

Management of Conventional and Non-Conventional Water Sources: A Systematic Literature Review

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Abstract

A global transition in water management is currently underway, marked by the declining reliability of conventional sources and the accelerated adoption of non-conventional alternatives. This shift is driven by escalating pressures from climate change, population growth, and freshwater overexploitation. While the literature on management of water sources (WSs) is extensive, empirical clarity on Hybrid Water Systems Management (HWSM)—the integration of conventional and non-conventional WSs within a single system—remains limited. The present study addresses this gap through a systematic literature review using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) approach, which ensures methodological transparency and applicability. From over 9000+ peer-refereed articles retrieved from three major scientific databases (ScienceDirect, Scopus, and Web of Science Core Collections), published between 1999 and 2024, 44 studies were identified as the most relevant and consequently analyzed. The literature review refines the classification of WSs, distinguishing conventional sources, such as groundwater and surface water, from non-conventional alternatives, such as desalinated water, treated wastewater, gray water, and rainwater harvesting. The analysis also indicates that non-conventional WSs are now more prominent in the literature than conventional ones. Overall, the present study demonstrated that modern water management strategies increasingly emphasize optimization and circular reuse. In contrast, earlier approaches tend to focus more on water conservation and economic efficiency. The literature also indicates a gradual shift from traditional supply-dominant models toward integrated, cost-effective, and sustainability-oriented approaches that combine multiple sources and advanced allocation techniques.

Keywords: management; water; conventional; non-conventional; systematic literature review



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1. Introduction

Water is an essential resource for human survival, economic development, and environmental sustainability [1]. Furthermore, the United Nations' (UN) Sustainable Development Goal 6 [2] establishes access to safe water as a human right, fundamental to health, dignity, and reducing inequalities worldwide [3]. However, the growing global population, industrial expansion, and climate change are intensifying water scarcity [4–7]. About 1.9 billion people already live in areas with potentially severe water shortages [8]. This number is expected to rise to approximately 3 billion people by 2050, placing immense pressure on available water resources [9]. As a result, water sources (WSs)—both conventional and

non-conventional—have become a focus of interest and have attracted significant attention from researchers [10–17], as well as ordinary Internet users (Figure 1).

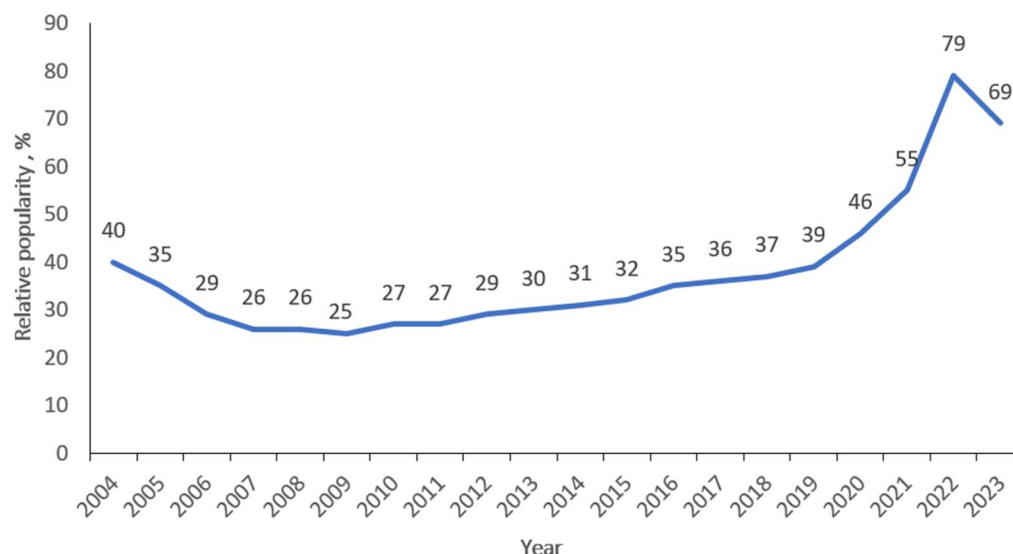


Figure 1. Web search interest in the “water sources” topic—relative popularity of queries in 2004–2023 (Source: Calculated using data from Google Trends [18]). Note: The data indicates trends in public interest, highlighting periods of increased attention to specific water management topics. Relative query popularity was calculated as the proportion of search queries for a given topic relative to the total search volume for all topics over the same period, normalized to a scale from 0 to 100 (low (0) to high (100)), indicating the relative level of interest in the topic.

