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Development Directions of Water Management by Comparing Rio Grande do Norte to Hungary

Abstract

International cooperation facilitates the development of water management. In many cases, development does not necessarily require the invention of new things, but the exploration and implementation of good practices that have already proven themselves in other parts of the world. Knowledge sharing improves theory and helps to find appropriate practical solutions. From time to time, it may be useful to examine the state of development of water management in comparison with other countries. Climate change and demography turn attention to water management and collaboration. The authors of this article examine and compare the water management of Hungary and Rio Grande do Norte. Both places face similar challenges in many aspects. The main objective of this article is to recommend future development directions in terms of water management. Research results might stimulate further common cooperation between the countries and work on international projects. The authors examined and compared the climatic and hydrological conditions, organizational structure and the challenges, water management needs to face.

Keywords: water management, flooding, water scarcity, development, climate change

Introduction

Water knows no boundaries. We believe that international cooperation on both institutional and individual base might be an essential tool to facilitate the development of water management. Common work of experts and scientists might evolve discussion and help to identify practical solutions to the given challenges. We, as the authors, have different background and knowledge in terms of

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Brazilian and Hungarian water management and we decided to research the development directions by comparison.

Brazil consists of 5 regions including the Northeast Region. Rio Grande do Norte (RN) is one of the states in the Northeast Region. Rio Grande do Norte means Great River of the North in English. Its area is 52,797 km² compared to the 93,030 km² area of Hungary. In this paper, we primarily focus on comparing RN to Hungary. Both Rio Grande do Norte and Hungary have a long history of water management. Despite the distance of locations, both parties face similar challenges in many aspects. At first sight, both Brazil and Hungary might seem to be water abundant countries in general but if we examine the situation in details, we might recognise the vulnerabilities in terms of climate change and the unequal distribution of water resources. We are committed to analyse the water management of RN and Hungary and identify similarities and development possibilities.

The main objective of this article is to analyse the water management of Hungary and Rio Grande do Norte by comparison and recommend development directions.

Joint research might lead to further discussions and fruitful collaborations in international projects. Our research results might facilitate the future development of Brazilian and Hungarian water management and even might inspire others to have new ideas.

Climate Patterns

Climate is a core factor of water management. We consider it important to overview briefly the climate situation of Hungary and Rio Grande do Norte to put our water management activities into context.

Situated in the Northeast of Brazil (NEB), the State of Rio Grande do Norte is influenced by two different climates, according to Köppens's classification (Beck et al., 2018). Tropical zone with dry summer (type AS) and low latitude with semiarid climate (type BSH). More than 90% of Rio Grande do Norte is in the semiarid zone (Silva, Spyrides & Lucio, 2012). Meanwhile, Hungary has a typical continental climate with hot dry summers and mildly cold winters. Large parts of the country are semi-arid or dry sub-humid, similarly to RN. According to the worldwide used aridity index, Hungary is identifiable as an 'affected country' under the terms of the United Nations Convention to Combat Desertification (URL1).

The mean annual rainfall on the eastern coast of RN is over 1000 mm, while in the south-western and north-western areas, it ranges from about 700 mm to 1000 mm (Alvares, Stape, Sentelhas, Gonçalves, Sparovek, 2014). In the central part, the rainfall is lower than 700 mm. The marked rainfall variability within the same

year in the Northeast Region is associated with alterations in sea surface temperature patterns over the tropical oceans. It affects the position and intensity of the Intertropical Convergence Zone over the Atlantic Ocean, as well as the temperature anomalies observed in the Pacific Ocean, which happen in years with La Niña and/or El Niño (URL2). Extreme weather events experienced in the RN are related to the variability of atmospheric circulation patterns (Vale, Spyrides, Andrade, Bezerra & Silva, 2020). The high solar radiation, associated with the variable rainfall regime contribute to the increase of evaporation rates, which mostly vary from about 1000 to 2000 mm per year, but in some cases can reach 3000 mm per year (URL2). In Hungary, the mean annual rainfall is about 500-750 mm. In the Great Plain area, which is significant in terms of agriculture, it is mostly lower than 600 mm (Lakatos & Bihary, 2011). Regarding precipitation, we must mention that the mean annual values blur the challenges. In Hungary, there is a significant seasonal difference. Extreme weather patterns cause challenges to water management concerning both water scarcity and flood. For example, in 2020, a new daily rainfall record was set by 178 mm/day at Station Vése, Hungary. But on the other hand, the Spring of 2020 was the 3rd driest spring in Hungary, on record from 1901 (URL3). Based on the statistics of the Hungarian Meteorological Service, we can state that the amount of rainfall is slightly decreasing.

