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DIMENSIONS OF GLOBAL WATER SECURITY IN SEMIARID AREAS, A SYSTEMATIC REVIEW

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Abstract

Droughts and desertification processes are problems that make it difficult to guarantee global water security for rural communities in Brazil and around the world. Based on this, we aimed to identify which types of water technologies enable access to and prospecting for water in semiarid regions. To this end, the bibliometric method was used to understand the insertion of global water security in the last decade through research in the Scielo, Scopus and Web of Science databases. It was found that in the context of local water security, studies on rural communities are scarce; however, in these regions, Geographic Information Systems (GIS) are used to determine the allocation of water technologies to places with water scarcity problems. We conclude that studies on water security are promising when using different types of technologies for access to water in semiarid regions, such as cisterns and wells.

Keywords: Climate Change, Water Technologies, and Rural Communities.

Resumo / Résumé

DIMENSÕES DA SEGURANÇA HÍDRICA GLOBAL EM ÁREAS SEMIÁRIDAS, UMA REVISÃO SISTEMÁTICA

As secas e os processos de desertificação são problemas que dificultam dificulta a garantia da segurança hídrica global de comunidades rurais no Brasil e no mundo. A partir disto objetivamos identificar quais tipos de tecnologias hídricas possibilitam o acesso e a prospecção de água em regiões semiáridas. Para tanto, foi utilizado o método bibliométrico para compreender a inserção da segurança hídrica global na última década por meio de pesquisas nas bases de dados Scielo, Scopus e Web of Science. Constatou-se que no contexto da segurança hídrica local, os estudos sobre comunidades rurais são escassos, no entanto, nestas regiões são utilizados Sistemas de Informações Geográficas (SIG) para determinar a alocação de tecnologias hídricas para locais com problemas de escassez de água. Concluímos que os estudos sobre segurança hídrica são promissores ao utilizarem diferentes tipos de tecnologias para acesso à água em regiões semiáridas, como as cisternas e os poços.

Palavras-chave: Mudanças Climáticas; Tecnologias Hídricas; Comunidades Rurais.

DIMENSIONS DE LA SÉCURITÉ GLOBALE DE L'EAU DANS LES ZONES SEMI-ARIDES

Les processus de sécheresse et de désertification sont des problèmes qui rendent difficile la garantie de la sécurité mondiale de l'eau pour les communautés rurales du Brésil et du monde entier. À partir de là, nous visons à identifier quels types de technologies de l'eau permettent l'accès et la prospection de l'eau dans les régions semi-arides. À cette fin, la méthode bibliométrique a été utilisée pour comprendre l'insertion de la sécurité mondiale de l'eau au cours de la dernière décennie à travers des recherches dans les bases de données Scielo, Scopus et Web of Science. Il a été constaté que dans le contexte de la sécurité hydrique locale, les études sur les communautés rurales sont rares, mais dans ces régions, les systèmes d'information géographique (SIG) sont utilisés pour déterminer l'attribution des technologies de l'eau aux endroits confrontés à des problèmes de pénurie d'eau. Nous concluons que les études sur la sécurité de l'eau sont prometteuses lorsqu'elles utilisent différents types de technologies pour accéder à l'eau dans les régions semi-arides, comme les citernes et les puits.

Mots-clés: Changement Climatique, Technologies de L'eau et Communautés Rurales.

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INTRODUCTION

Semiarid regions cover approximately 40% of the continental surface of planet Earth (Huang et al., 2020). According to United Nations (UN) data, around 2.1 billion people live in these regions (Brazil, 2024). These areas face difficulty accessing water, aggravated by natural factors such as droughts and desertification processes, which are intensified by global climate change (Scott, Shrestha, and Lutz-Ley, 2020; Nascimento, 2023). In this context, extreme droughts are an increasingly common global problem that worsens human survival, impacting economic and social activities (Kiem and Austin, 2013), especially in semiarid areas.

Access to water is one of the main challenges for global water security (Cholé et al., 2022). In semiarid regions, there is a lack of water infrastructure (Mady et al., 2020). These infrastructures involve a set of technologies that allow access to water, such as wells, cisterns, dams, water mains, underground dams, and natural rivers, which, according to Souza et al. (2016), favor local water security.

The semiarid regions of Brazil, especially those linked to the state of Ceará, constantly suffer from water insecurity (Albuquerque et al., 2020). In these places, the water supply is made up of reservoirs that have their level reduced in periods of drought (Zhang et al., 2021) and are affected by desertification (Silva and Oliveira, 2017). These municipalities usually cannot provide large-scale water infrastructure (Oliveira, França, and Martins, 2020) and do not have accurate information on water use in rural communities.

Brazil's semiarid regions constantly suffer from extreme droughts that affect rural water supply (Rualino, Silveira, and Neto, 2021), where, according to Amorim and Bacha (2022), around 45% of families are concentrated. The water supply in these communities is challenging (Souza Filho, Dantas Neto and Silva, 2013; Andrade and Nunes, 2014), with restricted water access technologies (Katz and Sara, 1997), and the implementation of water security (Cunha, 2020) for the population of these small settlements.

Some research has proposed alternatives for water access and security (Mishra et al., 2021; Joshua et al., 2022; Babuna et al., 2023). Vieira (2003) states that in extreme drought conditions, the subsoil can meet the emergency demand for access to water. Matos and Santos (2016) point out that rainwater harvesting is one of the alternatives for local water security.

