

WATER AND URBAN PLANNING IN THE BRAZILIAN SEMIARID: AN INTEGRATIVE REVIEW

Água e planejamento urbano no semiárido brasileiro: uma revisão integrativa

Agua y planificación urbana en el Semiárido brasileño: una revisión integrativa

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ABSTRACT

The integration between water management and urban planning represents one of the main challenges for semi-arid cities. This study aimed to analyze the relationship between water issues and urban planning in cities within the Brazilian Semi-Arid region. To this end, an integrative literature review was conducted across the Academic Search Premier (EBSCO), DOAJ, ScienceDirect, Scopus, and Web of Science databases, using the keywords "water", "urban planning", and "Semi-arid", combined with the Boolean operator AND. Open-access articles published between 2015 and 2026 in any language were included, while duplicates and studies that did not align with the proposed objective were excluded. The findings from the analyzed studies revealed that unplanned urban growth exacerbates water vulnerability, technological innovations and water reuse strategies still face institutional barriers, and the integration between master plans and water resource policies remains incipient. It is concluded that, despite existing legal frameworks and instruments, the integration between water management and urban planning remains fragmented.

Keywords: Water; Urban planning; Brazilian Semi-Arid.

Article History

Received: 18 april, 2026
Accepted: 31 july, 2026
Published: 02 august, 2026

<https://doi.org/10.33237/2236-255X.2026.7988>



RESUMO

A integração entre a gestão da água e o planejamento urbano constitui um dos principais desafios das cidades do Semiárido. Este estudo teve por objetivo analisar a relação entre a questão hídrica e o planejamento urbano nas cidades do Semiárido brasileiro. Para tanto, realizou-se uma revisão integrativa da literatura nas bases Academic Search Premier (EBSCO), DOAJ, ScienceDirect, Scopus e Web of Science, utilizando os descritores “água”, “planejamento urbano” e “Semiárido”, combinados pelo operador booleano AND. Foram incluídos artigos publicados entre 2015 e 2026, de acesso aberto, em qualquer idioma, excluindo-se duplicidades e estudos que não atendiam ao objetivo proposto. Os resultados apontados pelos trabalhos analisados revelaram que o crescimento urbano desordenado intensifica a vulnerabilidade hídrica, que as inovações tecnológicas e estratégias de reuso ainda enfrentam barreiras institucionais e que a integração entre planos diretores e políticas de recursos hídricos é incipiente. Conclui-se que, apesar de marcos legais e instrumentos existentes, a integração entre a gestão hídrica e o planejamento urbano permanece fragmentada.

Palavras-chave: Água; Planejamento urbano; Semiárido brasileiro.

RESUMEN

La integración entre la gestión del agua y la planificación urbana constituye uno de los principales desafíos de las ciudades del Semiárido brasileño. El presente estudio tuvo como objetivo analizar la relación entre la problemática hídrica y la planificación urbana en las ciudades del Semiárido brasileño. Para ello, se realizó una revisión integrativa de la literatura en las bases de datos Academic Search Premier (EBSCO), DOAJ, ScienceDirect, Scopus y Web of Science, utilizando los descriptores “agua”, “planificación urbana” y “Semiárido”, combinados mediante el operador booleano AND. Se incluyeron artículos de acceso abierto publicados entre 2015 y 2026, en cualquier idioma, excluyéndose los registros duplicados y los estudios que no respondían al objetivo propuesto. Los resultados revelaron que el crecimiento urbano desordenado intensifica la vulnerabilidad hídrica, que las innovaciones tecnológicas y las estrategias de reutilización del agua aún enfrentan barreras institucionales y que la integración entre los planes directores y las políticas de recursos hídricos sigue siendo incipiente. Se concluye que, a pesar de la existencia de marcos legales e instrumentos de planificación, la integración entre la gestión hídrica y la planificación urbana permanece fragmentada.

Palabras clave: Agua; Planificación urbana; Semiárido brasileño.

1 INTRODUCTION

Water scarcity in the Brazilian Semi-Arid, framed within a global water crisis scenario (UN, 2025), becomes increasingly alarming due to the inadequate extraction of water resources, population growth, and the impacts of climate change. These factors directly compromise environmental sustainability and pose challenges to territorial management.

In this context, the impacts of the water crisis are even more evident in the Brazilian Semi-Arid, where water scarcity constitutes one of the main obstacles to environmental sustainability. It is a region marked by climatic irregularity, nutrient-poor soils, and water



scarcity (Ab'Saber, 2003) - conditions that influence urbanization processes and render urban planning tailored to these limitations essential.

In this scenario, water not only conditions population access to essential services, but also guides territorial expansion and defines quality of life. As highlighted by Souza, Souza, and Sousa (2022), water availability in the Semi-Arid is directly associated with the region's social, economic, and territorial transformations, standing as a key structural element of land occupation and urban-regional dynamics.

The understanding of this reality can be constructed at the intersection with the production of urban space and the multiple agents operating within it; as Corrêa (1995) states, urban space is simultaneously fragmented and articulated, reflecting and influencing social organization. It constitutes a symbolic territory and an arena of contention, resulting from the actions of various actors: owners of the means of production, landowners, real estate agents, the State, and historically excluded social groups (Corrêa, 1995).

From this perspective, the city is not merely a physical arrangement, but the product of social conflicts that materialize in space. Among these agents, the State plays a singular role, organizing urban space through legislation, master plans, and investments in infrastructure and services.

According to the aforementioned Author, the State alternately favors landowners and real estate agents or acts on behalf of the collective interest. Santos (2018) reinforces this ambiguity by highlighting the selectivity and inequality inherent in state policies which, far from being neutral, frequently reinforce territorial hierarchies and social inequalities. In the Semi-Arid region, this logic is further conditioned by water scarcity, which influences everything from public investments in water supply to land value appreciation in serviced areas, while also impacting the survival strategies of local populations.

In light of these contradictions, unplanned urban growth often occurs without considering territorial features and available natural resources. This underscores the urgency of understanding urban planning as an essential mechanism for spatial management, equity, and sustainability.

Within this challenging framework, it becomes critical to align the analysis of water management and urban planning with the Sustainable Development Goals (SDGs) outlined in the United Nations 2030 Agenda. SDG 6 aims to ensure the availability and sustainable management of water and sanitation for all, whereas SDG 11 seeks to make cities and human settlements inclusive, safe, resilient, and sustainable (UN, 2015). These guidelines

highlight the necessity of integrated policies that treat water as a core structural element of urban planning, particularly in vulnerable areas such as the Brazilian Semi-Arid region.