Traditionally, conventional WSs, such as surface water (e.g., lake water, river water, reservoirs) and groundwater (e.g., spring water, well water), have been the primary means of meeting domestic, agricultural, and industrial water needs [12,19]. However, these WSs are increasingly under stress due to over-extraction, pollution, and changing precipitation patterns [20–22].

In response, non-conventional WSs (e.g., desalinated water, treated wastewater, grey-water, rainwater) have emerged as viable alternatives to supplement water supplies [23,24]. Desalination, for example, has become necessary in arid and semi-arid regions where the natural availability of fresh water is limited [25,26]. Similarly, wastewater treatment and reuse contribute to a circular water economy, offering opportunities to reuse water for irrigation, industry, and even potable use [27,28].

Despite these advancements, integrating conventional and non-conventional WSs within a single management system remains a serious challenge. The effectiveness and sustainability of such systems depend on many factors, including economic feasibility, energy consumption, physical/technological constraints, public perception, and regulatory constraints [29–31]. Moreover, water resource management is often fragmented, with different institutions separately managing surface water, groundwater, desalination, and wastewater reuse, leading to inefficiencies and conflicts in allocation strategies [32,33]. Thus, a comprehensive understanding of how these diverse sources can be integrated to optimize water security is crucial.

In a recent study, Gárate-Ríos et al. [34] reviewed the water resource management literature from 2016 to 2021 across multiple databases, identifying an urgent need for new management paradigms that integrate economic, social, and environmental pillars. Similarly, Sriyono [35] identified five dominant research topics based on Scopus data available as of 2020: water resources, water quality, governance, sustainability, and climate

change. These topics reflect a growing call to expand the scope of water management to include socio-environmental systems.

Expanding the scope, Ciampittiello et al. [36], analyzing the literature from 1990 to 2022, stressed the importance of integrating ecosystem protection and restoration within water governance frameworks. This ecological emphasis is also supported by emerging approaches like nature-based solutions and circular water systems, which aim to align water management with environmental sustainability.

Agricultural water use, which globally accounts for over 70% of freshwater withdrawals [21], has been a prominent concern. Hasan et al. [37] reviewed the literature from 2016 to 2023 and identified trends in sustainable water management, including the adoption of water-efficient technologies (e.g., drip irrigation and mulching), transboundary cooperation, and participatory governance. In addition, Rbaibi & SahibEddine [38] identified that effective resolution of interrelated WS challenges is closely linked to integrated management through the Water–Energy–Food Nexus approach.

While numerous studies examined the literature on WSs, existing literature reviews that examine the management of WSs from different perspectives do not focus on the unique characteristics of combined conventional and non-conventional water systems management. To date, most bibliographic literature reviews on WS management remain subjective in terms of document selection, relying on qualitative synthesis or focusing on a single, narrowly defined aspect of the topic. Thus, a holistic approach based on an interdisciplinary literature review is needed to identify the full range of studies focused on integrating conventional and non-conventional water sources within a single management system, hereafter referred to as Hybrid Water Systems Management (HWSM). However, to the best of our knowledge, no systematic literature review of this type has been published to date.

The present study aims to fill this gap by identifying existing research on HWSM, with a focus on the joint management of conventional and non-conventional water sources within a single integrated system.

To achieve this goal, this study adopts the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) methodology. Unlike traditional approaches such as content analysis [39], co-citation analysis [40], or citation-based clustering [41], which can involve subjective decisions and limited scope, PRISMA provides a structured, fully replicable framework for identifying and selecting relevant studies [42,43]. It utilizes Boolean search queries to retrieve studies from the literature systematically [44] and employs tools like Covidence for screening and data extraction, thereby reducing potential selection bias and enhancing the reliability of the findings [43,45]. Yet, to the best of our knowledge, no studies carried out to date have attempted to use the PRISMA methodology in order to determine the comprehensive list of existing research on the management of conventional and non-conventional water sources within a single management system.