With this in mind, this article aimed to identify which types of technologies enable access to and prospecting for water in semiarid regions, with a focus on guaranteeing human water security, with particular attention to small rural communities in semiarid areas, such as those located in the state of Ceará. To this end, a systematic review of the specialized literature was carried out, opting for a bibliometric approach.

METHODS

We have used the Scielo, Scopus, and Web of Science databases to collect data and information on the issue of water security in semiarid regions and rural communities. The aim was to gather documentary support for the subsequent analysis based on the works published in these scientific knowledge bases that the academic community has already consolidated.

The analysis was carried out in three stages. The first stage consisted of acquiring data from the selected platforms, followed by filtering and selecting documents such as period of publication, type of document, and content affinity analysis to find the pre-selected documents for content analysis. Data processing involves converting TXT files to Excel to generate graphic and cartographic products.

The second stage analyzes the quantitative relationship corresponding to the interaction between the clusters: neural networks and keyword clouds. This mapping consists of identifying the main characteristics of the abstracts and making it possible to identify the main geographical regions of interest of the researchers and their affiliations.

The third stage consists of a qualitative research analysis, focusing on content description. The aim was to identify the main areas of study and the challenges related to access to water and water prospecting in these regions.

The articles were selected according to the flowchart (Figure 1).

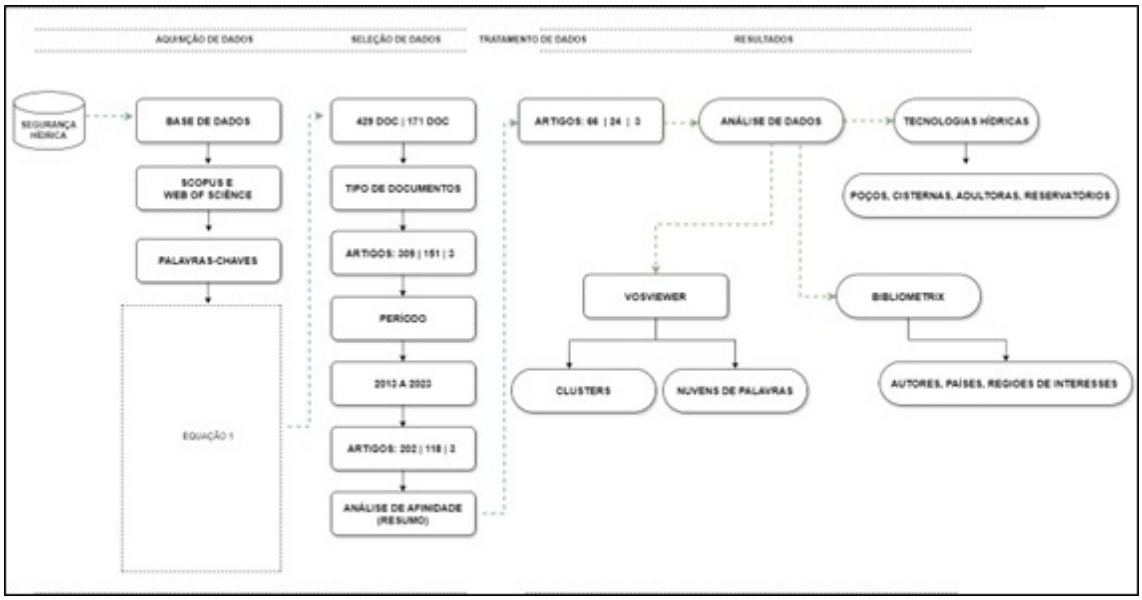


Figure 1 - Research development flowchart. Org: Author (2024).

The temporal delimitation of the analysis of water security was due to the need to recognize the role of global climate change in extreme drought events and the challenges of access to water in small rural communities. Scientific articles were selected to support the systematic review of global water security.

For the bibliometric query, Equation 1 below was applied to the Scielo, Scopus, and Web of Science databases, using Boolean operators such as "AND" (to search for records containing all the terms) and "OR" (to include related words and expressions).

Equation 1:

("water security" OR "water insecurity" OR "water governance" OR "water access" OR "water supply") AND ("Ceara" OR "Northeast Brazil" OR "Brazilian semiarid" OR "semiarid regions" OR "arid areas" OR "semiarid" OR "drought" OR "desertification" OR "extreme events") AND ("rural communities" OR "rural" OR "subsistence farmers" OR "traditional communities" OR "family farmers" OR "low-income communities" OR "tribal communities") AND (("reservoir volume" OR "ground water storage" OR "water infrastructure" OR "water storage" OR "water reuse") OR ("water resource management technologies" OR "remote sensing" OR "GRACE" OR "gravity recovery and climate experiment" OR "GLDAS" OR "global land data assimilation system" OR "altimetry" OR "water storage models" OR "hydrological models" OR "groundwater models" OR "groundwater monitoring" OR "groundwater") OR ("aquifers" OR "wells" OR "cisterns" OR "reservoirs" OR "dams" OR "water pipelines" OR "rainwater harvesting" OR "water storage" OR "water purification" OR "desalination" OR "water reuse" OR "community-based water management"))	1

The content analysis was carried out through an individual and thorough reading of the selected documents to ascertain the characteristics of the studies, the geographical regions of interest to the researchers, and the main challenges related to access to water. In addition to identifying the main types

of water technologies implemented in these regions for prospecting and access to water in rural communities.