Despite the existence of master plans, public policies, and strategies focused on water issues, studies that systematically analyze how this resource has been incorporated into urban planning remain scarce. This gap is particularly significant given Brazil's commitments to the 2030 Agenda, especially regarding SDGs 6 and 11. Against this backdrop, the central guiding question emerges: how is the water issue incorporated into the urban planning of cities in the Brazilian Semi-Arid region? To answer this question, this article aims to analyze, through an integrative literature review, the relationship between water issues and urban planning in cities within the Brazilian Semi-Arid.

This article is structured around the theoretical framework, which addresses the key concepts, instruments, and contradictions of Brazilian urban planning, alongside the methodology, which focuses on the criteria used for selecting articles in the integrative review. Subsequently, the results and discussion developed from this survey are presented. Finally, concluding remarks are provided, highlighting the identified relationship between urban planning and water within the territory of the Brazilian Semi-Arid region.

2 URBAN PLANNING IN BRAZIL: CONCEPTS, CONTRADICTIONS, AND INSTRUMENTS

Urban planning can be understood as an instrument designed to guide land use and occupation in cities, serving as a normative and political foundation for spatial organization. According to Pujadas and Font (1998, p. 12), its purpose is "[...] an organization of land use based on the redistribution of expansion opportunities and the identification of needs, potentials, limitations, and comparative and competitive advantages." This conception demonstrates that urban planning extends beyond the physical spatial arrangement of the city, articulating multiple dimensions and considering both available resources and context-imposed constraints.

From this same perspective, Souza (2004) reinforces that urban development and management must be understood as a field that interconnects social, political, economic, and environmental factors. This approach is particularly relevant in the Brazilian Semi-Arid region, where water scarcity imposes itself as a key determinant of urban expansion, demanding planning strategies that integrate natural resource management into urban policies.



This understanding of urban planning becomes even more relevant in light of the challenges posed by climate change. Hassane and Moura (2026) emphasize that urban and environmental planning plays a strategic role in mitigating climate risks and adapting cities, particularly in vulnerable territories.

In Brazil, the trajectory of urban planning was consolidated through key institutional milestones. The 1988 Federal Constitution incorporated the principle of the social function of property in Articles 182 and 183, establishing guidelines for a more democratic and inclusive urban management, moving beyond the sectoral character that had prevailed until then.

Subsequently, the Estatuto da Cidade (City Statute, Law No. 10,257/2001) regulated these principles and instituted tools such as the master plan, zoning, progressive property tax, onerous grant of the right to build, and environmental impact assessment, fostering advances in the pursuit of greater equity and the promotion of sustainability. These instruments, by guiding land use and occupation, constitute the legal foundation that can enable the integration of water management into urban planning.

Although the Estatuto da Cidade establishes guidelines for democratic management, Barbosa and Sousa (2025) warn that the exemption of Master Plans for cities with fewer than 20,000 inhabitants creates a scenario of diverse planning approaches in small municipalities of the Semi-Arid region, resulting in deficient urban layouts and a lack of local growth regulation.

In this context, Barbosa and Sousa (2025) argue that the absence of a legal requirement to formulate a Master Plan does not justify the lack of municipal laws and instruments aimed at regulating urban expansion, given that this gap can materialize as deficiencies in street design, zoning, and infrastructure provision.

These aspects demonstrate that, even with the advances in the legal framework, urban planning in Brazil still faces structural limitations. For Maricato (2001), the absence or weakness of planning results in informal cities that are environmentally fragile and socially unequal, exacerbated by institutional fragmentation that hinders the integration between social, economic, and environmental policies.

From this perspective, the effectiveness of urban planning depends not only on the existence of legal instruments, but also on the institutional capacity of municipalities to implement them in accordance with their territorial singularities and societal participation (Barbosa; Sousa, 2025).



In this scenario, the State emerges as a central and contradictory agent in urban planning. Its actions reflect what Rolnik (2015) defines as the capture of urban space through mechanisms of accumulation that subordinate the right to the city and housing to capital interests. As a consequence of this logic, the increasing delegation of State functions to the private sector has contributed to predatory expansion patterns, urbanization lacking adequate infrastructure, the deepening of sociospatial segregation, and the consolidation of unsustainable cities (Rolnik; Klink, 2011). Lefebvre (1991) also wrote from this perspective, emphasizing that, although a mediator of social relations, the State frequently legitimizes these dominant interests, perpetuating inequalities.

In counterpoint to the limitations of the current model, Maricato (2001) proposes adopting the river basin as the planning and management unit, highlighting the importance of both water withdrawal and sewage and waste disposal, which affect all users within a shared water system. This approach reinforces the need to integrate water management into urban planning practices.

The fundamental objective of urban planning and management is to promote urban development geared toward social justice and the improvement of quality of life (Souza, 2004). In this sense, strengthening urban planning as a public instrument capable of addressing inequalities, regulating land use, and articulating the environmental dimension - with water as a structural element of sustainability - becomes imperative. The United Nations 2030 Agenda broadens this horizon, particularly through SDG 6 (universal access to water and sanitation) and SDG 11 (inclusive, safe, and sustainable cities).

In this regard, understanding urban planning through the lens of water management becomes essential to addressing the contradictions between rhetoric and practice. This study contributes to this debate by investigating how water has been incorporated into urban planning in the Brazilian Semi-Arid region, where water vulnerability most sharply exposes the tensions and limitations of urban policies. Such reflection seeks to support the implementation of more effective and integrated public policies.

3 METHODOLOGY

Considering the relevance of the theme and the need for robustness regarding the intended analysis, an Integrative Literature Review (ILR) was employed. The ILR provides a deep understanding of the topic by encompassing works with diverse research methods and synthesizing existing knowledge (Toronto, 2020).



The development of this study followed the six stages proposed by Souza, Silva, and Carvalho (2010) for conducting an ILR. These steps ensure methodological consistency and the scientific validity of the research, comprising: (I) formulation of the guiding question; (II) systematized search in databases; (III) data collection; (IV) rigorous selection of texts; (V) thorough reading and critical analysis of texts; (VI) discussion of results.