The review identifies the main conventional WSs—groundwater, surface water, and fresh/potable water (used in cases where studies refer to drinking-quality water without specifying whether it originates from groundwater or surface water)—alongside eight non-conventional alternatives, such as desalinated water, treated wastewater, gray water, and rainwater. As the present analysis shows, non-conventional water systems are now more prominent in the literature than conventional ones, indicating a significant shift in water management practices. Modern water strategies increasingly emphasize optimization and reuse, particularly in high-income and water-scarce regions. Overall, trends indicate a shift away from traditional supply-dominant models toward integrated, cost-effective, and sustainability-driven approaches that combine multiple sources and advanced allocation methods.

The remainder of the paper is structured as follows: Section 2 outlines our research approach. Section 3 presents the key findings, highlighting the latest trends and challenges in hybrid water resource management. Section 4 discusses the results of the analysis. Section 5 offers the conclusions, discusses the limitations and suggests recommendations for future research.

2. Materials and Methods

According to the PRISMA protocol guidelines [43], this review consists of a structured sequence of steps: (1) selection of search keywords; (2) selection of search parameters; (3) building and tailoring the search string; (4) conducting the initial search and eligibility assessment, and (5) evaluation of results. A detailed discussion of each step is provided in the subsections that follow.

2.1. Selection of Search Keywords

Following our definition of the search topic as “Management of conventional and non-conventional water sources”, the following search components were a priori defined: the search object (“Water Source *”); alternative terms (“Conventional water *”, “Non-conventional water *”, “Water Supply System *”, “Water Resource System *”); elements (“Surface water *”, “Groundwater *”, “Brackish water *”, “Effluent”, “Greywater”, “Reclaimed wastewater”, “Harvested rainwater”, “Atmospheric Water *”, “Desalinated water *”, “Urban runoff *”). Within this structure, elements represent a subset of the search components that capture specific categories of conventional and non-conventional water. To further refine the search and exclude irrelevant results, we also defined exclusion terms not directly related to the search topic: “Biodiversity”, “Ecology”, “Culture *”, “Hydrodynamic *”, “Design *”, “Energy *”, “Health *”, “Climate”, and “Educat *”, where * represents a wildcard search term. The main search terms used in the present systematic literature review are shown in Figure 2.