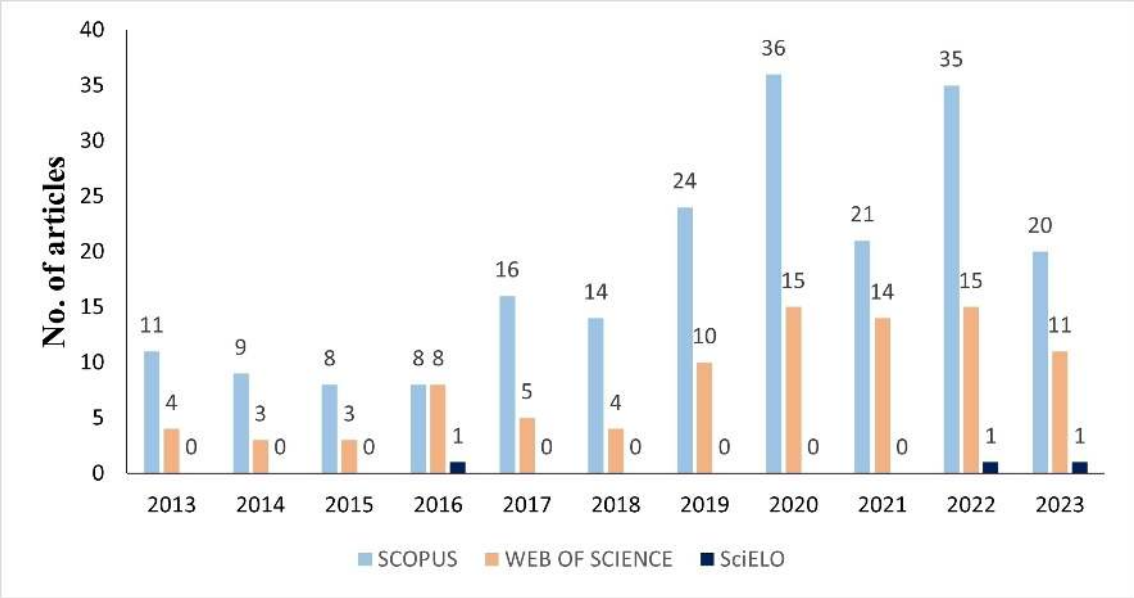
The results were mapped using the identifying the number of articles published, and the geographical regions where the researchers work and are interested. With this, it was possible to analyze the technologies for prospecting access to water; the discussions were based on the published works and the challenges and future prospects of the theme.

The bibliometric analysis of the documents is presented in the form of figures and graphs. The analysis of the results relating to water technologies is initially linked to semiarid regions and rural communities abroad, such as in Africa, North America, and Asia. Subsequently, they were compared with domestic communities in the Brazilian semiarid region - SAB, with a special focus on Ceará.

Finally, the followed by the use of the R software programming language with the biblioshiny() script, to generate graphs of the and the sources of publications on the subject.

RESULTS

For the content analysis, 99 documents were selected as scientific articles, 3 of which were linked to Scielo, 66 to Scopus, and 24 to Web of Science. These articles were selected according to their affinity with the theme to explore the nexus of content relating to water security and the development of technologies for prospecting and access to water in semiarid regions, as shown in Graph 1 below.



Graph 1 - Scientific production on water security in the last decade. Org: Author (2024).

Figure 1 indicates that the SciELO database had the lowest number of publications, followed by Web of Science and Scopus. Scopus recorded the highest scientific output on water security, attributed to its indexing policy, which has led to a higher volume of publications on this subject. Lastly, a significant increase in Scopus publications was observed, particularly from 2021 to 2023, as well as in Web of Science, which saw a rise in publications from 2020 to 2023.

Even with a sample of 99 selected documents, only 32% of the articles were directly related to the theme. In other words, 68% of the documents did not directly connect to the content, as they did not present any water access technology. This naturally supports the thesis that research on rural communities in the context of water security is scarce. The content analysis of water access and water prospecting technologies applied in rural communities highlights the scarcity of publications in this area. However, it reveals important insights into semiarid regions' challenges, such as the impact of specific technologies like cisterns and wells. According to Web of Science, there is no single most relevant

author, as all are aligned with the same number of published documents. However, it is essential to locate the sources of these publications and correlate them with researchers' areas of interest. Next, we identify Figure 2, the most cited documents in Scopus.