Agriculture faces the biggest challenge during the subsequently dry and hot days. The chance of a moderate drought significantly increased in the last years (Földi, 2019). The average temperature in the Rio Grande do Norte is predominantly higher than 24 degrees Celsius (Alvares et al., 2014). Although in Hungary, the mean average temperature is just about 10-12 degrees Celsius, the summers are hot and dry. The hottest day was 30th August at 37.4 degrees Celsius at Station Mezőkovácsháza in 2020 (URL4).

RN's main biomes are the Caatinga (95%) and the Atlantic Forest (5%). The elevations range from 580 to 830 m, with a predominance of shallow rocky soils with low water retention capacity (Silva, Spyrides & Lucio, 2012). In Hungary, we can find different types of soils, but in terms of drought, the most problematic is the sandy soil with low water retention capacity for example in the Nyírség area.

According to the report of the Intergovernmental Panel on Climate Change the North-eastern region is threatened by transformation of semi-arid conditions into a semi-desert in the next 60 years (URL5). If this happens, the RN state will be greatly affected, as it has about 90% of its territory with semi-arid climate characteristics (Silva, Spyrides & Lucio, 2012).

Water Management of RN state and Hungary face similar challenges in the mitigation of climate change-driven extreme events. We need to find solutions to adapt to climate change and handle the environmental and socio-economic impacts.

Hydrology and administrative structure

Hungary's whole area is located in the Danube River Basin, while RN's area is divided among several different river basins. We compared the directions of the main rivers' flow. The Danube collects the rivers of the Carpathian Basin. It flows east until Verőce and then turns south. The River Apodi and the Piranhas-Açu, as the main rivers of RN, flow north, northeast, while the other smaller rivers of RN flow east. Piranhas-Açu is the main river of RN and it is an interstate river. The hydrographic basin of the Piranhas - Açu River covers a territory of 42,900 km² distributed between the States of Paraíba and Rio Grande do Norte, where approximately 1,552,000 inhabitants live (URL6). The territory of it is similar to the area of River Dráva, a tributary of Danube. The international river basin area of Dráva is about 40,000 km². The international Danube River Basin spans across more than 800,000 km² and it extends into the territory of 19 countries and is considered the most international river in the world, where approximately 83 million inhabitants live (URL7).

Figure 1: *Hydrographic Basins of Rio Grande do Norte*
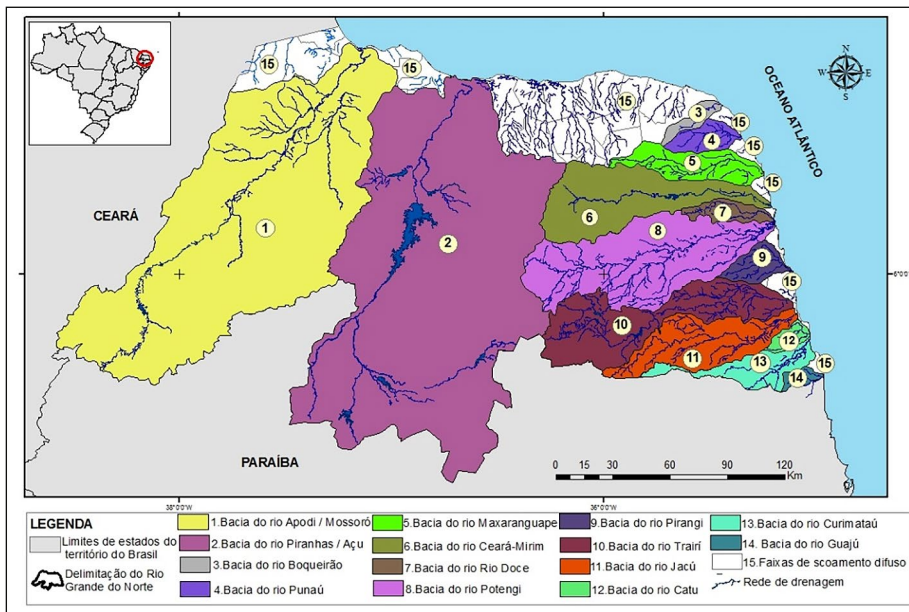
Note: Trolei & Silva (2018).

