Mercator, Fortaleza, v.21, e21025, 2022. ISSN:1984-2201

ADAPTIVE GOVERNANCE AND WATER SECURITY IN THE CONTEXT OF CLIMATE CHANGE IN THE SEMI-ARID

https://doi.org/10.4215/rm2022.e21025

Eric Mateus Soares Dias [a*] - Zoraide Souza Pessoa [b] - Rylanneive Leonardo Pontes Teixeira [c]

(a) Master degree in Urban and Regional Studies. Universidade Federal do Rio Grande do Norte, Natal (RN), Brasil.
ORCID: http://orcid.org/0000-0001-9347-8932. **LATTES:** http://lattes.cnpq.br/7228847321681517.
(b) PhD in Environment and Society. Professor at the Universidade Federal do Rio Grande do Norte, Natal (RN), Brasil.
ORCID: https://orcid.org/0000-0002-9509-5027. **LATTES:** http://lattes.cnpq.br/7738736219606737.
(c) in Urban and Regional Studies. Universidade Federal do Rio Grande do Norte, Natal (RN), Brasil.
ORCID: https://orcid.org/0000-0001-8635-3234. **LATTES:** http://lattes.cnpq.br/8405796140306191.

Article history:
Received 30 December, 2021
Accepted 01 November, 2022
Published 15 December, 2022

(*) CORRESPONDING AUTHOR
Address: UFRN. Campus Universitário, CEP: 59078-970, Lagoa Nova, Natal (RN), Brazil. Tel: (+55 84) 3342-2299
E-mail: ericmateusemsd@gmail.com

Abstract

The aim of this paper is to analyze whether the management of water resources in the state of RN meets the requirements of adaptive governance in order to enable adaptation processes to the possible impacts of climate change in semi-arid regions. To do so, the work follows the guidelines of a qualitative, exploratory and descriptive approach using a set of research instruments: bibliographic survey, case study, structured interviews and content analysis. The results show that the management of water resources in RN presents a series of challenges and obstacles to configure itself in a climate adaptive governance perspective. In summary, it is concluded that the management of water resources in the state of RN still does not meet the requirements of a robust adaptive governance capable of operating responses to the risks of climate change and ensuring water security.

Keywords: Climate Change. Adaptation. Management of Water Resources. Sustainability. Brazilian Semi-arid.

Resumo / Resumen

GOVERNANÇA ADAPTATIVA E SEGURANÇA HÍDRICA EM CONTEXTO DE MUDANÇAS CLIMÁTICAS NO SEMIÁRIDO

O objetivo deste artigo é analisar se a gestão de recursos hídricos no estado do RN atende aos requisitos da governança adaptativa, de modo a possibilitar a segurança hídrica e os processos de adaptação aos possíveis impactos das mudanças climáticas em regiões semiáridas. Para tanto, o trabalho segue as orientações de uma abordagem de natureza qualitativa, exploratória e descritiva, utilizando-se de um conjunto de instrumentos de pesquisa: levantamento bibliográfico, estudo de caso, entrevistas estruturadas e análise de conteúdo. Os resultados apontam que a gestão de recursos hídricos do RN apresenta uma série de desafios e entraves para se configurar numa perspectiva de governança adaptativa climática. Em síntese, conclui-se que a gestão de recursos hídricos do estado do RN ainda não atende aos requisitos de uma goverança adaptativa robusta e capaz de operar respostas aos riscos das mudanças climáticas e garantir a segurança hídrica.

Palavras-chave: Mudanças Climáticas. Adaptação. Gestão de Recursos Hídricos. Sustentabilidade. Semiárido Brasileiro.

GOBERNANZA ADAPTATIVA Y SEGURIDAD HÍDRICA EN EL CONTEXTO DE CAMBIO CLIMÁTICO EN SEMIÁRIDO

El objetivo de este artículo es analizar si la gestión de los recursos hídricos en el estado de RN cumple con los requisitos de gobernanza adaptativa, para posibilitar procesos de adaptación a los posibles impactos del cambio climático en regiones semiáridas. Por tanto, el trabajo sigue las pautas de un enfoque cualitativo, exploratorio y descriptivo, utilizando un conjunto de instrumentos de investigación: relevamiento bibliográfico, estudio de caso, entrevistas estructuradas y análisis de contenido. Los resultados muestran que la gestión de los recursos hídricos en RN presenta una serie de desafíos y obstáculos para configurarse en una perspectiva de gobernanza adaptativa al clima. En resumen, se concluye que la gestión de los recursos hídricos en el estado de RN aún no cumple con los requisitos de una gobernanza adaptativa robusta capaz de operar respuestas a los riesgos del cambio climático y garantizar la seguridad hídrica.

Palabras-clave: Cambio Climático. Adaptación. Gestión de Recursos Hídricos. Sustentabilidad. Región Semiárida Brasileña.