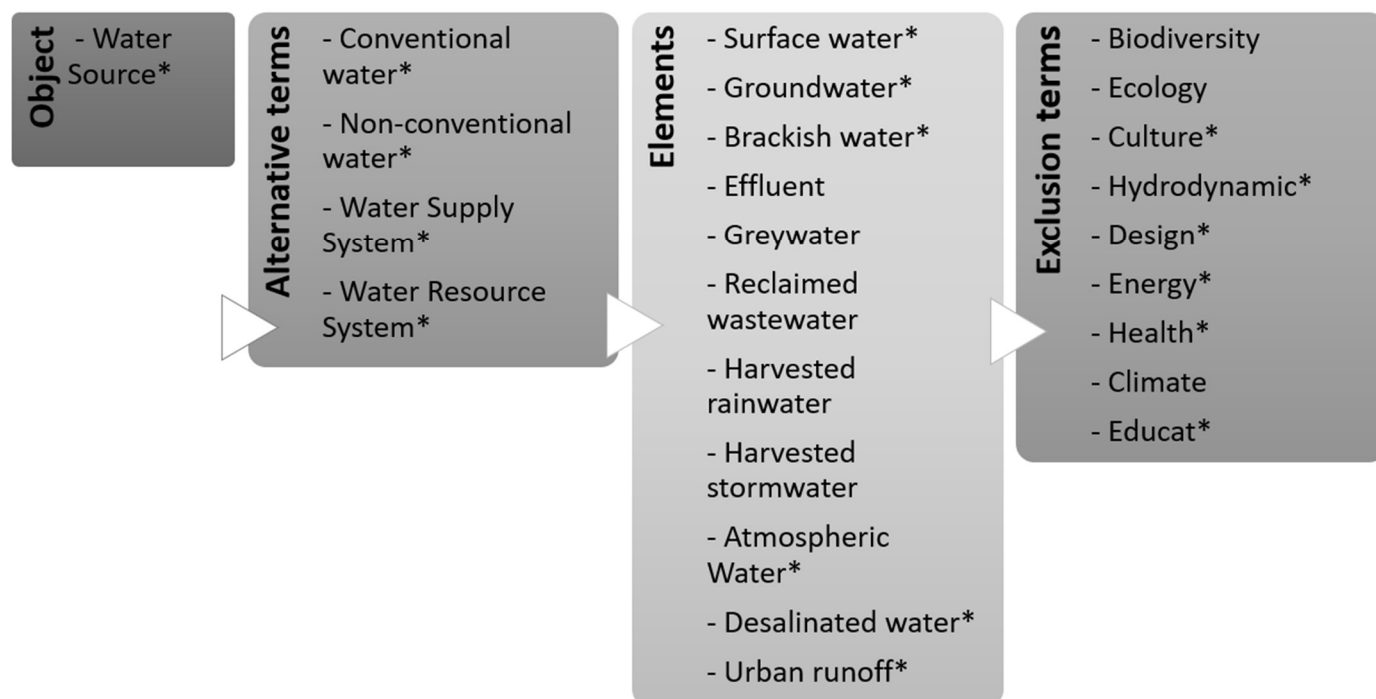


Figure 2. Search terms used in the systematic literature review. Note: The figure presents the study selection criteria, illustrating the scope and focus areas of the literature review; * represents a wildcard search.

2.2. Selection of Search Parameters

A recent study by Gusenbauer & Gauster [46], based on an analysis of 404 systematic literature reviews and meta-analyses, found that only a portion of popular academic databases meet the requirements for systematic literature reviews and are suitable for evidence synthesis using adapted PRISMA and Cochrane Handbook guidelines. Of the 101 academic databases available, the most frequently used and adopted for systematic literature reviews in our research field are Web of Science Core Collection, Scopus, APA PsycINFO, and ScienceDirect [34,35,37,38,47,48]. Therefore, ScienceDirect, Scopus, and Web of Science Core Collections were selected as the main databases for the present study.

According to Zare et al. [49], the roots of integrated water resources management and assessment can be traced back to previous decades, but the field began to expand significantly around the 2000s and gained popularity among researchers, especially since 2009 [47]. As a result, the present study covers the period from 1999 to 2024. However, the effective search period is limited to 2002–2024, as no relevant studies that focus on the management of HWSM were found before 2002.

The literature review includes only original research articles published in English, the dominant language in modern scientific communication [45,50]. However, our study excludes “grey literature” (e.g., government reports, policy statements, professional newsletters, issues papers), focusing on articles published in peer-refereed scientific journals [51]. In addition, we do not limit the search by the organizational affiliation of the authors, the number of co-authors, sources of financial support, or the geographical location of publication, as such criteria were considered irrelevant for the purposes of this study.

2.3. Building and Tailoring the Search String

The initial search employed Boolean operators (“AND”, “OR”, and “NOT”) to structure the queries [52]. Due to individual differences in search functionalities across academic databases [53–55], the search syntax was customized for each database individually (see details in Appendix A).

2.4. Conducting the Initial Search and Eligibility Assessment

The initial search was performed on 10 January 2025. Following the initial identification, the titles and abstracts of the pre-identified publications were screened, and duplicate items, along with publications not directly related to the subject of research, were excluded from further consideration:

- Studies on flood risk management unrelated to WS management;
- Studies on water demand forecasting that are not linked to specific WSs;
- Studies of societal inequality in access to water;
- Studies on societal behavior regarding water usage;
- Studies on renewable energy unrelated to water management;
- Studies of pricing in water markets;
- Studies of AI-powered water quality index prediction;
- Studies related to climate change impacts on water resources;
- Studies on specific ICT technologies, including data collection, data Storage, data analysis, data protection, and cybersecurity in water systems.

2.5. Evaluation of Results

The application of exclusion criteria resulted in 165 publications being selected for detailed full-text analysis. This stage allowed us to filter out publications that did not report the required elements, resulting in 44 articles for further categorization and analysis.

Following this, essential information was extracted from the pre-identified publications, including the publication year, geographical context, and research domain.