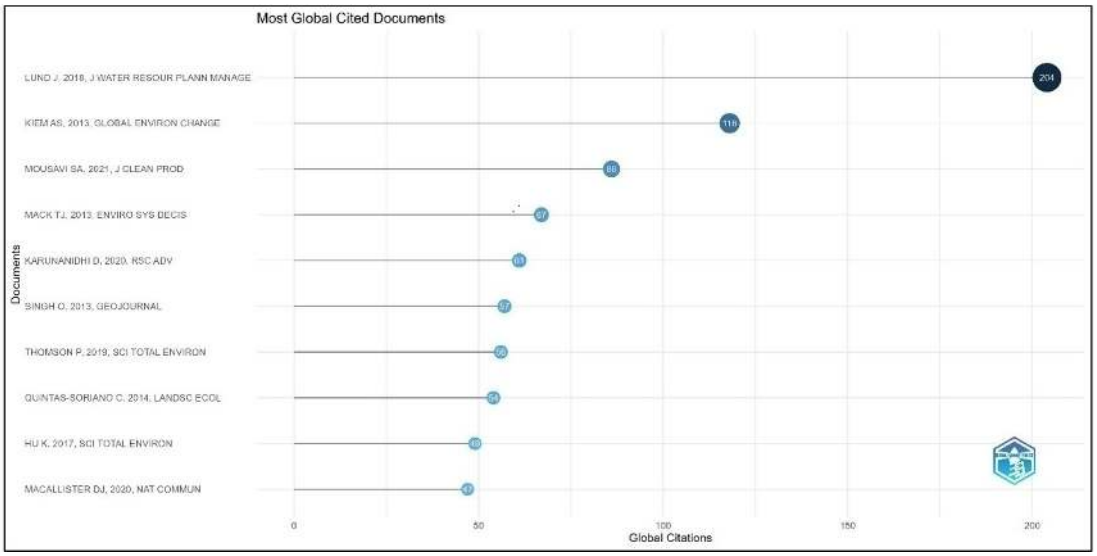


Figure 2 - Most Cited Documents in Scopus. Source: R (2024).

Lund's (2018) document, titled "Lessons from California's 2012–2016 Drought," describes how droughts can impact various ecosystems and highlights that rural communities are the most vulnerable areas regarding human supply, as they largely depend on isolated systems such as wells. Kiem (2013) published the article "Drought and the Future of Rural Communities: Opportunities and Challenges for Climate Change Adaptation in Regional Victoria, Australia," which describes the economic impact of droughts on two nearby rural communities, one with a water supply system and one without. Droughts were observed to cause significant financial losses in the region, directly impacting agricultural practices. Additionally, an insight into the emergence of a parallel water market in the region was observed. Next, in Figure 3, we analyze the most cited documents in Web of Science.

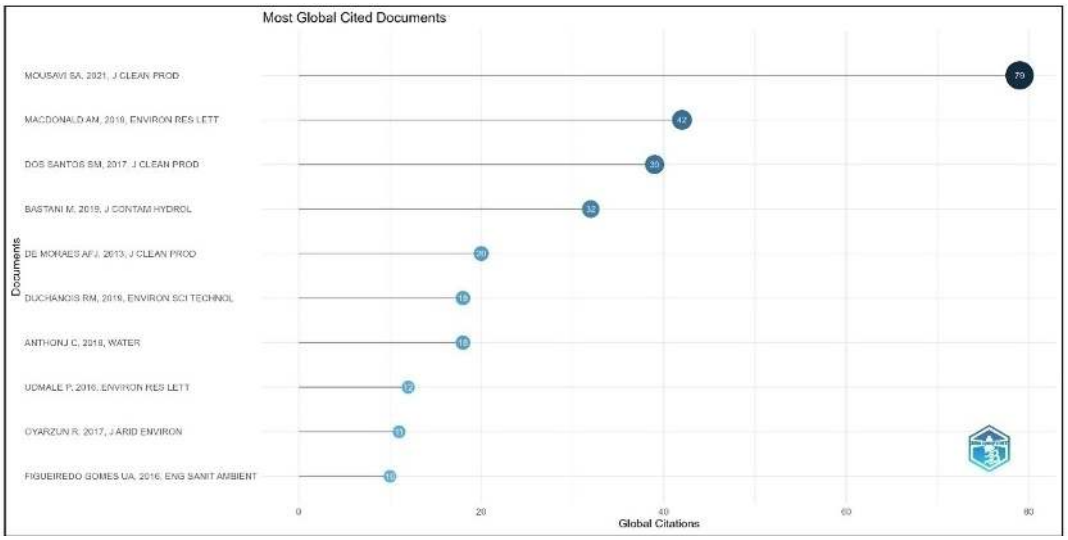


Figure 3 - Most Cited Documents in Web of Science. Source: R (2024).

Mousavi's (2021) article, titled "Decision-making Between Renewable Energy Configurations and Grid Extension to Simultaneously Supply Electrical Power and Fresh Water in Remote Villages for Five Different Climate Zones," discusses the relationship between water security and the production of a hybrid system to serve remote rural communities using solar energy across various climate zones in Iran, Asia. MacDonald's (2019) publication "Groundwater and Resilience to Drought in the Ethiopian Highlands" discusses water access processes in two rural communities through wells.