INTRODUCTION

With the advance of climate change at a global level, there is no way to debate water security without considering the imposition of new risks to populations and ecosystems as a result of these changes. Therefore, water and climate are inseparable issues, since the water sector is strongly affected by climate change (PUGA, 2018). At the same time, actions to guarantee water security must incorporate the risks of climate change, especially in regions with low water availability such as the Brazilian semi-arid region which historically faces drought events.

It is undeniable that it was possible to learn a lot from the occurrence of the great droughts which, despite the misfortunes, made it possible to develop strategies for coexistence with the semi-arid region, avoiding the most obvious consequences of the great droughts of the past: hunger, malnutrition, misery and the rural exodus (MCBEAN; RODGERS, 2009). However, future climate scenarios point to a tendency for the semi-arid region to become even more arid, as well as an increase in the frequency and intensity of droughts, with an increasing water availability shortage (AMBRIZZI et al., 2007; MARENGO, 2008).

The recent drought episode in the period 2012-2017 is considered the worst in the last 100 years, and highlighted the great vulnerability of water systems in the semi-arid region where several cities have collapsed, as the main reservoirs reached dead volume for the first time since they were inaugurated (FRANÇA; MORENO, 2017).

All these issues raise changes and improvements in managing water resources, which must be guided by developing the capacity to operationalize responses against so many uncertainties regarding the impacts of climate change on water resources. In this sense, with increasingly complex problems to ensure water security, more adaptable and flexible management is required to act under the rapid changes that are occurring in the climate. This discussion enters into the myriad of an increasingly necessary management model and which has been debated by some authors, namely that of adaptive governance (DIETZ; OSTROM; STERN, 2003; DESSAI et al., 2004; FOLKE et al., 2005; ADGER et al., 2007).

In view of the above, this article seeks to understand this problem from a case study in the semi-arid region of Rio Grande do Norte (RN), whose semi-arid climate represents 93% of its territory, thus being the second state with the largest semi-arid portion of Brazil. The state presents a similar climatic context and responses to climatic events as the other states inserted in the Brazilian semi-arid region, which makes it possible for reflections carried out within the scope of this study to launch theoretical-methodological reflections for the others.

From this contextualization, the following question is asked: how is the management of water resources aimed at the semi-arid region of the state of RN incorporating the principles of adaptive governance in the context of climate change? In this sense, the objective of this article is to analyze whether the management of water resources in the state of RN meets the requirements of adaptive governance in order to enable water security and adapt processes to the possible impacts of climate change.

The article is structured in four moments, in addition to this introduction: first, there is the methodology used to develop this article; then, the essential concepts for understanding this study are approached; next, the results obtained in this work are analyzed and discussed; and finally, the main considerations about the analyzes and discussions carried out in the course of this article.

METHODOLOGICAL PROCEDURES

This study implements a qualitative, exploratory and descriptive approach to achieve the objective proposed in the introduction and uses case study methods and semi-structured interviews for a deeper understanding of the study object (MINAYO; SANCHES, 1993; BABBIE, 2001; FRANCO, 2003).

The results and discussions presented herein were developed in three phases: the first was exploratory, consulting bibliographies and collecting secondary data; the second was the field stage with semi-structured interviews; and the third stage involved data systematization, analysis and interpretation.

The first phase enabled a review of key concepts and understanding the studied area in its various aspects (environmental, social, economic, political and institutional) from a bibliographic and documentary survey in articles, books, websites, reports, laws and plans in institutions such as the Rio Grande do Norte Water Management Institute (o Instituto de Gestão das Águas do Rio Grande do Norte - IGARN), the Environment and Water Resources Secretariat (a Secretaria de Meio Ambiente e Recursos Hídricos - SEMARH), the State Civil Defense (a Defesa Civil Estadual - DC), the Institute for Sustainable Development and the Environment (o Instituto de Desenvolvimento Sustentável e Meio Ambiente - IDEMA), and the Brazilian Institute of Geography and Statistics (o Instituto Brasileiro de Geografia e Estatística - IBGE). This phase comprised the entire research period. The second phase involved conducting the interviews, and was essential to understand the perception of institutional interlocutors who manage water resources in RN, as well as obtaining data and information on the subject in the context of the state. Thus, a total of 14 actors were interviewed between November 2019 and February 2020, divided into two groups: social actors, composed of seven researchers (from the Federal University of Rio Grande do Norte - UFRN, from the State University of Rio Grande do Norte - UERN and from Universidade Federal Rural do Semi-Árido - UFERSA), with these participants being graduate students and/or professors who have developed research on the environment, climate change and water resources, including experience working in public environmental agencies. The other group were institutional actors, which was formed by seven representatives of public agencies (such as Civil Defense, SEMARH, IGARN and IDEMA), which consisted of technicians, managers and other important leaders for the decision-making process on environmental and climate issues in the state. The interviews were guided by a previous script with open questions. They generally lasted 45 minutes and were recorded with the permission of the interviewee.

In the third and final phase (analysis and discussions), the data were triangulated and an analysis of incorporating adaptive governance requirements for managing water resources in RN was conducted based on the theoretical discussions of Dietz, Ostrom and Stern (2003), as presented in the topic of analysis and discussion of the results.