3. Results

3.1. PRISMA Flow Diagram

Figure 3 presents the PRISMA flow diagram, detailing the identification, screening, and inclusion of records at each stage of the analysis. The initial search yielded 9294 publications, which were subsequently narrowed down to 44 publications selected for the current review. For the next step, Figures 4 and 5 visualize the keywords' co-occurrence as determined by the VOSviewer tool [56], where keywords are represented as nodes grouped into clusters. Larger nodes in Figures 4 and 5 denote terms that occur more frequently in the reviewed publications.

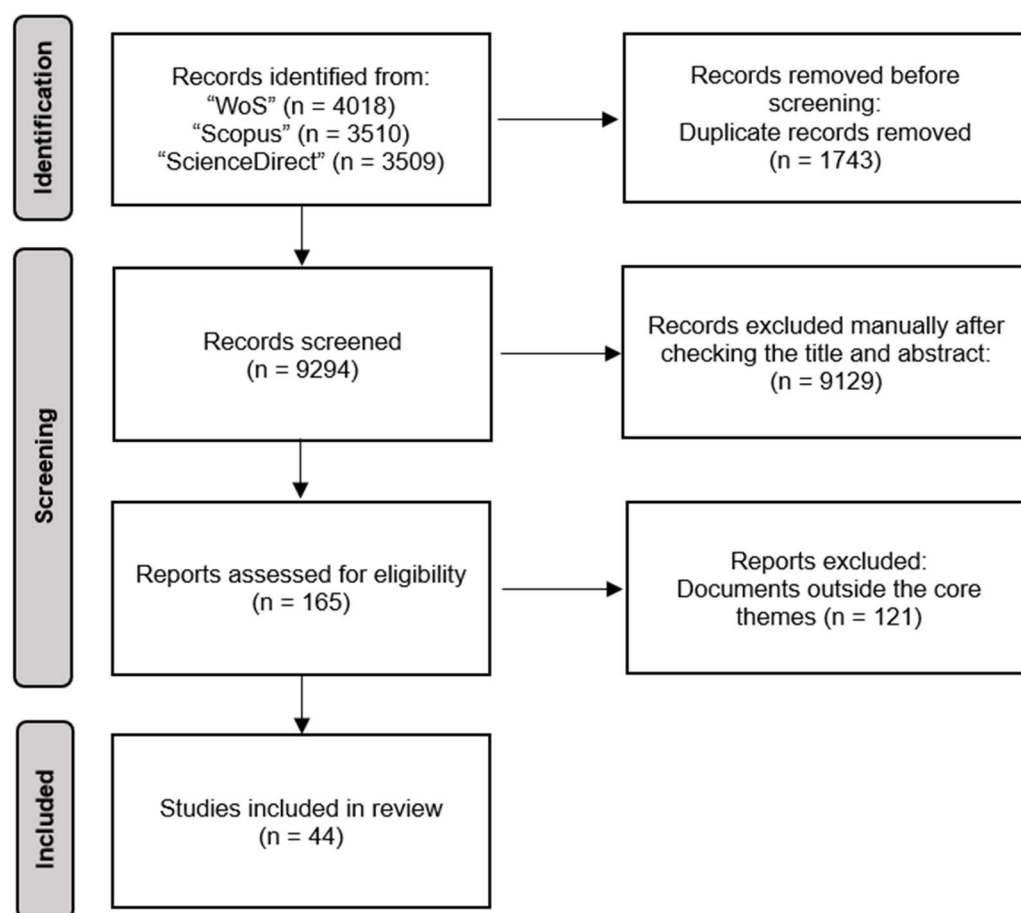


Figure 3. PRISMA flow diagram showing the systematic process of article screening from initial identification to final inclusion. Note: The search was performed in January 2025; the diagram is generated using the PRISMA2020 R package [57].

As Figure 4 shows, four clusters were identified: (1) a red cluster focused on groundwater and water conservation, (2) a green cluster on water management, optimization, and wastewater reuse, (3) a yellow cluster on irrigation, economics and agriculture, and (4) a blue cluster focusing on uncertainty, quality, and wastewater. "Desalination" is the central term, strongly linked to groundwater, agriculture, economics, and treated wastewater, indicating its integrative role in the management of non-conventional WSs.