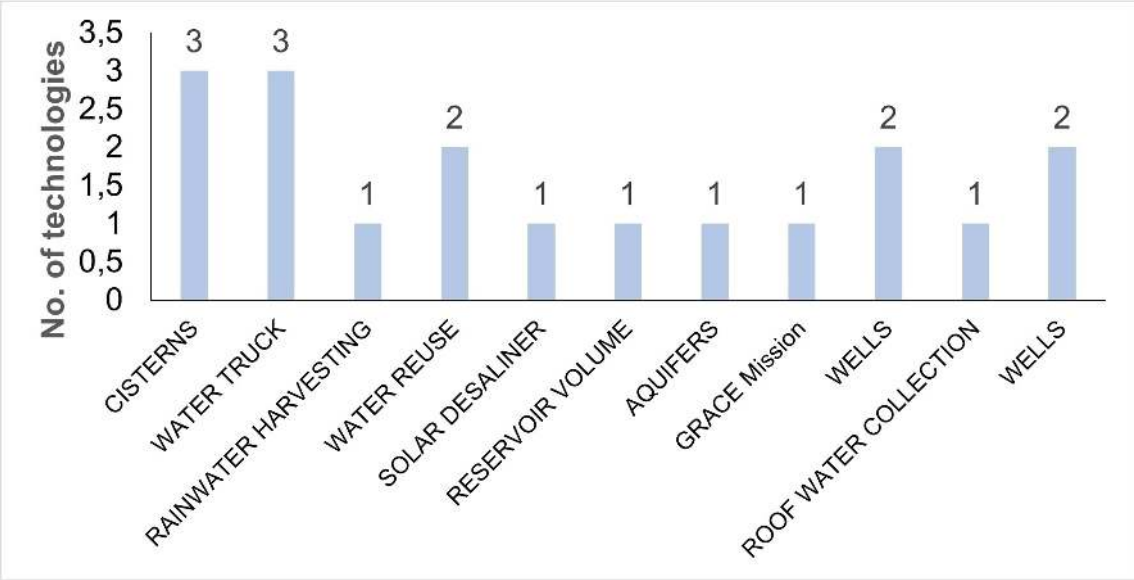
Parallel to content analysis, it was identified that a range of factors influences the difficulty of implementing water access technologies in these regions and communities, such as the limitations of the technologies, the lack of information about suitable regions for technology installation, and the need for complementary technologies. In other words, although isolated systems like wells and cisterns ensure immediate local water security, long-term viability, depending on domestic use and family size, remains uncertain, presenting a series of imminent challenges for local water security.

WATER INFRASTRUCTURE TECHNOLOGIES

There is no precise definition of water technologies in the scientific literature. Still, the term is linked to the set of water infrastructure works related to supplying water to the population. According to Hermann (1971), water resource systems are collections of hydraulic engineering works and possibly natural components, such as stretches of riverbeds. Thus, we emphasize here that technologies are understood as a set of engineering works providing water access.

For Gesualdo et al. (2021), the challenges to be overcome with local water security are, for example, identifying technologies that can guarantee access to water for rural populations. Therefore, to determine which water technologies are developed in these semiarid regions and how they enter specific areas in rural communities, we used specialized scientific literature to provide the necessary support for the identification process.

Initially, we identified which technologies are developed in semiarid regions, as seen in graph 2 below.



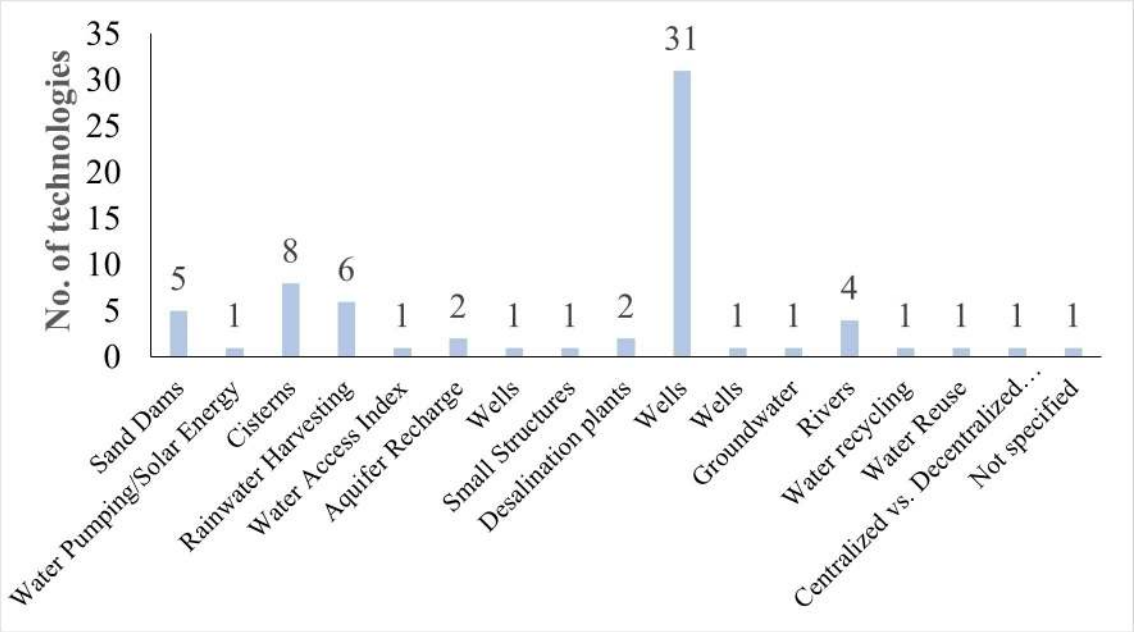
Graph 2 - Water access technologies in semiarid regions. Org: Author (2024).

Graph 2 shows that 18 articles were unrelated to rural communities, i.e., their research area: the study area is in the semiarid region is associated with a river basin, a city or a region. However, he found that these articles presented different types of technologies enabling prospecting and water access. It noted that the spatial distribution of the technologies goes beyond the need for direct access to water,

such as wells in Asia in Karunanidhi et al. (2020), and Arienzo et al. (2022) in North America. Cisterns are widespread in South America, as Cunha (2020) and Santana et al. (2023) highlight.

The need for access to water and adaptation to the semiarid climate has led to the emergence of new studies, such as the measurement of water harvesting "captured on the roof of residential areas" in South America by Gomes et al. (2021), as well as the prospecting of the level of "reservoir volume" in Fleury, Kergoat, and Grippa (2023), in Africa.