Following methodological rigor, the research question was based on the PICO strategy by Stern *et al.* (2014), in which "P" (refers to the population/problem) corresponds to Urban Planning; "I" (refers to the interest) where the water issue emerges; and "Co" (refers to the context) identified as the Brazilian Semi-Arid region. Thus, based on these definitions, the guiding question of the research was: How is the water issue incorporated into the urban planning of cities in the Brazilian Semi-Arid region, according to the literature?

In the operationalization of the search, the survey was conducted across five database platforms recognized for their comprehensiveness and relevance in indexing studies in the fields of urban planning, environment, and water resources, namely: Academic Search Premier – ASP (EBSCO); Directory of Open Access Journals – DOAJ; ScienceDirect; SCOPUS; and Web of Science.

The choice of these databases is justified by their inclusion of high-impact national and international journals, ensuring broader thematic coverage and scientific rigor in the literature survey. In the "advanced search" field, the descriptors "água", "planejamento urbano", and "Semiárido" were combined using the Boolean operator (AND), noting that the full search string across all databases was: "água" AND "planejamento urbano" AND "Semiárido".

In compliance with recommendations from the evaluation process, this strategy was fully reapplied in July 2026, maintaining the same descriptors, Boolean operators, databases, and methodological criteria, with the search timeframe updated through July 2026. The reapplication resulted in minor variations in the number of records retrieved across the databases, stemming from updates in their indexing and retrieval processes, which reduced the final corpus to seven articles.

For the selection of studies, inclusion and exclusion criteria were established. Inclusion criteria comprised full-text scientific articles available in open access, published in any language between January 2015 and July 2026. Exclusion criteria involved the removal of duplicate records across databases and studies that did not address the research objective and guiding question.



The analysis process of the results was guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol, according to Page *et al.* (2021). In this stage, the screening of studies is detailed through the identification, screening, eligibility, and inclusion phases.

Subsequently, the selected studies were organized by using the Synthesis Matrix method, defined by Cunha, Cunha, and Alves (2014) as a compilation of the central aspects of the investigation, providing the researcher with an integrated overview of the data.

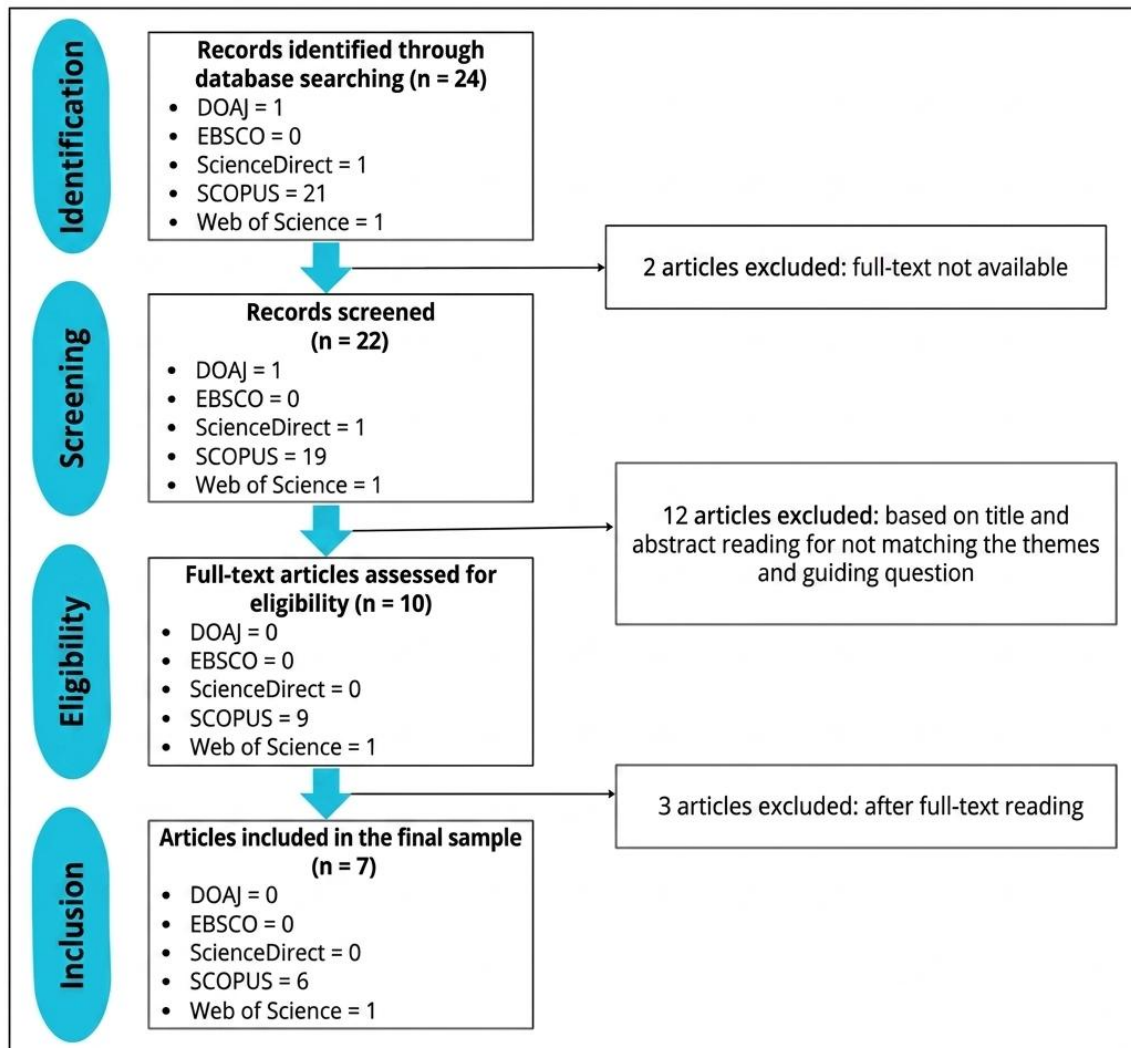
For data systematization, information such as authors, year of publication, database, objective, method, territorial scope, and results were organized, allowing a comparative visualization of the data related to urban planning and the water issue in the Brazilian Semi-Arid region, thus contributing to the establishment of analytical categories.

Subsequently, a critical reading of the material was conducted following Content Analysis by thematic categories, as proposed by Bardin (2016), aiming to understand theoretical and methodological approaches as well as identify the core contributions discussed by the authors. Subsequently, the discussion was developed based on these categories considering the literature review, aiming to address the research objective and answer the central question.

