action boards, local action boards, territorial environmental health councils, municipal risk management councils, territorial planning councils, the Inter-institutional Committee for Environmental Education, citizen oversight bodies, municipal councils and/or committees for rural development, culture councils and/or committees, and councils and/or youth committees, indigenous communities and ethnic groups. In total, 583 people were surveyed, of which 257 were men (44.1%) and 326 were women (55.9%); 270 of these live in the capital city of Manizales (46.3%) and 313 in the towns and villages of the geographical department (53.7%).

**RESULTS**

According to the results obtained regarding the level of information on climate change, it is evident that in the department of Caldas, 57.3% of the community consider themselves informed, while 31.5% consider themselves either a little or not informed at all (see Figure 2). Highlighting that 68.5% of the inhabitants of the geographical department consider themselves either informed or very informed about climate change is important. This facilitates the correlation of the perception of the impacts of climate change in the region.

Figure 3 shows the most common means of communication by which people obtain information about climate change. The internet is the means by which the population in Caldas, Manizales and other towns obtain their information.

Over the last decade, 57.7% of the communities of the department consider that temperature has been highly variable, while 37.7% consider that it has been warmer (see Figure 4). On another point, the communities perceive highly variable rains or rainfall (50%), while 28.5% consider that rainfall has increased (see Figure 4).

Figure 5 illustrates the risk of climate change to the quality and availability of water. Forty-nine percent of the population feels this resource is very threatened and that it is essential for people's quality of life. Also, they perceive that the main impact of climate change is the rationing of water or non-purified water. In the city of Manizales, the capital of the department, 87% of those surveyed perceive the availability of water as threatened and highly threatened as an effect of climate change.

The main impacts of climate change for the department according to the perception study are landslides (11.3%); unexpected changes in temperature (11%); periods of extreme heat or cold (10.6%) and loss of fauna and flora (9.5%). In the subregions, residents chose impacts such as unexpected changes in temperature (10.6%); droughts (10.2%); landslides (10.2%) and periods of extreme heat or cold (10.2%) (see Figure 6). In contrast to these results, it can be seen that in other towns and villages of the geographical department, one of the greatest impacts of climate change chosen were droughts (10.2%); water rationing (7.5%) and severe rains or intense storms (7.3%).

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Figure 2 | Community perception on the level of information of the communities of Caldas, Colombia about climate change.

Figure 3 | Perception of community of information media about climate change.

Figure 4 | Perception of the variation in temperature and rainfall in the last decade.
Some adaptation measures to climate change for the water resource dimension proposed by those surveyed are: defining watershed protection zones and areas supplying aqueducts, planting native trees, controlling logging and recovering water recharge areas, promoting protection and conservation watersheds, control and monitoring the quality of water sources, control of discharges from factories, promoting clean-up days for water sources, developing a specialized centre for work in training youth committees in water care, strengthening basin councils and early warning systems.

The adaptation and mitigation measures for the proposed sanitation dimension are: managing the construction of wastewater treatment plants; proper management of discharges; encouraging projects for the correct disposal of liquids caused by coffee processing; maintenance of sewerage systems; construction of septic tank systems and scupper cleaning, among others.
DISCUSSION

At the global level, various studies have been carried out concerning the perception of populations on climate change and how this global phenomenon has a direct influence on the availability and quality of water (Echavarren et al. 2019). The data obtained from these perception studies provide relevant information for designing adaptation strategies to respond to climate change. The main effects that communities perceive as being caused by climate change are droughts (Bishop 2013; Takakura et al. 2020; Thokchom 2020; Wang et al. 2021) and frequent floods (Yang et al. 2018; Thokchom 2020).