As shown above in figure 2, the Apodi / Mossoró and the Piranhas-Açu are the main river basins. The other basins of lesser territorial extension of drained area flow into the east coast of the state, such as the basins of the Boqueirão, Punau, Maxaranguape, Ceará-Mirim, Doce, Potengi, Pirangi, Tairi, Jacu, Catu, Curimatau and River Guajú. Among these catchments, the main river basin of the capital of RN, called Potengi, runs through several territories before flowing into the city of Natal.

The comprehensive legislation on water management was reinforced almost at the same time in Brazil and in Hungary. In Hungary, the Law XVII of 1995 on water management was an important milestone in this regard. Similarly, in Brazil, Law no. 9,433 of 1997 instituted the National Water Resources Policy (PNRH), also known as the Water Law. Concomitant with the institution of the PNRH by Law no. 9,433, the National Water Resources Management System (SNGRH) was created, structured to promote the management of water resources in an integrated, participatory, and decentralized manner. It is composed of six entities: National Water Resources Council, National Water Agency, Water Resources Councils of the States and the Federal District, Hydrographic Basin Committees, and Water Agencies (Farias, de Feritas Amorim & Saraiva Junior, 2018). Hungary is a member state of the European Union and therefore the implementation of the common water policy of the EU is fundamental. International relations are important, therefore Hungary participates in the International Commission for the Protection of the Danube River (ICPDR) and many other organizations and working groups. Hungary regularly reviews its River Basin Management Plan in accordance with WFD and framed its own National Water Strategy (Jenő Kvassay Plan), too.

In Hungary, there are 12 regional water directorates that cover the whole area of Hungary. They are organised on a water basin level but also the administrative boundaries are considered. Both in Rio Grande do Norte and in Hungary, water management is organised on a river basin level. Regional directorates of Hungary are coordinated by the General Directorate of Water Management. In case of emergency, for example, if there are more water directorates affected by severe water pollution or a significant flood, there is a structural reorganisation and a so-called National Technical Coordinating Committee manages the situation. Water management issues primarily belong to the Ministry of Interior but other ministries are also involved for example the Ministry of Agriculture or the Ministry for Innovation and Technology regarding EU funded projects or the Ministry of Foreign Affairs and Trade. Figure 2 shows the 12 water directorates of Hungary.

Figure 2: *Water Directorates of Hungary*
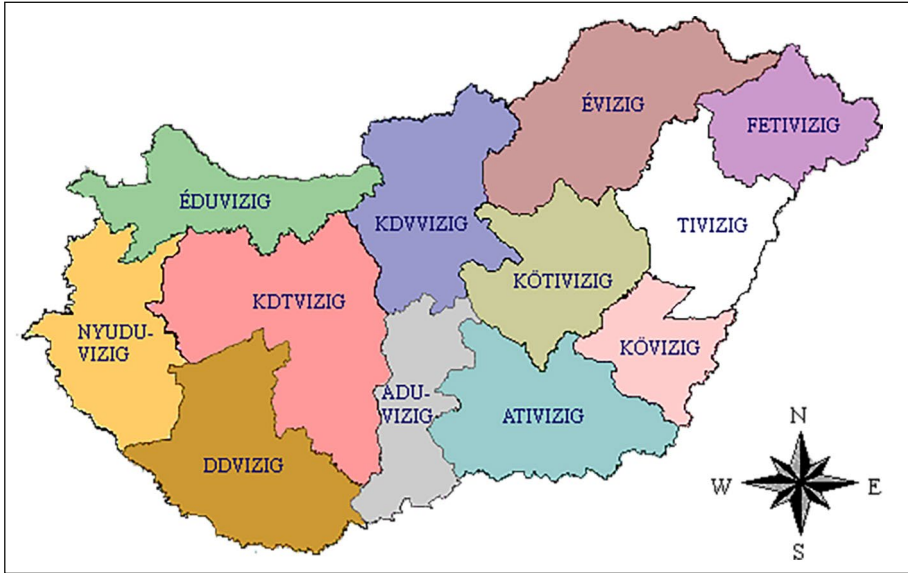
The water management of Rio Grande do Norte is divided into state entities of water resources management. The State Water Resources Policy and State Water Resources Management System aim to establish the institutional procedure under which the state water policy should be implemented and provide systematic management of the water resources considering the quality and quantity (URL8). There is a State Council of Water Resources (CERH) which is responsible for analysing proposals, conflict arbitration, and articulating promotion of the water resources in the state. Concerning funding the State Water Resources Fund (Funerh) is responsible. There is a particular institution responsible for the planning named State Water Resources Plan. The water resources management body is the Water Management Institute of the State of Rio Grande do Norte. It is responsible for granting the right to use water resources, licenses for hydraulic works and dam safety. Furthermore, the Secretariat for the Environment and Water Resources is also involved in water resources management. It has 3 committees installed, in addition to the Water Basin Committee of Piancó-Piranhas-Açu, which is interstate but also recognized by the State Council of Water Resources and an integral part of the State Water Resources Management System. The structure is controlled by the State Secretaries and Entities, responsible for the management of the basins and water resources of the states.