4 RESULTS

The search conducted across the five databases initially yielded 24 studies, indicating a limited body of scientific literature on the topic. After applying the inclusion and exclusion criteria, the *corpus* was narrowed down to 7 articles aligned with the research objective and guiding question. The systematization of this process is presented in Figure 01, constructed based on the PRISMA protocol (Page *et al.*, 2021).

Figure 01 - Flowchart of the selection process for articles included in the ILR



Source: Prepared by the authors (2026).

As shown in Figure 01, seven articles were included in the ILR. The characterization of these studies is presented in the summary matrix of the articles (Table 01).

Table 01 - Summary matrix of the ILR articles

Author, year, Database	Objective	Method	Geographic Scope	Results
Aguilar <i>et al.</i> , 2022. SCOPUS	To analyze the relationship between the master plan of a river basin	Bibliographic, documentary, and comparative analysis.	Municipalities in the Northeastern Semi-arid region, State of	The plans converge on rural sanitation, environmental recovery, and permanent preservation areas.



	and the municipal master plans in the Northeastern Semi-arid region.		Pernambuco, Brazil.	
Aires <i>et al.</i> , 2024. SCOPUS	To evaluate land use impacts on water availability in the Pau dos Ferros dam.	Uses the DPSIR framework and AcquaNet software for water management scenarios, along with satellite imagery and morphometric analyses.	Pau dos Ferros, Rio Grande do Norte, Brazil.	Landscape analysis revealed physical/environmental changes and indicated paths for strategic water management, guiding control measures and the mitigation of negative impacts resulting from human activities.
Araújo and Oliveira, 2021. SCOPUS	To develop and apply a hybrid AHP-Entropy approach with flow network modeling to simulate the Epitácio Pessoa hydrosystem based on water demand management alternatives, identifying and prioritizing the best options.	Hybrid approach combining flow network modeling methodologies with multicriteria and entropy methods as a decision-support tool in complex water systems.	Paraíba - PB.	Insufficient supply due to management focused solely on the São Francisco River diversion, suggesting sustainability-oriented measures such as water-saving mechanisms, water reuse, loss reduction, and greater irrigation efficiency.
Calado <i>et al.</i> , 2020. SCOPUS	To evaluate the integration between the Water Resources Master Plan of the Paraíba River Basin and the municipal master plans surrounding the Epitácio Pessoa reservoir.	Documentary review and comparative analysis between municipal and basin plans. On-site visits.	Municipalities of Boqueirão, Barra de São Miguel, and Cabaceiras – PB, Brazil.	Coherence among the objectives, principles, and guidelines of the analyzed documents.



Costa <i>et al.</i> , 2021. SCOPUS	To estimate the urban drainage satisfaction index of the services provided to the population of the urban area of Pau dos Ferros/RN.	Use of interviews, application of questionnaires, and on-site visits.	Pau dos Ferros-RN, Brazil.	Water satisfaction: 35.3% low, 52.9% medium, and 11.8% high.
Medeiros, Rufino and Aragão, 2024. WEB OF SCIENCE	To investigate the relationships between water consumption and the spatial and temporal dynamics of the built environment in small municipalities in the state of Paraíba.	Historical precipitation series, remote sensing, citizen science, parametric and non-parametric statistical methods, as well as the Landscape Expansion Index (LEI).	Municipalities in the Paraíba Semi-arid region, Paraíba, Brazil.	Local particularities and indicator limitations. During the last water crisis, emergency and point-source supply solutions hindered the direct relationship between urbanized area and consumed volume, as official data did not reflect the reality captured by citizen science.
Silva, Brandão and Ribeiro, 2022. SCOPUS	To analyze the feasibility, seasonality, and reliability of rainwater harvesting in public buildings in the Brazilian Semi-arid region.	Simulations using Netuno software (behavioral models). Water consumption monitoring in 30 buildings at UFCG. Historical precipitation time series (25 years).	Campina Grande – PB, Brazil.	Rainwater harvesting yields environmental and economic benefits.

Source: Prepared by the authors (2026).

Based on the careful analysis of the data, conducted using the synthesis matrix, common elements were identified among the selected studies. Consequently, the authors were grouped into the following analysis categories: Cities, water vulnerability, and urban expansion; Integrated water management and technological innovation; Spatial planning, public policies, and water governance (Table 02).



Table 02 - Categorization of the Integrative Literature Review (ILR) articles

Authors	Categories
Aires <i>et al.</i> (2024); Costa <i>et al.</i> (2021); Medeiros, Rufino, and Aragão (2024).	Cities, water vulnerability, and urban expansion.
Aguiar <i>et al.</i> (2022); Araújo and Oliveira (2021); Calado <i>et al.</i> (2020); Medeiros, Rufino, and Aragão (2024); Silva, Brandão, and Ribeiro (2022).	Integrated water management and technological innovation.
Aguiar <i>et al.</i> (2022); Calado <i>et al.</i> (2020).	Spatial planning, public policies, and water governance.

Source: Prepared by the authors (2026).

5 DISCUSSION

The analyzed articles provided a comprehensive overview of water-related challenges in urban planning across Brazilian semi-arid regions. Based on the three analytical categories, a progression is observed that organizes from the empirical processes of cities (5.1) to the proposed technical solutions (5.2) and, finally, to the institutional and governance dimensions (5.3). This analytical framework allows for a progressive understanding of how water issues have been incorporated into urban planning in the Semi-arid region.

5.1 Cities, water vulnerability, and urban expansion

This category investigates how growth and land occupation patterns in semi-arid cities contribute directly to the region's water vulnerability, manifested in terms of scarcity, pollution, and hydrological regime instability.

The Brazilian Semi-arid region has become progressively more urbanized, with millions of inhabitants concentrated in human centers, a phenomenon also described by Fernandes and Felipe (2022). Within this dynamic, often disorderly and unplanned urban growth entails environmental and social damages (Costa *et al.*, 2021; Medeiros, Rufino, and Aragão, 2024), intensifying pressure on limited water resources.

The study by Medeiros, Rufino, and Aragão (2024) demonstrates that the sprawl of the urban footprint, observed in all analyzed municipalities, occurs predominantly through "edge expansion" and "peripheral expansion," reflecting an inefficient use of urban infrastructure.