In this study, according to the perceptions provided by the inhabitants of the department of Caldas, in relation to the level of information, 57.3% of the surveyed population consider themselves informed regarding climate change. However, these results differ from those obtained in the first national survey of public perception called: *What do Colombians think about climate change?* where 75.1% state that they are a little or not at all informed and only 18.7% of the population consider themselves informed about the phenomenon. It should be noted that this survey was carried out in 57 towns throughout the country, where a total of 1,150 surveys were conducted (IDEAM et al. 2016). Caldas is one of the geographical departments, which has advanced the most in environmental education in the country. It has a well-defined policy, which integrates the subject of climate change in the School Environmental Projects and in the University Environmental Projects, as well as the Citizen Projects of Environmental Education. The theme of climate change is also incorporated in the ONDAS programme of the Ministry of Sciences as a line of research, which aims to promote in children and young people an interest in research and the culture of science, technology and innovation. Caldas has been a leader in this programme, which is functioning in all its 27 towns.

At the national level, approximately 90.9% of the population learned about the phenomenon from the television, followed by the internet (5.3%) (IDEAM et al. 2016). In Caldas, however, means of communication beyond the internet and television have been highlighted. The study shows that newspapers, radio and specialized channels are also sources of information regarding climate change. This diversity in communication channels is the product of the promotion of the Social Appropriation of Knowledge strategy led by the Ecosystem of Science, Technology and Innovation in the department of Caldas, which seeks to effectively reach the territories using all available means. In rural areas due to limitations in access to the internet, other communication media such as radio are essential.

Changes in the climatic variables are also perceived by the inhabitants of the department. Some respondents consider that the temperature has been highly variable (57.7%) and others consider that it has been warmer (37.7%) over the last decade. At the national level, the majority of respondents (56.7%) considered that the temperature was warmer and for others (36.6%) it was highly variable (IDEAM et al. 2016). Local studies of climate change signs agree with trends of increases in temperature, determined by the altitudinal gradient and changes in vegetation cover (McMartin et al. 2018) which alter the water resources. Likewise, climate variability is marked by the dynamics of the Southern Oscillation phenomenon (ENSO), where the inhabitants feel the increases in temperature during the El Niño phenomenon and the reductions in La Niña, influence the extreme events and the adaptation measures of productive systems (Quintero-Angel et al. 2012). At an international level, people perceive the hottest climate (Assan et al. 2020) and attribute that as a cause of periods of drought. The increase in temperature and prolonged periods of droughts are perceived as problems for the agricultural sector (Nnko et al. 2021). For the region, the respondents mentioned problems of drought and increases in food prices.

Caldas is vulnerable to increases in temperature, which have a negative impact on the moors, on endemic species, as well as on the dynamics of pests and invasive species. There is also evidence of a reduction in strategic ecosystems that affect surface water bodies (Corpocaldas 2019). Additionally, signs of climate change have been detected in hydrographic basins and in extreme events which affect the different economic activities and affect vulnerability and risk in the territory (Mussetta et al. 2017). Warmer air can retain more moisture; this is associated with stronger storms and weather-related disasters. More specifically, severe storms put pressure on water quality and increased suspended solids reduce the level of dissolved oxygen in the superficial waters (Fathy & Rosenbach 2020). In the department of Caldas, water rationing occurs in the rainy season due to the load of suspended solids and the level of turbidity of the water. Respondents report a higher incidence of water rationing in rural villages and areas.

Respondents perceive precipitation as highly variable (50%) and increasing (28.5%). At the national level, however, both decreases (54%) and high variability (31.2%) are perceived. In the Caldas region, the ENSO affects rainfall with increases during La Niña and decreases during El Niño. In 2010 and 2011, a La Niña event was registered with social, environmental and economic repercussions of great magnitude (BID – CEPAL 2012) and in the department of Caldas, there were events triggered by the heavy rain including mass movements, landslides and floods. In 2018, an El Niño event occurred which
affected the entire country and in the department of Caldas, there were effects on the availability of water in several towns, according to the Regional Water Study. In another point, fires in vegetation cover were registered especially in the lower areas of the valleys of the Cauca and Magdalena rivers. Precipitation and storms have increased and these extreme weather events affect food security, biodiversity and the well-being of agricultural households (Assan et al. 2020). In the Caldas region, respondents report the presence of heavy rains and storms, landslides, erosion and floods.