For the specific studies in rural communities, it was observed that various technologies have been implemented graph 3, in different geographical regions to meet the population's need for access to water.



Graph 3 - Water access technologies in rural communities. Org: Author (2024).

Global climate change and extreme droughts are significantly affecting rural communities, which are developing different types of technologies to gain access to water, the most widely used being the drilling of wells, dams, reservoirs, cisterns, and rivers in times of flood. However, some rural communities have been developing water reuse systems in South America, as pointed out by Leiva et al. (2021), as well as water recycling on the African continent, as highlighted by Owen and Chitonge (2022).

We identified that wells and cisterns are the best technologies for immediate access to water in rural communities. However, one technology alone does not guarantee local water security. Joint investments in other technologies, adductors and pipelines, are necessary.

Although this study leaves this gap, at the same time, it reveals promising and strategic insights into the challenge of local water security, such as the studies on water prospecting using different types of technologies, such as remote sensing in Gomes et al. (2021), the application of Geographic Information Systems - GIS, in Al-Gburi et al. (2022), and the Gravity Recovery and Climate Experiment (GRACE), in Hu et al. (2017).

Although these studies reveal specific limitations on the types of technologies adopted by rural communities, we identified the central regions of interest to these researchers, so we mapped the location of these studies (see Figures 4 and 5) below.

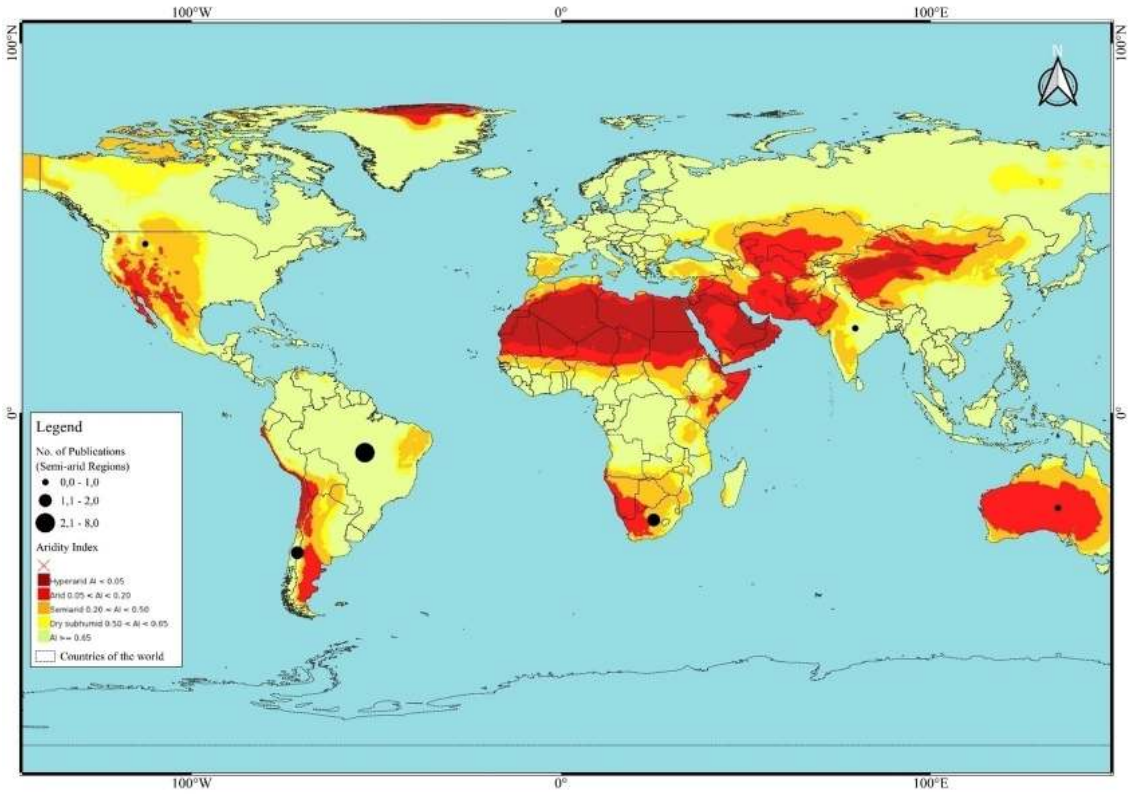


Figure 4 - Scientific production of countries. Org: Author (2024).