Water vulnerability manifests as a direct impact on water bodies and erosive processes. Aires *et al.* (2024) highlight that occupation without strategic spatial planning



leads to vegetation cover degradation and an increase in erosive processes, especially in areas with low vegetation index and steep slopes.

This process was also observed by Almeida *et al.* (2020), who found, in the upper Pajeú River, that environmental degradation is linked to human activities that harm and pollute the environment, such as the removal of riparian vegetation and the discharge of untreated domestic sewage directly into the riverbed. The expansion of residential areas, in turn, leads to soil impermeabilization, which, according to Aires *et al.* (2024), contributes to soil erosion and reduced water quality.

This body of evidence allows for an understanding that water vulnerability is not restricted to an environmental condition, but it expresses the very way urban space is produced. As Corrêa (1995) points out, urban space results from the action of different agents with distinct interests, which implies an unequal occupation of the territory. In this sense, the degradation of water resources stems not only from a lack of planning, but from an urbanization model that unequally distributes infrastructure, risks, and access to water, as also highlighted by Santos (2018).

Regarding urban impacts, failures in spatial planning and drainage exacerbate vulnerability. Costa *et al.* (2021) analyzed Pau dos Ferros/RN and found that the absence or non-implementation of the master plan compromises runoff and water infiltration, resulting in waterlogging and flooding during periods of intense rainfall, especially in areas close to water bodies or in lower altitude areas.

Although studies on the Semi-arid region point to episodes of water supply collapse, as observed in Paraíba between 2012 and 2017 (Medeiros, Rufino, and Aragão, 2024), and supported by Fernandes and Felipe (2022) when describing a similar situation in Pau dos Ferros/RN (between 2012 and 2018), a paradox is observed: the precariousness of the supply did not prevent the development and expansion of cities. This result indicates that vulnerability is chronic, but social and economic dynamics, driven by the Municipal Human Development Index (HDI-M) and Gross Domestic Product (GDP), have found alternative, often precarious, means of water subsistence, perpetuating the cycle of disorderly occupation and pressure on water sources (Medeiros, Rufino, and Aragão, 2024).

This paradox indicates that water scarcity does not act as a limit to urban growth, but rather as an element subordinated to the logic of spatial production. Such dynamics reinforce the interpretation that urban planning, by failing to incorporate water as a structuring variable, allows for the continuation of territorial expansion processes

disconnected from environmental conditions. In this sense, the water crisis ceases to be a containment factor and comes to be incorporated as a precariously managed risk.

More than confirming theoretical reflections, the paradox exposes the very essence of contradictory urbanization as described by Corrêa (1995) and Santos (2018). Urban expansion occurring despite low water availability is not accidental, but the expression of a development model that, as criticized by Maricato (2001) and Rolnik and Klink (2011), prioritizes land value appreciation and the logic of capital over sustainability and the population's water security. It becomes clear, therefore, that the state's unequal role materializes by permitting growth that exacerbates the very vulnerability it should mitigate.

In short, the analysis of this category demonstrates that water vulnerability in the Semi-arid region stems not only from environmental limitations, but from the way urban space has been produced. The paradox between continuous city expansion and persistent water scarcity reveals that urban planning still inadequately incorporates the territory's hydrological specificities. Consequently, urban expansion tends to reproduce conditions of vulnerability, reinforcing the need to integrate water as a structuring element of spatial planning.

5.2 Integrated water management and technological innovation

This category addresses methodological tools and technological solutions—in terms of both modeling and planning as well as alternative infrastructure—that can contribute to water demand management and enhance resilience in the Semi-arid region.

The necessity to manage water demand in the face of crises has stimulated the use of sophisticated approaches. Araújo and Oliveira (2021) developed a hybrid approach (AHP-Entropy and flow network modeling) to simulate and prioritize water demand management alternatives for the Eptácio Pessoa reservoir in Paraíba (PB).

This methodology supports decision-making by identifying crucial criteria, such as human supply and irrigation needs, maintenance of the established target volume for the reservoir, and consumption reduction. The results of the study by Araújo and Oliveira (2021) suggest prioritizing sustainability-oriented measures, including water-saving mechanisms, reuse, loss reduction, and irrigation efficiency.

Although these solutions represent significant advances, their effectiveness encounters structural limits when disconnected from integrated urban policies. As Souza (2004) argues, urban planning cannot be reduced to technical solutions; it must consider the

social and institutional relations that shape the territory. In this sense, the adoption of technologies such as water reuse and rainwater harvesting tends to operate as isolated measures, incapable of tackling the structural inequalities that characterize water access in the Semi-arid region.

In terms of infrastructure, decentralizing supply through alternative solutions is fundamental to resilience. Silva *et al.* (2022) analyzed the potential for rainwater harvesting (RWH) in buildings within the Semi-arid region (Campina Grande/PB) and demonstrated the feasibility of these systems even under low rainfall, thereby contributing to the reduction of potable water consumption and alleviating pressure on water bodies. Calado *et al.* (2020) also highlight the role of the Environmental Plan for the Conservation and Use of the Artificial Reservoir Surrounding Area (PACUERA) of the Epitácio Pessoa Reservoir, which designates areas for multiple uses, such as tourism and leisure, thereby diversifying spatial management.

Medeiros, Rufino, and Aragão (2024) point out that during the 2012–2017 drought, the population relied on multiple alternative sources, including reservoirs, wells, rainwater, and water trucks. Water distribution via water trucks became consolidated through a public policy coordinated by the Ministry of Integration and Regional Development, which aims to ensure water access across several areas of the northeastern semi-arid region directly affected by drought-especially rural areas while also becoming an alternative for cities facing water scarcity.

The integration of these solutions, however, is hindered by the limitations and inconsistencies of the data available during drought periods, given that these volumes were not recorded in official databases, such as the National Information System on Sanitation (SNIS), thereby limiting the ability to forecast realistic future scenarios and to accurately correlate consumed volume with urbanized area (Medeiros, Rufino, and Aragão, 2024).

As a result, planning relies on incomplete information, compromising public policy formulation and future scenario forecasting. This represents a disconnect between lived reality and formal management instruments.

In addition to harvesting, the focus must be on rational use. Aguiar *et al.* (2022) mention that the Capibaribe Hydro-Environmental Plan included programs for rational water use in industries, as well as the implementation of pilot wastewater reuse units, indicating that reuse is a recognized strategy, although effective implementation remains challenging due to a lack of resources and clear definition of responsibilities. In line with these findings, Almeida *et al.* (2020) also advocate for the strengthening of agroecological practices and

technical assistance to ensure the sustainability of agricultural production and proper water management.