WATER (IN)SECURITY IN THE BRAZILIAN SEMI-ARID REGION AND THE EMERGENCE OF ADAPTIVE CLIMATE GOVERNANCE

THERE is no doubt that the average global temperature has undergone an exponential increase since the industrial revolution and that human activities have a great responsibility for this fact from the increasing emission levels of Greenhouse Gases (GHG) which alter the solar radiation balance (IPCC, 2014). This corroborates the changes in natural climate dynamics, noting that “the surface has been warming by almost 0.2°C per decade in the last two decades, which is a rate 50 times faster than its natural cycle observed until then” (NOBRE; REID; VEIGA, 2012, p. 08).

Despite the great visibility of the climate change topic and its improvement in the field of Climate Sciences, which has produced increasingly robust climate models due to the high degree of complexity involved in issues related to climate change, there is still a universe of uncertainties around (above all) the different forms of climate impacts and their magnitude, both temporal and spatial (KNUTTI et al., 2010).

Even so, some evidence shows that it is very likely that the increase in temperature and changes in the rainfall regime (for example) could induce changes in the frequency, intensity, spatial dimension and duration of climatic events, resulting in unprecedented extremes, along with adverse effects on several systems, especially with regard to water resources (WISE et al., 2014). These may consequently increase, promote and expose the vulnerability of populations, altering the functioning of societies and their well-being (VEYRET, 2013).

It is worth noting that some systems (populations, territories, sectors) are more vulnerable, meaning they have an internal condition of sensitivities, whether from a social, economic or environmental point of view, which influence or increase exposure and susceptibility to suffering impacts (ADGER; KELLY, 1999; VEYRET, 2013). In this context, Marengo et al. (2017) show that the Brazilian semi-arid region is a vulnerable territory and highly exposed to the adverse impacts of climate change.

The semi-arid climate region covers the nine states of the Brazilian Northeast and part of Minas Gerais, and presents natural climatic conditions with high temperatures, high evapotranspiration rates and a short rainy season, which in turn condition a null water availability most of the time (courses of 'intermittent water') and great inter and intra-annual rainfall variability (ANA, 2019), triggering several socioeconomic problems (SANTOS et al., 2010). These aspects add to the pressures for use and the marked environmental degradation that has occurred since the time of colonization with intense exploitation of natural resources (SALES, 2002), increasing the region's vulnerability to the possible impacts of climate change (MARENGO et al., 2016).

Climate projections in the semi-arid region of Brazil indicate that the gradual increase in the average temperature of the earth will lead to changes in rainfall patterns and consequently a decrease in precipitation. Thus, an increase of 0.5ºC to 1.0ºC in the average temperature of the earth by the end of the 21st century would mean a decrease between 10% and 20% in precipitation by 2040 (PBMC, 2013; VIEIRA et al., 2015; MARENGO et al., 2017). Warmer conditions worsen regional water deficits and can trigger advanced aridity and desertification processes, negatively affecting the guarantee of water, food and energy security (EAKIN; LEMOS; NELSON, 2014).

The problems and challenges to water security cover the entire national territory, but the semi-arid region deserves special attention, as it has less than 5% of the country's water reserves, most of which are underground, with high salinity and unsuitable for consumption (BRAZIL, 2016). It is possible to affirm that the advances were considerable for overcoming the water deficit and minimizing the impacts of the recurrent droughts reported since the 16th century, which in the past have generated human losses, intense migration and a strong impact on the region's development.

In the last decades, a set of public policies enabled the permanence and coexistence of populations with the semi-arid climate, mainly by expanding water supply with public infrastructure of large and medium-sized dams and implementing the plate cisterns program for diffuse rural populations. However, some emergency actions such as fueling by water trucks, food delivery and emergency aid are still needed today (LIMA; MAGALHÃES, 2019).

Water security is conditioned by the supply and demand of water, being totally dependent on climate dynamics and the management of available resources. It is in this sense that the challenges to water security are evident and demonstrate the susceptibility of water systems to climatic extremes of drought in the Brazilian semi-arid region, demonstrating the need for an increasingly robust management of water resources so that all people have access to water. sufficient potable water, at an affordable cost and that guarantees its production.

In the context of ongoing climate change, the old challenges gain new aggravating factors and managing water resources becomes increasingly complex in a scenario of profound uncertainties. Therefore, regulatory institutions need to understand climate variation modes and the supply and demand for water, so that they understand the hydrological and socioeconomic risks involved, being able to take more assertive initiatives against such problems. This will consequently facilitate incorporating climate change risks and defining mechanisms for adaptive governance of water resources and guarantee water security in the medium and long term (RAADGEVER et al., 2008).

Despite the advancement of science and knowledge promotion about climate and water, there are still many gaps which need to be overcome, given that past experiences are no longer sufficient to support water management thinking in the future in the context of climate change. It is also necessary to consider that water resources do not only require technical knowledge, but a dialogue between the natural and human sciences to meet an emerging demand, which is the governance of water resources (PUGA, 2018).