Figure 3: *State Water Resources Management System of Rio Grande do Norte*
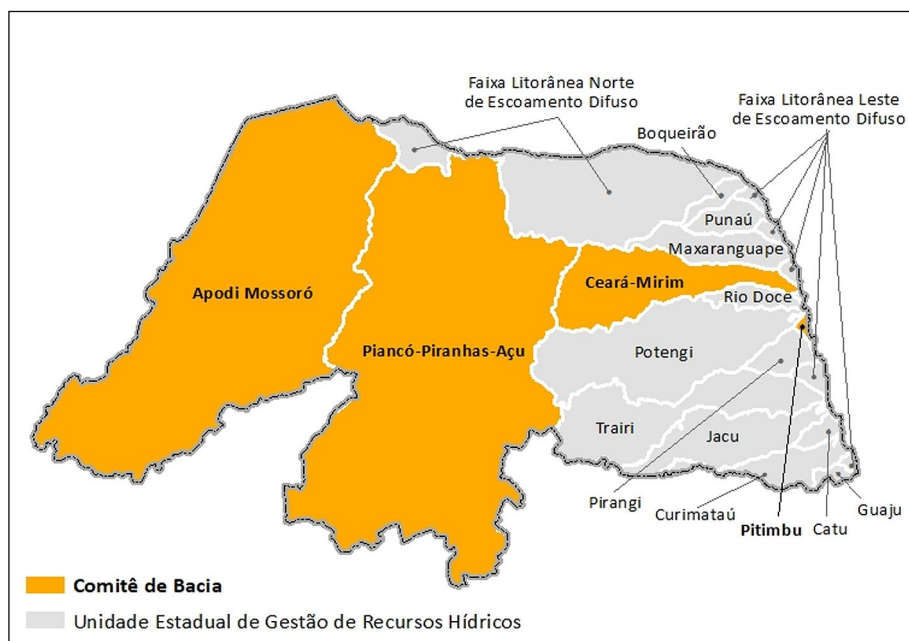
Note: URL8.

Both Hungary and Rio Grande do Norte have detailed water legislation from the '90s to ensure the safety of the society, regulate water utilization, preserve and improve the state of the water. We stated that the water-related responsibilities are shared among different entities and the water directorates are organised on a catchment base in both cases. Public water management organizations have to face multifaceted, complex challenges.

Challenges in focus

Ensuring safe water and meeting different types of water demands are remarkable challenges for water management. Climate change will probably intensify extreme weather events. Floods and droughts threaten both RN and Hungary.

In this article, regarding flooding, we primarily concentrated on flood management in terms of rivers and did not examine the flood risk from sea-level rise. Extreme rainfall events might occur more frequently in many regions of Europe (Coffel, Horton & de Sherbinin, 2018; Nerem et al., 2018). Increasing flood risk

is forecasted in the European Union due to extreme weather events and inappropriate land use (Alfieri, Dottori, Betts, Salamon & Feyen, 2018). Hungary is among the countries most exposed to flooding in the EU and has the highest relative share of people living in such areas, about 1.8 million people, which means 18% of the population. (Tóth, 2019). 23% of Hungary is considered to be a flood-prone area that means 21 248 km². (Szlávik, 2013). Floods also have a negative environmental and socioeconomic impact on Rio Grande do Norte. Population share at river flood risk is 10.27% and 2.87% at flash flood risk in Rio Grande do Norte (Debortoli, Camarinha, Marengo & Rodrigues, 2017).

RN and Hungary are also among the countries threatened by flash floods. Due to climate change, presumably, flash floods may become more severe. In Brazil, intense rainfall events that triggered flash floods and landslides were responsible for 74% of the deaths related to natural disasters in the 1991–2010 period (Bresch, 2011). Both RN and Hungary apply structural and non-structural measures to prevent or mitigate flood damages. In the EU, severe floods reinforced the need for coordinated action, therefore the member states work on the implementation of Directive 2007/60/EC on the assessment and management of flood risks, commonly known as Flood Directive (FD).