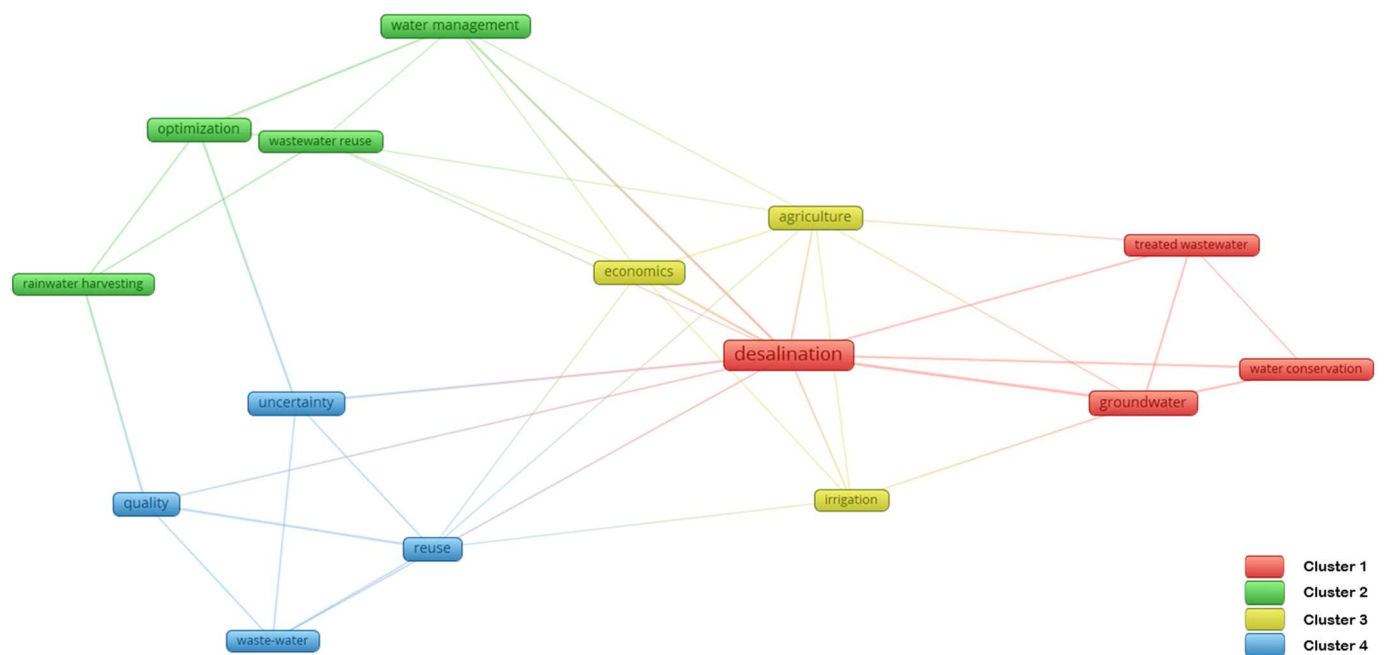


Figure 4. A network visualization that highlights the relationships and co-occurrence of keywords across the reviewed literature, illustrating major research clusters and their relationships. Note: The diagram is generated with the VOSviewer software, version 1.6.15.