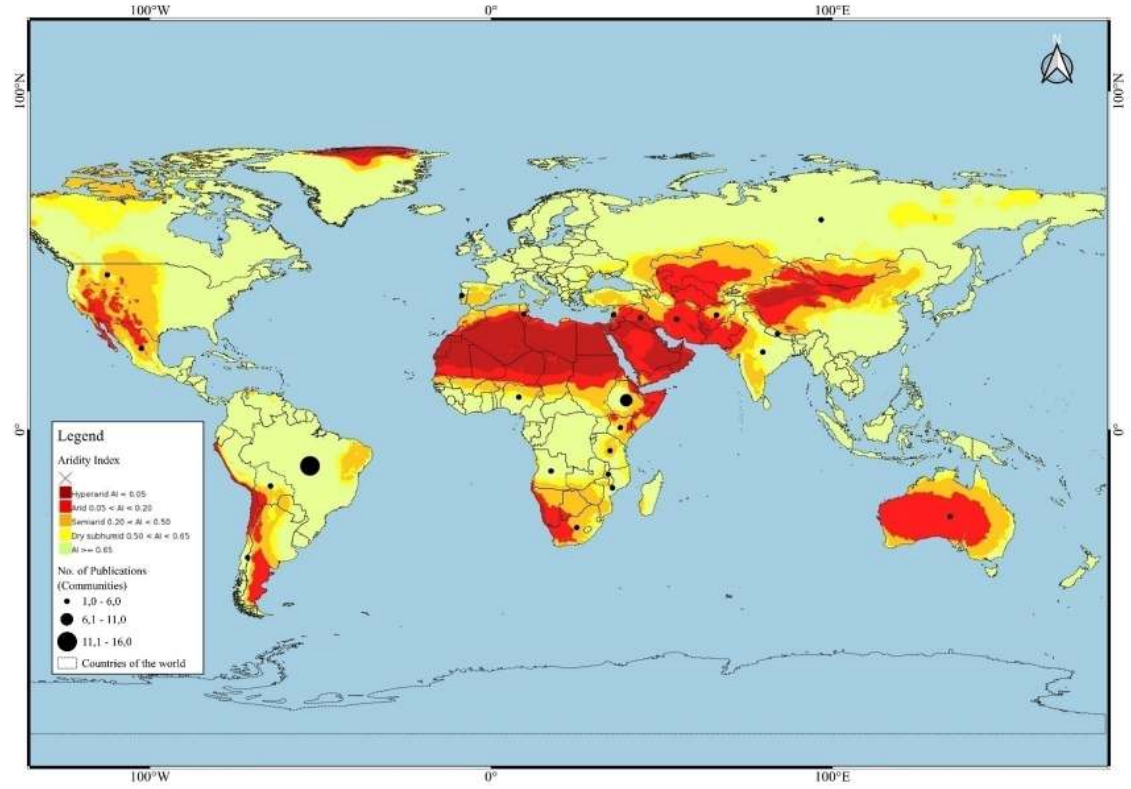


Figure 5 - Scientific production of rural communities. Org: Author (2024).

Although scientific production on local water security highlights multiple challenges of global scientific output in semiarid regions, the Scielo, Scopus, and Web of Science databases are the most reliable sources for accessing the information consolidated by the academic community.

Thus, we identified in the specialized literature that the central regions of interest to researchers are South America, Africa, and Asia. In common, these rural communities are challenged by the scarcity of public investment. On the other hand, they adapt to survival needs, such as digging wells by hand, as shown by Uribe et al. (2014). On the other hand, in South America, there have been improvements in public investment in the construction of water technologies such as cisterns and desalination plants.

As important insights, it was identified that the political discussion on global water security is already a reality through political events such as the World Water Forum and investments in basic sanitation by the World Bank. However, specific studies on rural communities are scarce, with only 73 articles found. The insights also revealed that rural communities develop different techniques to gain access to water, whether nature-based, such as rivers or springs, or constructed, such as wells, rainwater harvesting and reservoirs.

In addition, the studies by Piemontês et al. (2022) are promising when zoning strategic areas for the installation of dams in Africa, which demonstrated the importance of applying spatial analysis supported by Geographic Information Systems (GIS) to zone areas suitable for the installation of water infrastructure in rural communities.

Based on this theoretical framework, we compared the studies carried out in Brazil (see Figure 6), in South America and identified the main regions of interest. Then, we pointed out which studies have been carried out in rural communities in Ceará.