These results corroborate the argument of Souza (2004), according to which urban planning and management must pursue social justice and quality of life. By integrating technological innovation and environmental management, the analyzed studies point to concrete pathways for realizing planning as a public and inclusive instrument, as advocated by Maricato (2001).

It is concluded that the incorporation of technological innovations represents an important step forward for water management in the Semi-arid region, but its effectiveness depends on integration with urban planning and consistent public policies. In isolation, these solutions tend to respond to supply crises in a ad hoc manner, without addressing the institutional and informational weaknesses that limit the construction of more resilient cities.

5.3 Spatial Planning, Public Policies, and Water Governance

This category examines institutional and regulatory frameworks especially Municipal Master Plans (PDM) and water governance necessary for integrated management, highlighting the weak coordination between the municipal (territorial) and river basin (water) levels. As discussed in the theoretical framework, authors such as Maricato (2001) and Rolnik and Klink (2011) point to the state as a central and contradictory agent in urban planning, at times mediating and at other times reproducing inequalities. The results of the empirical studies analyzed confirm this ambiguity.

The National Water Resources Policy (PNRH) establishes the integration between water management and land-use management, and river basin plans should provide clear guidelines for PDMs regarding urban expansion, water source protection, and sanitation (Calado *et al.*, 2020).

However, studies demonstrate the fragility of this integration. Aguiar *et al.* (2022) found that, despite convergences in actions such as rural sanitation and the recovery of degraded areas, there is weak integration between the Capibaribe River Basin Hydro-Environmental Plan and the PDMs of Santa Cruz and Taquaritinga. A "negative alignment" (*sintonia negativa*) is observed, characterized by the neglect of environmental sustainability in guidelines focused on textile cluster activities, which the ongoing PDMs failed to adequately correct (Aguiar *et al.*, 2022). Furthermore, the analyzed PDMs do not provide mechanisms for implementing guidelines on environmental issues (Calado *et al.*, 2020).



Calado *et al.* (2020) complement this view by analyzing the PDMs surrounding the Epitácio Pessoa Reservoir. According to the authors, although the municipalities of Boqueirão/PB and Barra de São Miguel/PB have zoning regulations aimed at protecting the reservoir, the municipality of Cabaceiras/PB lacks more specific actions and a regulatory framework for the surrounding area. For Calado *et al.* (2020), municipalities must expand their understanding of water resources management and incorporate the river basin concept into integrated management.

Although the studies included in this review highlight weaknesses in the integration between urban planning and water management, Fernandes and Felipe (2022) illustrate a similar situation when analyzing the case of Pau dos Ferros/RN, where water management was not among the urban planning priorities. In the face of growing water demand and low precipitation since 2010, there is no record of strategic planning aimed at rationalizing water use from the Pau dos Ferros Dam/RN (Fernandes and Felipe, 2022).

More than an operational failure, this institutional fragmentation expresses how the state operates in the production of urban space. According to Lefebvre (1991), the state, although a mediator, tends to reproduce existing social relations, which, in the analyzed context, manifests as an inability to coordinate sectoral policies. In this context, the lack of integration among agents is not merely a technical problem, but a reflection of disputes and interests that cut across spatial management.

This interpretation is supported by Fernandes and Felipe (2022), who demonstrate that the reservoir management model involves multiple agents the National Department of Works Against Droughts (DNOCS), National Water and Sanitation Agency (ANA), Water Management Institute of the State of Rio Grande do Norte (IGARN), and Water and Sewage Company of Rio Grande do Norte (CAERN). However, no integration among these agents is observed, resulting in financial losses as well as environmental and social impacts.

A concrete example is the lack of implementation of the Environmental Plan for the Conservation and Use of the Artificial Reservoir Surrounding Area (PACUERA) a legal instrument designed to regulate land use surrounding reservoirs, included in the PDMs of Boqueirão and Barra de São Miguel, but not yet executed (Calado *et al.*, 2020). This gap between regulatory provision and practical execution convincingly exemplifies the contradictory role of the state (Corrêa, 1995). Rather than a simple governance failure, this inoperability reflects what Rolnik (2015) describes as the "war of places" (*guerra dos lugares*), in which planning instruments are captured by market logics that override environmental protection and the collective interest.

Thus, the non-execution of PACUERA is not a mere administrative lapse, but a symptom of a model that, in practice, creates normative instruments yet fails to enforce them, perpetuating the very vulnerability it ought to combat. For Calado *et al.* (2020), the inoperability of this instrument hinders the consolidation of integrated management among neighboring municipalities.

This mismatch between the existence of the instrument and its non-implementation highlights a recurring pattern in Brazilian urban planning: the dissociation between regulation and practice. Consequently, planning instruments do not function as effective mechanisms for territorial regulation, aligning with what Maricato (2001) identifies as the vulnerability of planning when faced with the concrete dynamics of urbanization.

The presented evidence reinforces Lefebvre's (1991) critique that the state, despite acting as a mediator of social relations in space, frequently legitimizes dominant interests, hindering genuinely democratic urban management. This confirms Santos' (2018) diagnosis regarding the selectivity of public policies, which tend to reproduce territorial hierarchies and inequalities.

In summary, the challenge of spatial planning and water governance lies in transcending fragmented management. Integration must be pursued during plan formulation, ensuring the active participation of all stakeholders and guaranteeing that the right to a sustainable city prevails over sectoral interests.

Finally, the analysis of water governance reveals a disconnect between the existence of normative instruments and their effective implementation. The fragile coordination between master plans and river basin plans demonstrates that water is still incorporated into urban planning in a fragmented manner, reinforcing the need to integrate it as a structuring element of spatial planning.

6. FINAL CONSIDERATIONS

The analyzed studies revealed that, although water availability is a structuring factor of the territory, its effective integration into urban planning remains incipient, confirming the gap identified in the literature. The results were organized into three categories that progressively highlight the multiple dimensions of the issue. The first category showed that disorderly urban growth and inappropriate land occupation have intensified water vulnerability, reflecting the lack of planning and territorial inequality.