Both Brazil and Hungary are considered water abundant countries in general. According to the Brazilian National Water Agency, Brazil is considered one of the countries with the highest availability of freshwater in the world (URL9). Also, according to the Food and Agriculture Organization of the United Nations, Brazil has the highest average precipitation per year, and the uppermost amount of water from external and internal natural resources than any other country (URL10). Despite the abundance of water resources, the distribution of the resources is unequal and both places are threatened by droughts. Brazil has twelve percent of the world's total fresh water but it is extremely unevenly distributed. About 73 percent of the country's water is concentrated in the Amazon River Basin, while the semiarid Northeast, where the State of Rio Grande do Norte is located, has only 3 percent of the country's water resources, about 1,200 cubic meter per capita (URL11).The State of Rio Grande do Norte in Brazil is part of the 'Drought Polygon', a region recognized by legislation as subject to repeated crises of prolonging droughts and, consequently, subject to special measures by the public sector according to the Superintendence of Economic and Social Studies of Bahia. The high rates of evaporation occurring in the Brazilian Semi-Arid, both in water-free surfaces (dams) and in the soil, represent a significant loss in the water availability of a region for the growth and development of species, which, over the centuries, may result in the selection and adaptation of those most resistant to water shortages (URL2).

Severe droughts pose challenges also to Hungary therefore water management and the agriculture sector need to discuss and work together. Agriculture faces the biggest challenge during the vegetation period. Prolonged drought makes irrigation inevitable.

In Hungary, the size of the irrigated area fluctuates around 100 thousand hectares per year. The size of the irrigated area in 2019 was approximately 108,300 ha. The states of irrigational canals and structures have deteriorated in many cases as a result of underfunding. In Rio Grande do Norte the size of the irrigated area is 61,189 hectares according to the Agricultural Census of 2017 by the Brazilian Institute of Geography and Statistics (URL12).

RN applies Drought Monitoring (DM) to monitor and reduce the impacts of the drought. It is a regular and periodic monitoring of the drought situation in the Northeast of Brazil (Martins et al., 2015). The DM monitors monthly how the drought is progressing in all the states of the Northeast and produces a drought map. This map presents an actual state of the drought situation and does not forecast the drought phenomena. The DM gathers meteorological, hydrological, and agricultural data considering not only the amount of rain (rainfall index), but the reservoir levels, soil moisture and other information that are key to obtain the complete picture of the drought in each region. To mitigate drought effects, the Hungarian water management also launched a drought and water scarcity operational monitoring system in 2018 (Fiala et al., 2018). It consists of more than 100 monitoring stations. These stations can measure different parameters and based on the results calculate indicators. The system provides data not just on the current state of drought but it is able to forecast the situation for some days. It serves as an informative tool for farmers interested in irrigation. A similar drought monitoring system based on the concept of the Hungarian system might be useful tool in Rio Grande do Norte, too. So, in further research, the conditions of implementation can be examined.

In RN, historically, reservoir, dam and weir constructions were parts of the main strategy adopted by the government to deal with the drought problem (URL13). In total, the RN state has more than 40 reservoirs with a water storage capacity of 4,289,280,000 m³ (Trolei & Silva, 2018). Those reservoirs store and collect rainfall water and water from rivers to be used during scarce periods for drinking water supply, irrigation and agriculture, livestock animal supply, and fishing. According to the Secretariat of Environment and Water Resources of Rio Grande do Norte, 10 out 12 of the main reservoirs of the RN state are with their reservation levels lower than 15% of their capacity (Trolei & Silva, 2018). The low levels of precipitation and humidity and high temperatures contribute to the high volume of water loss. We found that there are five aquifers in RN:

Açu, Barreiras, Aluvião, Jandaíra and Cristalino. These aquifers are used mainly for human supply, but people also use these resources for irrigating crops. We think that - wherever it is possible - primarily the surface should be used for irrigation. To supply municipalities without reservoirs, an extensive system of water canals and pipes serve as an alternative to mitigate water scarcity. This system consists of more than 1600 km of water pipes and it supplies 106 municipalities and 1,200,000 consumers in the RN state (Trolei & Silva, 2018). There is a total of 17 water canals and pipe systems in the RN state, and it has the function of transporting water from one location to another, either through atmospheric pressure (slope of the land) or via pumping. Another alternative to complement the water supply and reduce the water crisis is the use of water tank trucks which supply 65 out of the 167 municipalities in the RN. The use of tank water trucks is an indicator of the severe water crisis and public calamity affecting 40% of the state population (Trolei & Silva, 2018).