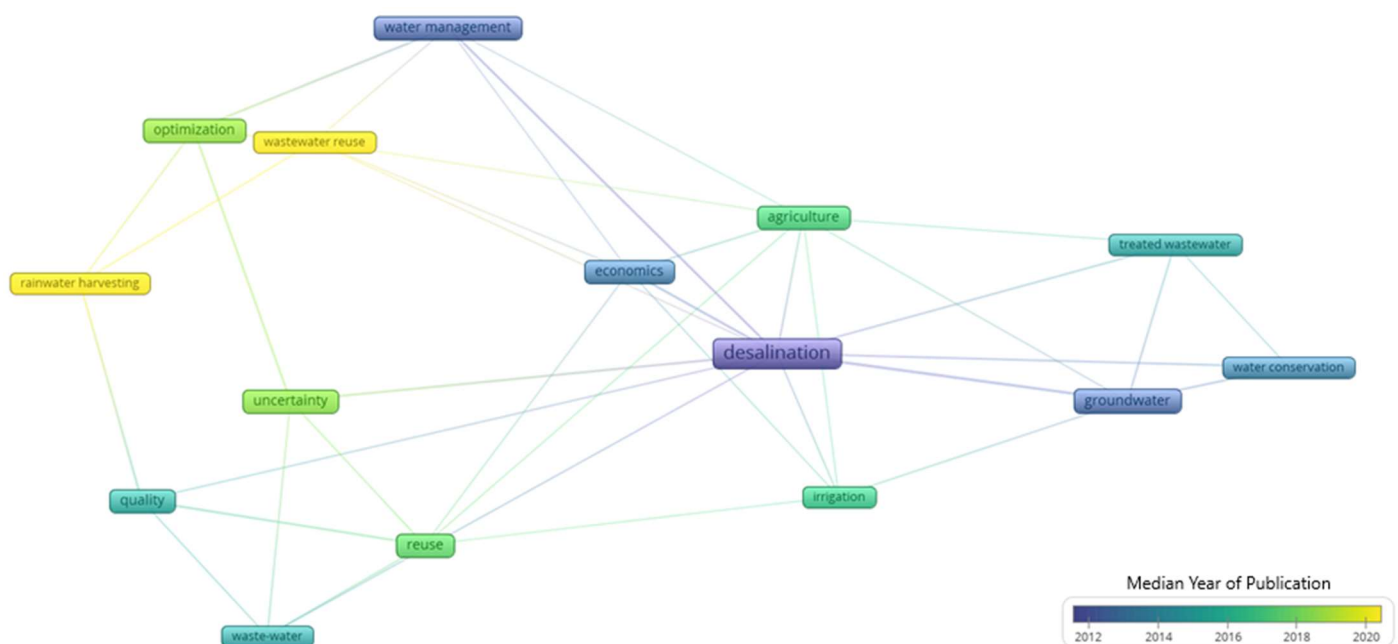


Figure 5. A network visualization that highlights the relationships and co-occurrence of keywords and median year of publication across the reviewed literature. Note: The diagram is generated with the VOSviewer software, version 1.6.15.

Figure 5 illustrates the temporal co-occurrence of keywords, with colors indicating the median year of publication (from 2012, marked in dark blue, to 2024, marked in yellow). “Desalination” remains the central node, highlighting its core role in research concerning both conventional and non-conventional WSs. The keywords most closely associated with desalination include groundwater, management, economics, agriculture, and reuse, reflecting its intersection with resource allocation, policy, and sustainable development efforts. Meanwhile, keywords such as rainwater harvesting, optimization, and wastewater reuse

(marked in yellow) indicate the current research focus, while keywords such as groundwater, economics, and water conservation (marked in darker colors) are fundamental topics that have been consistently studied over time. In other words, the results show that current WSs management strategies increasingly emphasize optimization and circular reuse rather than water conservation and economics.

3.2. Database Split

Among the 44 publications selected for full-text analysis, 25 (56.8%) come from Web of Science Core Collection, followed by 11 (25%) from ScienceDirect and 8 (18.2%) from Scopus (Figure 6). The observed differences in results can be explained by the different thematic focuses of the databases: Scopus database prioritizes disciplines such as humanities, arts, social sciences, and medicine [58], while the Web of Science Core Collection shows a stronger focus on the natural sciences and engineering [59].