Even so, water governance is not a simple issue, especially in regions where there is low water availability and high demand, as is the case of the Brazilian semi-arid region, which becomes even more complex with new risks being imposed by climate change. Thus, new knowledge and new approaches are needed to respond and adapt to climate change. Adaptation has generally become an emergency response to the impacts of ongoing climate change, making it necessary to reduce the vulnerabilities of populations, sectors and ecosystems.

From the perspective of climate change, adaptation is related to the process of adjusting natural and human systems to climate behavior in the present and in the future, constituting an anticipatory and

preventive measure to respond to risks (IPCC, 2014). This is an ongoing process in which knowledge, experience and institutional structures come together to seek options and determine actions, therefore involving a high degree of complexity in which decision-making must be done across different scales and by different actors (ADGER; VINCENT, 2005).

In this sense, there is a growing body of work on the needs and requirements for adaptive governance (CLARVIS; ALLAN; HANNAH, 2014), which is a conceptual focus of this article. Due to the great inertia of States to implement effective actions to respond to the risks of climate change, these efforts seek innovative forms of governance to articulate proposals for their impacts in different sectors. Thus, it is necessary to recognize that scientific uncertainties about the future should not inhibit adaptation (ADGER; VICENT, 2005). The State needs to understand that its choices in the context of climate change must be made in the midst of uncertainties (DOVERS, 2009).

Therefore, adaptive governance emerges as a planning strategy in different impact scenarios, but before which it is necessary to establish an overview of adaptive alternatives (DESSAI et al., 2004). It is also a flexible strategy and allows for interference in public policies or adaptation actions throughout the implementation process, including changing them when convenient (LINDOSO, 2015). Therefore, good adaptive governance assumes that adaptation involves coordinated adjustments at different spatial scales, decision-making levels, and time horizons (ADGER, 2006).

For Dietz, Ostrom and Stern (2003) and Folke et al. (2005), adaptive governance involves a dynamic process which considers social learning, as well as the contribution of different actors to creating and implementing policies and strategies for resource management. For example, Dietz, Ostrom and Stern (2003) point out that the following aspects should be considered for good adaptive governance: providing adequate information; participatory institutions; conflict management; compliance with rules; availability of physical, social, institutional and technological infrastructure; and institutional flexibility, associated with the ability to learn and rethink rules and norms according to environmental changes, as will be presented in the analysis and discussion of the results further on.

ADAPTIVE GOVERNANCE OF WATER RESOURCES IN THE CONTEXT OF CLIMATE CHANGE IN RN

The state of RN is part of the Northeast East Atlantic hydrographic region, which has the lowest water availability in the country (ANA, 2017). Thus, much water infrastructure was installed to capture water during the short rainy season, store and distribute it throughout the state in order to overcome this deficit. However, public supply still goes through moments of weakness in major drought periods, with supply capacity being exceeded and municipalities experiencing water collapses and restrictions on access to water for consumption, especially for their family's productive activities.

The volume of the reservoirs during the last drought period (between 2012-2017) was at a very low level and, despite the years 2018 and 2019 considered rainy, the reservoirs did not fully recover their capacities, and some municipalities continued without a normalized supply. Rainfall was also on average in 2020, so many reservoirs recovered their capacity.

The measure adopted in periods when municipalities face water collapse is usually to declare an emergency due to drought, so that they can obtain resources and more attention for State actions. One of the strategies adopted to provide water to collapsing municipalities and mitigate drought effects is to use water trucks to transport water. In 2014, two years after the onset of the drought, 159 municipalities declared an emergency. In 2019, even with average rainfall normalizing, there were still 133 municipalities in an emergency situation recognized by the national Civil Defense, with the validity term of this condition lasting until March 2020.

All of these problems demonstrate how Rio Grande do Norte requires more prepared management of water resources in view of the complexity and challenges to meet the needs of human supply and thus ensure the quality of life and the socioeconomic development of the region. A study carried out by Trolei and Silva (2018) indicates that most municipalities, especially in the semi-arid territory, are highly critical to water collapse, and demand more efficient water infrastructure and integrated management of water resources. It was declared at the World Water Forum in 2020 that the water crisis is much more a management problem than a limitation of the resource itself.

The responsible body within the scope of water resources management in RN is SEMARH, created by Complementary Law No. 163, of February 25, 1996, with the attribute to plan, coordinate and execute state public actions which contemplate the supply and the management of water resources and the environment in the state.

SEMARH conducts the State Water Resources Policy, State Law No. 6,908/1996, and the Integrated Water Resources Management System (SIGERH), which is the main regulatory framework for water management. The instruments provided for in the law are: the State Water Resources Plan, the State Water Resources Fund, the information system, granting the right of use and licensing water works, classifying water bodies and charging for the use of water.

As stated by Tundisi (2013), it was observed that there has been an advance in the legal and institutional frameworks at the national scale in recent decades, making water management more efficient; but it is not yet at the ideal level of governance, meaning at the organizational, constitutional and operational level to guarantee water security. In this context, a new idea of governance emerges from the need for institutions and policies to adopt new approaches to deal with new problems and changing contexts, which is conventionally called adaptive governance. It is along these lines that this analysis is based on the requirements of adaptive governance, as according to the study by Dietz, Ostrom and Stern (2003) presented in Table 1.