The second category highlighted management and technological innovation initiatives aimed at rationalizing water use such as reuse, rainwater harvesting, and scenario modelling - while also pointing out limitations stemming from data scarcity and institutional fragility. The third category demonstrated that, despite existing legal instruments such as Municipal Master Plans and PACUERA, the integration between water management and spatial planning still relies on more coordinated and participatory governance.

The study contributes to the academic debate by articulating recent evidence with critical approaches to urban planning, reaffirming its political and unequal character. It also provides theoretical, practical, and social insights by highlighting the urgency of integrating water management and spatial planning as a foundation for more sustainable cities in the Semi-arid region.

As an agenda for future research, it is recommended to evaluate the effectiveness of management instruments in integrating water and urban planning. Ultimately, the findings of this review point not only to a management gap, but to an ethical imperative: that of aligning the Right to the City with respect for the hydrological limits of one of the country's most vulnerable territories, the Brazilian semi-arid region.

ACKNOWLEDGMENTS

This work was supported by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brasil (CAPES) – Finance Code 001 and the Fundação de Apoio à Pesquisa do Estado do Rio Grande do Norte (FAPERN), through the RN Mais Científico Program. Rafaela Moreira Gurgel da Costa is a CAPES scholarship recipient, and Taynan Araújo de Oliveira is a FAPERN scholarship recipient.

REFERENCES

- AB'SABER, A. N. Caatingas: o domínio dos sertões secos. In: **Os domínios de natureza no Brasil: potencialidades regionalistas**. São Paulo: Ateliê Editorial, 2003. p. 83-101.
- AGUIAR, W. J. de; BRAGA, R. A.P.; SELVA, V. S. F.; SOBRAL, M. do C. M. Integração entre planos diretores municipais e planos de bacias hidrográficas no Semiárido Nordeste: perspectivas para a governança. **Revista Brasileira de Geografia Física**, Niterói, v. 15, n. 1, p. 487-502, 2022. DOI: 10.26848/rbgf.v15.1.p487-502. Disponível em: <https://periodicos.ufpe.br/revistas/rbgfe/article/view/251132>. Acesso em: 24 set. 2025.

AIRES, A. de A; DUNGA DA COSTA, J.; MEDEIROS BEZERRA, J.; ALVES, A. Análise integrada da paisagem na Microbacia Hidrográfica da barragem de Pau dos Ferros, Rio Grande do Norte. **Revista Brasileira de Geografia Física**, Niterói, v. 17, n. 5, p. 3682-3699, 2024. DOI: 10.26848/rbgf.v17.5.p3682-3699. Disponível em: <https://periodicos.ufpe.br/revistas/rbgfe/article/view/260064>. Acesso em: 24 set. 2025.

ALMEIDA, S. V. G. de; OLIVEIRA, D.A. H.C. de; SOUSA RÊGO, Veneziano Guedes de; MEDEIROS, Felipe Silva de; FARIAS, Soahd Arruda Rached; LIMA, J. Rodrigues de. Diagnóstico ambiental no Rio Pajeú, Itapetim, Pernambuco: contribuições educacionais para o desenvolvimento sustentável. **Revista Verde de Agroecologia e Desenvolvimento Sustentável**, Pombal, v. 15, n. 2, p. 168-176, 2020. DOI: 10.18378/rvads.v15i2.6518. Disponível em: <https://www.gvaa.com.br/revista/index.php/RVADS/article/view/6518>. Acesso em: 19 set. 2025.

ARAÚJO, M. D. de; OLIVEIRA, R. de. A hybrid approach associating flow network modeling with AHP Entropy for simulating and ranking water-demand management alternatives. **Revista Ambiente e Água**, Taubaté, v. 16, n. 2, e2627, 2021. Disponível em: <https://www.scielo.br/j/ambiagua/a/vY3SBpdD8PY9PPNRjTVTSMH/?format=html&lang=en>. Acesso em: 19 set. 2025.

BARBOSA, S. F. P.; SOUSA, M. L. M. de. Desafios do desenvolvimento de pequenas cidades no Semiárido: o caso de Água Nova – RN. **Revista da Casa da Geografia de Sobral**, Sobral, v.27, n.3, p. 100-117, 2025. Disponível em: <https://rcgs.uvanet.br/index.php/RCGS/article/view/1079>. Acesso em: 13 jul. 2026.

BARDIN, L. **Análise de conteúdo**. São Paulo: Edições 70, 2016.

BRASIL. **Constituição da República Federativa do Brasil de 1988**. Brasília: Presidência da República, 1988. Disponível em: https://www.planalto.gov.br/ccivil_03/constituicao/constituicao.htm. Acesso em: 26 set. 2025.

BRASIL. **Lei nº 10.257, de 10 jun. 2001**. Regulamenta os arts. 182 e 183 da Constituição Federal, estabelece diretrizes gerais da política urbana e dá outras providências. Brasília, DF: Diário Oficial da União, 2001. Disponível em: https://www.planalto.gov.br/ccivil_03/leis/leis_2001/l10257.htm. Acesso em: 26 set. 2025.

CALADO, T. de O.; SOBRAL, M. do C.; CARDOSO, A. Silva; MARQUES, E.A. Tavares. Planos diretores na articulação da gestão de recursos hídricos com o uso do solo no entorno de reservatórios. **Revista Brasileira de Geografia Física**, Niterói, v. 13, n. 3, p. 958-972, 2020. DOI: 10.26848/rbgf.v13.3.p958-972. Disponível em: <https://periodicos.ufpe.br/revistas/rbgfe/article/view/242770>. Acesso em: 25 set. 2025.

CORREIA, Roberto Lobato. **O espaço urbano**. 3. ed. São Paulo: Ática, 1995.

COSTA, T. T. da; BEZERRA, J. M.; MOURA, B. M. Duarte; RÊGO, A. T. Alves do; SOUZA, R. S.; ROQUE, F. S.; QUEIROZ JÚNIOR, A.B. de; COSTA, H. C. G.; NOBRE, S. B.; LIMA, R. I. B.R. L. Índice de satisfação de drenagem urbana na zona urbana de Pau



dos Ferros/RN. **Revista Brasileira de Geografia Física**, Niterói, v. 14, n. 1, p. 229-245, 2021. DOI: 10.26848/rbgf.v14.1.p229-245. Disponível em: <https://periodicos.ufpe.br/revistas/rbgfe/article/view/247039>. Acesso em: 25 set. 2025.