Climate change is one of the main forces, which cause the loss of biodiversity (Ocampo López 2011) and essential resources for survival, such as water (McMartin et al. 2018). The inhabitants of Caldas report the loss of flora and fauna and problems with water resources. Also, climate change and climate variability affect the demand for water and intensify the pressures on this resource (Bárcena et al. 2020). In Caldas, local studies show these effects (Jiménez et al. 2017). Despite the availability of water resources, which are abundant for the area according to National Water Studies (IDEAM), 49% of the population considers this resource to be very threatened because of climate change. In the workshops, they expressed the importance of water for their quality of life and mentioned that the abrupt changes in some territories due to mismanagement of water have led to the drying streams and springs, polluted rivers, floods, landslides and avalanches. Consequently, they prioritize actions for risk reduction and adaptation to climate change with emphasis on the conservation of ecosystem services, and the contributions of nature, such as domestic water supply for people.

For indigenous communities, achieving harmony with Mother Earth and returning to ancestral practices such as agro-ecology is necessary. Local studies (Ulloa et al. 2008) of the perception of the indigenous peoples of Caldas on climate change show that this is not a situation which is directly attributed to nature but is seen more as a consequence of human actions. The territories of the indigenous communities of Caldas face environmental problems related to the use of wood, open permits for forest use, lack of protection of micro-watersheds, expansion of the agricultural frontier, use of pesticides and the mismanagement of non-reusable waste. Even though the Regional Autonomous Corporation of Caldas (Corpocaldas) has made progress in the planning and management of hydrographic basins, deforestation, illegal mining and the illegal commercialization of species remain latent problems in the territory requiring joint work and, the need for the strengthening of territorial capacities and actions towards the governability and governance of water, especially.

Droughts, river erosion and floods are the main climatic risks which in turn have a significant effect on agriculture in the regions (Ahmed et al. 2021). The agricultural emphasis of Colombia and especially of the department of Caldas makes it imperative to look at adaptation in agriculture (Quintero-Angel et al. 2012). The residents’ perception of the vulnerability and risks associated with landslides, droughts and floods prioritize risk management and adaptation to climate change actions. Although the environmental authorities have made progress in risk management, especially with the installation of the Caldas Environmental Monitoring System, for risk reduction processes with disaster mitigation and response work, a greater approach to knowledge of risk is still required. Early warning systems and the promotion of adaptation actions with an emphasis on community-based adaptation and ecosystem-based adaptation are also required. For this, involving residents, in consultative capacities, as well as in the decision-making exercises, is essential. This will allow for prioritizing actions based on local knowledge.

CONCLUSIONS

The people of the Caldas geographical department see climate change as a series of variations in climate that are clearly visible in changes in temperature and rainfall. The residents state that these effects on the climate have caused the loss of ecosystems and biodiversity and have affected hydrographic basins, especially the quality and availability of water. They see themselves as highly threatened by the consequences of climate change and mention landslides, loss of fauna and flora, increased food prices, droughts, soil erosion and water rationing among the main impacts on their communities.

The protection of the hydrographic basins, planting of trees, control of discharges, empowerment of young people and the strengthening of the hydrographic basin councils are all adaptation actions suggested by the communities. Knowledge of risk is essential in the territory to promote climate actions with community participation techniques, such as early warnings and adaptation strategies based on their ecosystems.

RECOMMENDATIONS

In order to achieve effective progress in the implementation of local adaptation and mitigation measures, continuing with environmental education strategies and the social appropriation of knowledge is necessary, as well as greater coordination.
between government, public–private companies, academia and communities. Joint work involves a complex and systemic approach which leads to a greater understanding of territorial dynamics and the contexts in which they develop. Understanding the perceptions of the inhabitants facilitates interventions and provides new information which must be incorporated so as to guarantee the effectiveness of the programmes.

**DATA AVAILABILITY STATEMENT**

All relevant data are included in the paper or its Supplementary Information.

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