One of the roles of science in adapting to climate change is in the generation of knowledge and information, so systematized, accessible and reliable knowledge and information are important requirements, because even in the face of complexity and uncertainties, one must seek to identify the risks to the systems and understand the vulnerabilities of the affected systems, so that it is possible to define adaptation strategies (LEBEL et al., 2006; MARTINS; FERREIRA, 2012; DI GIULIO et al., 2019).

Within the scope of RN management, it was possible to identify that there are deficiencies in monitoring, in the systematization of data in short-term and medium-term forecasts, as well as in identifying and spatializing the potential impacts of climate change in the territory. The knowledge and information available meet short-term needs to some extent, but do not provide an overview that makes it possible to know, with certainty, whether there will be enough water to meet future demands or in the event of climatic extremes.

Another important aspect of adaptive governance is risk and conflict management. In this sense, it is pointed out that considering that climate change increases the risks of natural disasters, it is urgent to have articulation for anticipatory management in order to avoid impacts and conflicts over the various uses of water. Risk management has a strong relationship with knowledge provision, weather and climate forecasts, identification of vulnerable systems and disaster prevention measures.

In this sense, it can be said that risk management in the state of RN is more prepared for the risks of droughts than of intense rains due to greater learning from the recurrence of droughts. However, there is no anticipation of risks and actions occurring, above all, in an emergency after a disaster.

Conflict management has taken on new configurations based on participatory instances created in the state, with evidence for the river basin committees; but also for state councils such as the Civil Defense, where decisions are made to ensure water in quantity and quality for all people and activities. Despite advances due to low water availability, there are conflicts in some regions between small and large producers, which can be accentuated in climatic scenarios that threaten the capacity of water sources and even more water availability.

Another variable is compliance with rules, which is absolutely necessary to guarantee equal access to water, as well as to avoid conflicts and a lack of resource management. RN has an advanced and modern legal framework, but compliance is still challenging, both on the part of management for implementing the instruments, and for inspecting users who violate the rules of use.

Requirement	Variables	Water management in RN
Systematized, accessible and reliable information and knowledge	Data on environmental, social and economic aspects	- Data are mainly available to support the creation of plans, but they are not systematized. - Registration of users, grants and licenses still have low reach. - Communication and information on official websites, *IGARN* Itinerant, events, radio and TV communication and basin committees.
	Quantitative and qualitative monitoring of water	- The evolution of rainfall, levels of the main reservoirs and river flows are monitored.
	Medium and long-term climate and demand projections	- There are no long-term climate projections - The State Water Resources plan forecasts demand, but the new plan has not yet been completed.
Risk/conflict management	Prevention and response to disasters	- Emergency water security plan for 2017, with structuring and non-structuring actions to respond to prolonged periods of drought. - *IGARN* monitors 120 dams in the state to identify weaknesses. - State Council of Civil Defense of the State for decision-making on risk management. - Recovery program for dams and weirs with structures in a critical situation. - *CEMADEN* monitors and issues early warnings of the likely occurrence of natural disasters for the State Civil Defense agencies.
	Mechanisms for social participation and negotiated allocation	- The state *GRH* council and 3 river basin committees have been instituted and acted. - Discussion forums between the committees. - Update of the state water resources plan with the participation of society. - Water is allocated within the scope of the committees and *ANA*.
Compliance with rules	Well-defined usage rules	- Water bodies have not yet been classified into use class.
	Inspection and sanctions for non-compliance	- The inspection of uses and grants and licenses are fragile, mainly due to the lack of resources and technical personnel.
Presence of physical, technological and institutional infrastructure	Efficiency in the different uses of water, promoting increased capture, use, storage and reduction of rainwater losses	- There is no efficient monitoring of abstracted water losses. But a rate of 49.8% of losses in the distribution of captured water is estimated, which may be due to leaks or unauthorized withdrawal.
	Efficient institutional arrangement, well-structured bodies, financial and human capital, implementation of water resources management instruments	- Specific bodies to act in water resource and environmental management. - Water resources policy established, but with weaknesses in the implementation of instruments. - Lack of human capital and employee turnover. - There are not enough resources, mainly because there is no charge for the use of water and licensing of hydraulic works. - The transfer of federal resources occurs when the state declares an emergency situation, mainly due to drought. - Federal financial support for executing administrative activities, equipping the organ, hiring personnel, etc. - Financial support from the federal government for executing works.
	Providing water infrastructure that guarantees access to water in sufficient quantity and quality for its uses	- Provision of infrastructure (weirs, dams, wells, water mains) for collection and distribution in the territory. - Alternative diffuse systems (cisterns, underground dams, desalination plants). - Need for supply system maintenance.
Learning and Adaptation	Risk perception	- The actors interviewed perceive the risks in the sense of climatic events worsening with an occurrence history in the state.
	Policies and plans on climate change	- There is a commission working to elaborate State Policy to combat the effects of Climate Change since March 2020, but for which there was no specific legislation until then.
	Incorporation of climate change risks in management	- Risks are not yet a factor that guides decisions in water resource management, as they have not been internalized in the public agenda as an important agenda. - The *CBHPA* has been putting discussions on climate change on the agenda.