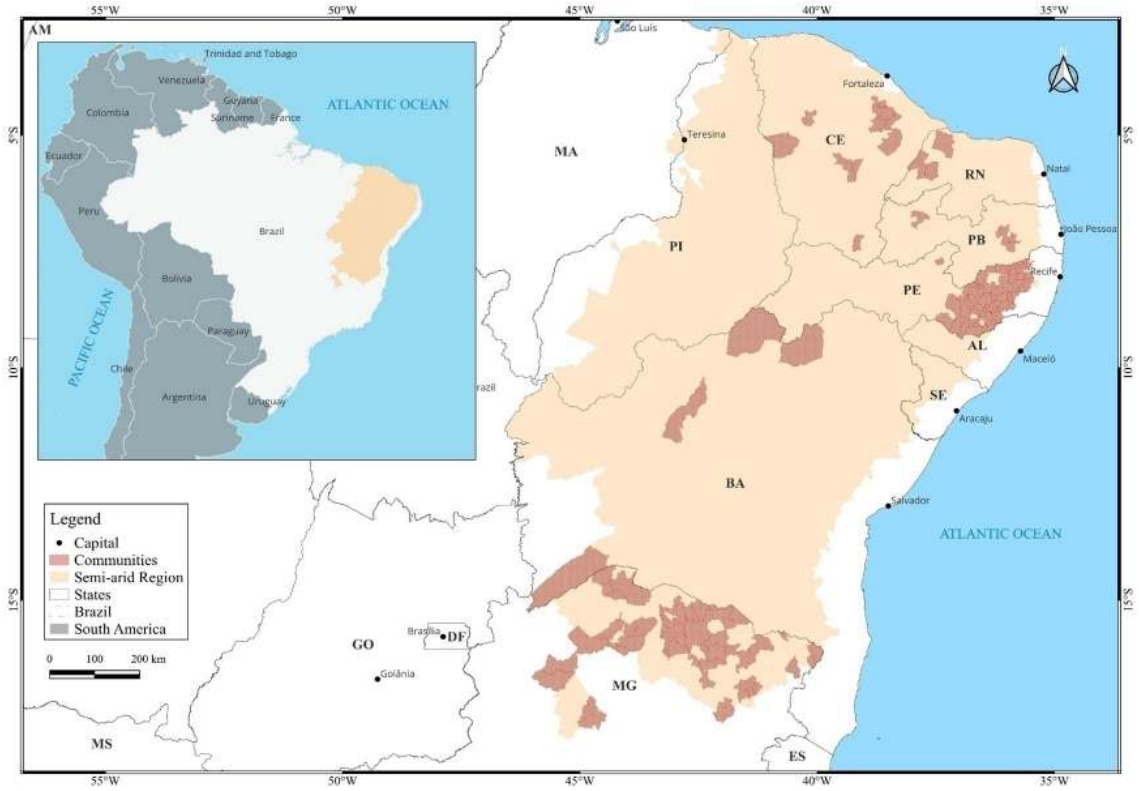


Figure 6 - Main areas of interest for water access technologies in semiarid Brazil - SAB. Org: Author (2024).

In northeastern semiarid Brazil, there are several technologies used to access water in rural communities, such as cacimbas, according to Silva, Brito and Filho (2021); wells, as seen in Oliveira, Silva and Júnior (2020); barreiro, in Faustino et al. (2016); açudes in (Rebouças, 1997; Barbosa et al. 2012; Novais, Junior and Oliveira, 2022; França et al. 2022); carro-pipa, in Farias, Carvalho Neto and

Vianna (2020); cordão de pedra, in Montenegro (2020); desalinizers in (Campos, Gomes and Campos, 2004; Silva, Silva, Silva, 2015; Neves et al. 2017); simplified systems, in Pinto and Hermes (2006); water mains and integration canals, in Cirilo (2008); cisterns, in Gomes and Heller (2016); and underground dams, in Cirilo et al. (2003), all of which are techniques that have been disseminated over time to help people adapt to the semiarid environment and form the region's water infrastructure.

Brazil's semiarid region is one of the most populated in the world, with 27 million people, corresponding to 12% of the national population. In rural areas, there are around 9.6 million people, or 36.88% of the semiarid population (IBGE 2010, apud ASA, 2023). Various rural communities occupy it, mostly composed of family groups living lives adapted to the semiarid climate.

According to Ferreira (2008), the domestic water supply of rural communities in the semiarid region is provided by cisterns, wells, and desalination plants due to the lack of a distribution network. According to Júnior et al. (2019), desalination plants are alternatives for supplying isolated communities. According to Grigg (2017), the types of water infrastructure for human supply vary from local wells or detours from small springs to large-scale systems for megacities.

As mentioned by the authors, a single type of technology does not guarantee the sustainability of local water security, as rural communities are susceptible to domestic shortages due to drought, evapotranspiration, and the kind of land use adopted by families. However, combining one or more technologies can favor the domestic supply of communities.

To implement local water security, studies are needed to assess the water behavior of semiarid regions so that the future of the next generations can be planned. In this sense, the specialized scientific literature identified studies that detected variations in water stored underground, and Rodell and Famiglietti (2002) found reductions of 113.7 mm in groundwater over 11 years in the High Plains of the United States, using data from the Grace space and experimental mission. For example, one of the applications of the Grace mission is linked to estimates of groundwater depletion through water use by wells in the Middle East, according to Joodaki, Wahr, and Swenson (2014).

The first studies using spatial and satellite data from the Grace mission in the Brazilian semiarid region were carried out by Rosenhaim (2017), when assessing water availability in the East Northeast Atlantic basin, where a variation in water availability of approximately 19246.11 hm^3 was found between 2002 and 2015, 60% of which was depleted by wells. This was followed by Melati et al. (2019), on the Araripe sedimentary aquifer and Camacho et al. (2022). Gonçalves et al. (2020) investigated the Urucuia aquifer in northeastern semiarid Brazil.

CHALLENGES, FUTURE PROSPECTS, AND FINAL CONSIDERATION

Local water security is an emerging challenge, especially in the peripheral regions of the global economy, such as South America, Africa, and Asia. Although the specialized scientific literature supports identifying various types of water access technologies, such as cisterns, wells, reservoirs, and desalination plants, these alone do not solve the water access challenges in rural communities.

This raises the challenge of integrating various water technologies throughout rural communities to facilitate domestic supply. To do this, knowing the social aspects of water demand and availability is necessary.

On the other hand, we have discovered that global water security is already a reality in political discussion, management, and participatory water governance. Thus, the challenge of breaking with semiarid regions' regional and local specificities to implement water security locally will arise in the future. Specific studies on water technologies and rural communities are still limited.

Future prospects reveal essential insights into regional and local water security, such as developing and applying technologies from the Grace mission, remote sensing, and GIS. Thus, studies that establish zoning of areas suitable for the insertion of water technologies in rural communities are promising.

The semiarid regions of Brazil and the world have presented different limitations as responses to global climate change, from local community organizations to lack of access to information on which

type of technology best favors access to water. However, it was noted that rural communities rely on groundwater as a source of domestic water, using local water technologies such as well drilling, water treatment plants, and desalination plants.

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