CUNHA, P. L. P.; CUNHA, C. S.; ALVES, P. F. Manual revisão bibliográfica sistemática integrativa: a pesquisa baseada em evidências. Belo Horizonte: Grupo Ânima Educação, 2014.

FERNANDES, C.; ALVES FELIPE, J. L. Demanda, oferta e a gestão hídrica da barragem de Pau dos Ferros/RN. **Acta Geográfica**, Boa Vista, v. 16, n. 42, p. 101-119, 2022. DOI: 10.18227/2177-4307.acta.v16i42.5439. Disponível em: <https://revista.ufr.br/actageo/article/view/5439>. Acesso em: 19 set. 2025.

HASSANE, A. L.; MOURA, N. S.V.. Instrumentos legais e institucionais para o planejamento urbano e ambiental em resposta às mudanças climáticas na cidade de Beira-Moçambique. **Para Onde!**, Porto Alegre, v.20, n.1, p.32-57. Disponível em: <https://seer.ufrgs.br/index.php/paraonde/article/view/146934/98713>. Acesso em: 13 jul. 2026.

LEFEBVRE, H. **O direito à cidade**. São Paulo: Centauro, 2001.

MARICATO, E. Planejamento para a crise urbana no Brasil. In: **Brasil, cidades:** alternativas para a crise urbana. Petrópolis, RJ: Vozes, 2001.

MEDEIROS, C K; RUFINO, I A. A.; ARAGÃO, R. Consumo de água e crescimento urbano: análises espaciais e relações possíveis. **Revista Brasileira de Gestão Urbana**, v. 16, e20230039, 2024. DOI: 10.1590/2175-3369.016.e20230039. Disponível em: <https://www.scielo.br/j/urbe/a/hCKRTrCgijh4Q57W775Kcyx/?format=html&lang=pt>. Acesso em: 18 set. 2025.

MINISTÉRIO DAS CIDADES. **Estatuto da Cidade e Legislação Correlata**: Lei nº 10.257, de 10 de julho de 2001. 2. ed. Brasília, DF: Senado Federal, Subsecretaria de Edições Técnicas, 2002. Disponível em: <http://www.geomatica.ufpr.br/portal/wp-content/uploads/2015/03/Estatuto-da-Cidade.pdf>. Acesso em: 26 set. 2025.

ONU – ORGANIZAÇÃO DAS NAÇÕES UNIDAS. **Mundo tem mais de 2,1 bilhões de pessoas sem água potável e 3,4 bilhões sem saneamento**. 26 ago. 2025. Disponível em: <https://news.un.org/pt/story/2025/08/1850796>. Acesso em: 20 set. 2025.

PAGE, M. J.; MOHER, D.; BOSSUYT, P. M.; BOUTRON, I.; HOFFMANN, T. C.; MULROW, C. D.; SHAMSEER, L.; TETZLAFF, J. M.; AKL, Elie A.; BRENNAN, Sue E.; CHOU, R.; GLANVILLE, J.; GRIMSHAW, J. M.; HRÓBJARTSSON, A.; LALU, M.M.; LI, T.; LODER, E. W.; MAYO-WILSON, Evan; McDONALD, S.; McGUINNESS, Luke A.; STEWART, L. A.; THOMAS, J.; TRICCO, A.C.; WELCH, V. A.; WHITING, P.; McKENZIE, J. E. RISMA 2020 explanation and elaboration: updated guidance and exemplars for reporting systematic reviews. **The BMJ**, London, v. 372, n. 160, p. 1-67, 2021. Disponível em: <https://www.bmj.com/content/372/bmj.n160>. Acesso em: 26 set. 2025.

PUJADAS, R.; FONT, J. **Ordenación y planificación territorial**. Madrid: Síntesis, 1998.



ROLNIK, R. **Guerra dos lugares**: a colonização da terra e da moradia na era das finanças. São Paulo: Boitempo, 2015.

ROLNIK, R.; KLINK, J. Crescimento econômico e desenvolvimento urbano: por que nossas cidades continuam tão precárias? **Novos Estudos CEBRAP**, n. 89, p. 89-109, 2011.

SANTOS, M. **A urbanização brasileira**. 5. ed. São Paulo: Editora da Universidade de São Paulo, 2018.

SILVA, M. B. M.; BRANDÃO, I.A. de P.; RIBEIRO, M. M. R. Feasibility, seasonality and reliability of rainwater harvesting in buildings of a university in Campina Grande, Paraíba. **Revista Brasileira de Recursos Hídricos**, Porto Alegre, v. 27, e17, 2022. DOI: 10.1590/2318-0331.272220210127. Disponível em: <https://www.scielo.br/j/rbrh/a/YRRzdFyVBQ69p6HD4TpfvRG/?lang=en>. Acesso em: 18 set. 2025.

SOUZA, M. L. **Mudar a cidade**: uma introdução crítica ao planejamento e à gestão urbanos. 3. ed. Rio de Janeiro: Bertrand Brasil, 2004.

SOUZA, M. T. de S.; SILVA, M. D. da; CARVALHO, R. de. Revisão integrativa: o que é e como fazer? **Einstein**, São Paulo, v. 8, n. 1, p. 102-106, 2010. DOI: 10.1590/S1679-45082010RW1134. Disponível em: <https://www.scielo.br/j/eins/a/ZQTBkVJZqcWrTT34cXLjtBx/?lang=pt>. Acesso em: 21 set. 2025.

SOUZA, S. D. G. de; SOUZA, A.C.N.de; SOUSA, M.L. M. de. Disponibilidade hídrica e a dinâmica urbano-regional do Semiárido brasileiro. **Confins**, v. 57, 2022. DOI: <https://doi.org/10.4000/confins.50094> . Disponível em: <https://journals.openedition.org/confins/50094>. Acesso em: 21 set. 2025.

STERN, C.; JORDAN, Z.; M., A. Developing the review question and inclusion criteria. **AJN - American Journal of Nursing**, Philadelphia, v. 114, n. 4, p. 53-56, 2014. DOI: 10.1097/01.NAJ.0000445689.67800.86. Disponível em: https://journals.lww.com/ajnonline/fulltext/2014/04000/developing_the_review_question_and_inclusion.30.aspx. Acesso em: 27 set. 2025.

TORONTO, C. E. Overview of the integrative review. In: TORONTO, C.E.; REMINGTON, R. (orgs.). **A step-by-step guide to conducting an integrative review**. Cham: Springer, 2020. p. 1-9.