Table 1 – Relationship between adaptive governance and water resource management in RN. Source: adaptation of the authors from Dietz, Ostrom and Stern (2003).

Of the instruments provided for in water resources legislation, whether at the federal or state scale, charging for the use of water and classifying water bodies into usage class has not yet been implemented in the state of RN. Furthermore, a water resources information system must be put into practice. The inspection of uses and grants and licenses still need more attention due to the intense drilling of wells and illegal capture.

Adaptive governance is only possible if physical, technological and institutional infrastructure which is capable of dealing with the complexity of water resource management is in place. Infrastructure

and technologies must provide increased efficiency in the different uses of water, promoting increased capture, use, storage and reduced rainwater losses. In this sense, there is a wide variety of technologies, techniques, methodologies and practices that already exist which can be replicated, as long as they are simple, sustainable and adapted to the context in which they will be implemented.

RN has a very wide collection, storage and distribution network for the context under analysis; but even so, it is still not enough to guarantee water security in periods with severe droughts, as experienced in recent years. For example, in the context of developing water infrastructure to expand the supply and distribution of water in the state, it is extremely important to highlight large projects which are in the planning and implementation phase, such as the transposition of the waters of the São Francisco River and the Seridó Project.

These projects aim to create joint solutions, in which the construction of the Oiticica dam in the Seridó region will receive water from the São Francisco River through the Piancó-Piranhas-Açu River. A series of facilities will also be built such as channels and water mains to distribute water to the municipalities. The gaps at the institutional level involve the lack of financial resources and human capital to implement the instituted water resources management policy.

Finally, the ability to learn and adapt represents the main requirement to enable adaptive governance and is intrinsically related to the other requirements for good adaptive governance according to Dietz, Ostrom and Stern (2003). First, there is the perception of risk, which is a condition for incorporating the risks of climate change into political-governmental agendas, more specifically into water resource management (KERN; ALBER, 2008). There is no adaptation to a certain phenomenon or event if they are not perceived as a risk (ADGER; VICENT, 2005).

Dias and Pessoa (2020) concluded that institutional and social actors with influence in decision-making about water resources in RN perceive the risks imposed by climate change on water resources, indicating the possibility of aggravating existing threats observed by them, as well as that the impacts of climate change on water resources expose many other systems to climate risks. However, according to the authors, these risks are not yet a factor which guides decisions on water resource management, as they have not been internalized in the public agenda as an important agenda.

Addressing adaptation strategies requires climate change to be a policy priority across all sectors in an integrated manner, and to build skills to identify, recognize, assess, anticipate and respond to climate risks. The RN government's official websites reported that the first steps were taken by creating a commission to discuss the creation of a State Policy on Climate Change. The institution of this policy will mark the entry of climate change in the political-governmental agenda of the state.

In view of the above, a learning and adaptation process is required for good adaptive governance, meaning of evaluation and continuous improvement (PAGAN; CRASE, 2004). This process involves: (1) an integrated assessment of current problems and the search for solutions in a participatory manner among the interested sectors and actors; (2) goal setting and policy formulation; and (3) implementation to test hypotheses through systematic monitoring and evaluation of policy outcomes, including changes (RAADGEVER et al., 2008).

CONCLUSION

In the context of water resource management focused on the semi-arid region of RN, it can be said that mechanisms were created over time to adapt to the semi-arid climate, which is conventionally called "coexistence with the semi-arid". Despite this, it is still challenging to live with the natural variability and extremes of the semi-arid climate. Thus, a first step towards adaptation would be to face current problems more robustly in order to increase management's ability to deal with possible increases in extremes as a result of climate change (HALLEGATTE, 2009; BRASIL, 2016). However, adaptation to climate change is another issue that involves new risks, greater complexity and uncertainties (BURTON, 2010).

In this sense, this analysis made it possible to reflect on the numerous challenges that still need to be overcome to ensure water security in a context of climate change and threats to the semi-arid region. Within the scope of RN State, it was possible to observe that despite advances in management, it does not meet the important requirements of good adaptive governance. An important aspect to consider in

this context is the need for integration between sectoral policies (federal, state and municipal) of territorial planning, urban development, waste management, health, environment, infrastructure, science and technology, among others which are evidently fundamental to ensuring water security and climate adaptation.

Therefore, it is stated that the objective proposed in the introduction was achieved by this article, insofar as it is possible to carry out an analysis of the water resource management in RN State in order to understand whether it meets the variables of adaptive governance, as established in the scientific literature. Empirically, it was found that water resource management in RN still does not meet the requirements of a robust adaptive governance capable of operating responses to climatic events, as well as guaranteeing the water security of the state.