The volume of daily water consumption is 331,744 m^3 in the RN state. It means about 100 litres/capita/day. In Hungary, the average daily water consumption per person is 90-100 litres (URL14). Comparing RN with Hungary we state that consumption is on a similar level. The connection level to the piped drinking water system in the case of municipalities is high in both cases. 166 out of 167 municipalities are supplied by piped water in RN (URL12). While all Hungarian municipalities are connected to the drinking water system and the total household connection is 95%.

In Natal, the capital city of RN, 417 analyses performed and 181 (43.41%) were not in compliance with the free residual chlorine standard (URL12). It might cause microbial proliferation in the water and thus reach the population with water-related diseases and contaminants, mainly acute diarrheal diseases. Therefore, we can affirm that 43% of the piped water does not meet the drinking water quality standards. Compared to Hungary it is a serious issue in RN.

In Hungary, 92%-97% of drinking water is from deep groundwater sources (URL15; URL16). Hungary's tap water can be safely consumed (URL17). According to the last water quality report, the adequacy level is over 95% for most water quality parameters (Bufa-Dőrr, Málnási, Oravecz, Vargha & Vecsey, 2021). Water network loss is also an important factor to be examined. In RN, the estimated value of water supply network losses is 46.3% (Farias et al., 2018). In Hungary, it is estimated at 48%. (Somos, 2011). Concerning the sewerage system, approximately 82% of the households were connected to the system in 2018, in Hungary (URL18). Against that in RN, the sewerage network system covers only 77 municipalities, roughly 46.1 % of the total number of municipalities (Farias et al., 2018).

According to the Piranhas-Açu Basin Committee and the Brazilian National Water Agency, the potential for the construction of dams and reservoirs is very close to the depletion point, beyond which the construction of new reservoirs, from the hydrological point of view, would cause diseconomies because of the intensification of evaporation losses. Also, according to them, optimization of the use of stored water is necessary, either through the introduction of more rational operating routines or through the technical improvement of the production processes. According to the Piranhas-Acu Basin Committee and the Brazilian National Water Agency, the occurrence of cyanobacterial blooms in the basin's reservoirs is compromising the water quality. A probable cause for the occurrence of the problem is the release of untreated sewage into the water bodies of the Basin (URL13). Considering that the water accumulated in the reservoirs is the main source of human and animal supply, it is necessary to prioritize investments by the government for environmental sanitation. Improving the water supply water resources management and effectiveness of the reservoirs and water canal and pipe system is vital to guarantee the water supply in the state. In this context, the state presents fragilities in its system and only the analysis and study of the individual characteristic of each municipality or municipalities in a similar situation will provide the solution for each case. The process of urbanization increased the impermeability of the soil and the amount of runoff water in the urbanized areas in the RN state (URL6). The infiltration area for the precipitation water decreased considerably over the years. Despite the fact that only 9% of the flood emergencies in Brazil are located in the Northeast, it is still a challenge in that region (URL6). To mitigate those effects structural and non-structural measures are implemented. There are case studies in the RN state to model precipitation and runoff water with the aim to control and prevent floods.

In summary, water management equally faces challenges in terms of flood and drought. Prolonged exposure to weather extremities burdens the economic competitiveness of Hungary and Rio Grande do Norte. We consider the implementation of an integrated water management approach necessary. We identified many points where improvement is needed in the future.

Conclusions

Water Management of Rio Grande do Norte and Hungary face similar challenges in the adaptation of climate change driven extremities. We deem that effective solutions can be found by international cooperation.

Both sides have their own complex water legislation and operate multifaceted water management organisation and system to ensure the safety of the society and equally preserve and improve their water resources.

Drought is one of the most remarkable pressuring factors. We suppose that the concept of the Hungarian drought monitoring system might be implementable in Rio Grande do Norte. In the future, further thematic research could be executed to examine the conditions of the implementation.

Improvement of piped water quality and the increase of sewerage system coverage probably will be a key challenge for Rio Grande do Norte in the following decade. Hungary has achieved significant results in the past in these areas, but the high network losses and the emerging pollutants show that further development is needed. The focus will inevitably turn to maintenance work and cost. Therefore, we think that the maintenance cost calculations should be a key part of future water supply and sewerage infrastructure development in Rio Grande do Norte.

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