This research is of paramount academic importance, as it contributes to scientific debate (especially nationally) on climate adaptive governance for water resources by investigating the case of the semi-arid region of RN. The article is also a warning for water resource management in RN by assuming that this territory does not incorporate climate adaptive governance in its management. It is further pointed out that this study is socially important, as the deficiencies in the face of this adaptive governance in RN have a direct impact on populations, especially those with low purchasing power.

ACKNOWLEDGEMENT

This work received financial support from CAPES from the author (a). It also received financial support from the Project “Gestão de riscos, vulnerabilidades socioambientais, sustentabilidade e capacidade adaptativa climática em cidades do semiárido do Nordeste” (Process no. 441883/2020-6/ CNPq/MCTI) under the coordination of the author(a):b, and of which the other authors are student researchers (a and c).

REFERENCES

ADGER, W. N.; VINCENT, K. Uncertainty in adaptive capacity. C. R. Geoscience, v. 337, p.399-410, 2005.

ADGER, W. N. Vulnerability. Global Environmental Change, v.16, n.3, p.268-281, 2006.

ADGER, W. N. et al. Assessment of adaptation practices, options, constraints andcapacity. In: PARRY, M. et al. (Ed.) Climate Change 2007: impacts, adaptation andvulnerability. Contribution of Working Group II to the Fourth Assessment Report of theIntergovernmental Panel on Climate Change. Cambridge, UK: Cambridge UniversityPress, p.717-43, 2007.

ADGER, W. Neil; KELLY, P. Mick. Social vulnerability to climate change and the architecture of entitlements. Mitigation and adaptation strategies for global change, v. 4, n. 3, p. 253-266, 1999.

AMBRIZZI, T. et al. Cenários regionalizados de clima no Brasil para o Século XXI: Projeções de clima usando três modelos regionais. Relatório 3, Ministério do Meio Ambiente - MMA, Brasília, 2007.

ANA – Agência Nacional de Águas. Região Hidrográfica Atlântico Nordeste Oriental. Brasília: ANA, 2017. Disponível em: . Acesso em: 27 abr. 2019.

ANA – Agência Nacional de Águas. Plano Nacional de Segurança Hídrica. Brasília: ANA, 2019. Disponível em: . Acesso em: 30 mar. 2021.

BABBIE, E. Métodos de Pesquisas de Survey. 1. ed. Belo Horizonte: UFMG, 2001.

BRASIL – Ministério do Meio Ambiente. Plano Nacional de Adaptação à Mudança do Clima. Brasília: MMA, 2016. Disponível em: . Acesso em: 30 jul. 2021.

BURTON, I. Addressing Strategic and Integration Challenges of Climate Change Adaptation. In: STERN, P. C.; KASPERSON, R.E. (Eds.) Facilitating Climate Change Responses: A Report of Two Workshops on Insights from the social and Behavioral Sciences. Washington: The NationalAcademy

Press. 2010.

CLARVIS, M. H.; ALLAN, A.; HANNAH, D. M. Water, resilience and the law: from general concepts and governance design principles to actionable mechanisms. Environmental Science & Policy, v. 43, p. 98-110, 2014.

DESSAI, S. et al. Defining and experiencing dangerous climate change. Climatic change, v. 64, n. 1, p. 11-25, 2004.

DIAS, E. M. S.; PESSOA, Z. S. Percepções sobre os riscos das mudanças climáticas no contexto da região semiárida do Rio Grande do Norte, Brasil. Desenvolvimento e Meio Ambiente, v. 55, 2020.

DI GIULIO, G. M. et al. Bridging the gap between will and action on climate change adaptation in large cities in Brazil. Regional Environmental Change, v. 19, n. 8, p. 2491-2502, 2019.

DIETZ, T.; OSTROM, E.; STERN, P. Struggle to Govern the Commons. Science, v. 302, n. 5652, p. 1907-1912, 2003.

DOVERS, S. Normalizing adaptation. Global Environmental Change, v. 19, n. 1, p. 4–6, 2009.

EAKIN, H.C.; LEMOS, M. C., NELSON, D. R. Differentiating capacities as a means to sustainable climate change adaptation. Global Environmental Change, v. 27, p. 1-8, 2014.

FOLKE, C. et al. Adaptive Governance of Social-Ecological Systems. Annual Review of Environment and Resources, v. 30, n. 1, p. 441–473, 2005.

FRANÇA, J. M. F.; MORENO, J. C. Uma reflexão sobre os impactos causados pela seca no Rio Grande do Norte de 2012 a 2016. Parcerias Estratégicas, v. 22, n. 44, p. 213-232, 2017.

FRANCO, M. L. P. B. Análise de conteúdo. Brasília: Plano Editora, 2003.

HALLEGATTE, S. Strategies to adapt to an uncertain climate change. Global Environmental Change, v. 19, n. 2, p. 240-247, 2009

IPCC – Painel Intergovernamental sobre Mudanças Climáticas. ALTERAÇÕES CLIMÁTICAS 2014: Impactos, Adaptação e Vulnerabilidade – Resumo para Decisores. Genebra: IPCC, 2014. Disponível em: . Acesso em: 28 de abr. de 2020.

KERN, K.; ALBER, G. Governing climate change in cities: modes of urban climate governance in multi-level systems. In: The international conference on Competitive Cities and Climate Change, Milan, Italy, 9-10 October, 2009. 2009. p. 171-196.

KNUTTI, R. et al. Challenges in combining projections from multiple climate models. Journal of Climate, v. 23, n. 10, p. 2739-2758, 2010.

LEBEL, L. et al. Governance and the capacity to manage resilience in regional social-ecological systems. Ecology and Society, v. 11, n. 1, 2006.

LIMA, J. R.; MAGALHÃES, A. R. Secas no Nordeste: registros históricos das catástrofes econômicas e humanas do século 16 ao século 21. Parcerias Estratégicas, v. 23, n. 46, p. 191-212, 2019.

LINDOSO, D. P. Adaptação à mudança climática: ciência, política e desenvolvimento sustentável. ClimaCom Cultura Científica, v. 2, p. 1-21, 2015.

MARENGO, J. A. et al. Características climáticas da seca de 2010 a 2016 na região semiárida do nordeste do Brasil. Anais da Academia Brasileira de Ciências, v. 90, n. 2, p. 1678-2690, 2017.

MARENGO, J. A. Vulnerabilidade, impactos e adaptação à mudança do clima no semiárido do Brasil. Parcerias Estratégicas. Brasília, v.13, n. 27, p.149-176, 2008.

MARENGO, J. A.; CUNHA, A. P.; ALVES, L. M. A seca de 2012-15 no semiárido do Nordeste do Brasil no contexto histórico. Climanálise, v. 3, n. 1, p. 1-6, 2016.

MARTINS, R. D'A.; FERREIRA, L. da C. Vulnerabilidade, adaptação e risco no contexto das mudanças climáticas. Mercator (Fortaleza), v. 11, n. 26, p. 237-251, 2012.

MCBEAN, G.; RODGERS, C. Climate Hazards and Disasters: the need for capacity building. Wiley Interdisciplinary Reviews, v. 1, n. 6, p. 871-884, 2009.

MINAYO, Maria Cecilia de S.; SANCHES, Odécio. Quantitativo-qualitativo: oposição ou complementaridade?. Cadernos de saúde pública, v. 9, p. 237-248, 1993.

NOBRE, C. A.; REID, J.; VEIGA, A. P. S. Fundamentos científicos das mudanças climáticas. São José dos Campos: Rede Clima/INPE, 2012. Disponível em: . Acesso em: 02 ago. 2021.

PAGAN, P.; CRASE, L. Does adaptive management deliver in the Australian water sector. In: Prepared for the 48th Annual Conference of the Australian Agricultural and Resource Economics Society, Melbourne, Victoria. 2004. p. 11-13.

PBMC – Painel Brasileiro de Mudanças Climáticas. Base Científica das Mudanças Climáticas. Contribuição do Grupo de Trabalho 1 do Painel Brasileiro de Mudanças Climáticas ao Primeiro Relatório de Avaliação Nacional sobre Mudanças Climáticas. Organização de T. Ambrizzi&M. Araujo. Rio de Janeiro, Coppe/Universidade Federal do Rio de Janeiro, 2013.

PUGA, B. P. Governança dos recursos hídricos e eventos climáticos extremos: a crise hídrica de São Paulo. Tese (Doutorado em Desenvolvimento Econômico) – Universidade Estadual de Campinas, Instituto de Economia, Campinas, 2018.

RAADGEVER, G. Tom et al. Assessing management regimes in transboundary river basins: do they support adaptive management?. Ecology and Society, v. 13, n. 1, 2008.

SALES, M. C. L. Evolução dos estudos de desertificação no Nordeste brasileiro. Revista GEOUSP, Espaço e Tempo, São Paulo, n. 11, p. 115-126, 2002.

SANTOS, D. N. dos et al. Estudo de alguns cenários climáticos para o Nordeste do Brasil. Revista Brasileira de Engenharia Agrícola e Ambiental, v. 14, p. 492-500, 2010.

TROLEI, A. L.; SILVA, B. L. da. Os recursos hídricos do Rio Grande do Norte: uma análise da vulnerabilidade territorial ao colapso no abastecimento de água. Confins – Revista franco-brasilera de geografia, n. 34, 2018.

TUNDISI, J. G. Governança da água. Revista da Universidade Federal de Minas Gerais, v. 20, n. 2, p. 222-235, 2013.

VEYRET, I. Os riscos: o homem como agressor e vítima do meio ambiente. 2. ed. São Paulo: Contexto. 315p., 2013.

VIEIRA, R. M. S. P. et al. Identifying areas susceptible to desertification in the Brazilian northeast. Solid Earth, v. 6, n. 1, p. 347-360, 2015.

WISE, R. M. et al. Reconceptualising adaptation to climate change as part of pathways of change and response. Global Environmental Change, v.28, p.325-36, 2014.