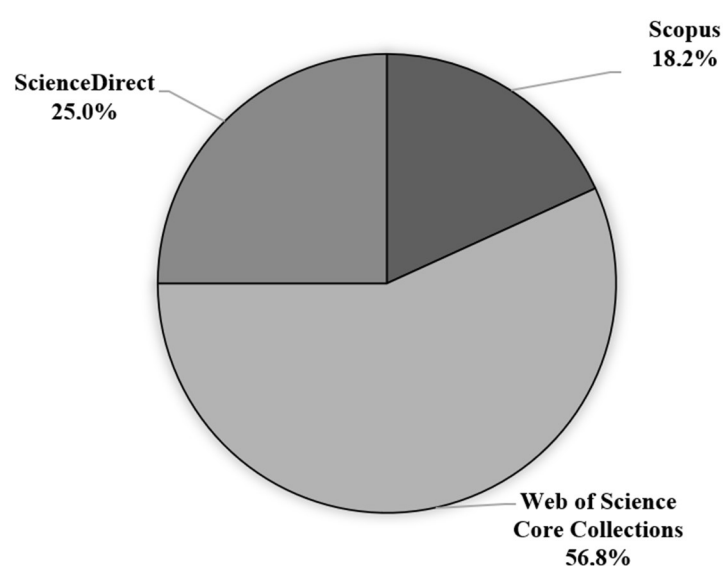


Figure 6. Split of publications among “ScienceDirect”, “Scopus”, and “Web of Science—Core Collections” databases (Total = 44). Note: Duplicate records across databases were removed before creating the distribution, ensuring that each publication was counted only once. For cluster analysis, each article was assigned to its dominant cluster.

3.3. Temporal Trends

Appendix B provides a detailed summary of relevant studies on HWSM. The results show a shift away from traditional supply-dominated models towards integrated, cost-effective, and sustainability-oriented approaches that combine multiple sources and advanced allocation techniques. Thus, optimization techniques ranging from multi-objective programming and heuristic algorithms to dynamic hydroeconomic models are increasingly being used to efficiently allocate WSs, minimize costs, and address uncertainty. Environmental and economic constraints such as water salinity, net present value, and energy costs are also frequently integrated into water allocation models to guide sustainable planning. In addition, reuse strategies involving treated wastewater and greywater are being promoted to reduce fresh/potable water withdrawals, especially for non-potable agricultural and industrial needs.

The temporal trend in the annual number of publications is shown in Figure 7. The results show that the first relevant publication on HWSM appeared in 2002, with low activity until 2012. From 2013 to 2021, interest steadily increased (2–4 articles published annually), with a peak of four papers lasting for several years. Although there was a slight

decline after 2022, the number of publications remained relatively high throughout 2023 and 2024. This trend reflects a growing interest in managing WSs in response to climate change and the challenges of urbanization.

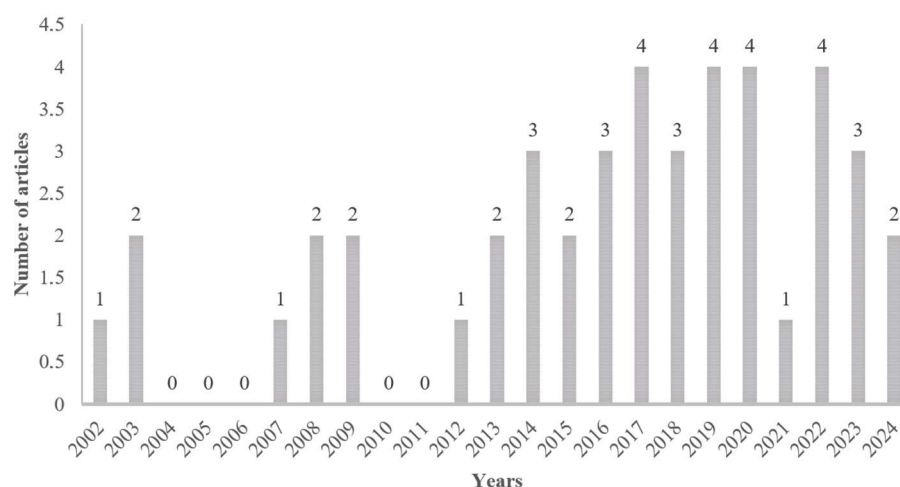


Figure 7. Temporal trends in the number of publications on the research topic (Total = 44).

3.4. Research Fields and Geographic Coverage

The distribution of publications by the research field is shown in Figure 8. The results show that publications on HWSM cover seven main areas: agriculture; biodiversity conservation; business economics; engineering; environmental sciences ecology; science technology; and water resources. However, the number of publications in the field of “water resources” appears to be the most frequent (20 out of 44 articles analyzed), while the topics of “agriculture” and “biodiversity conservation” are represented by only one publication each (see Appendix B for details).

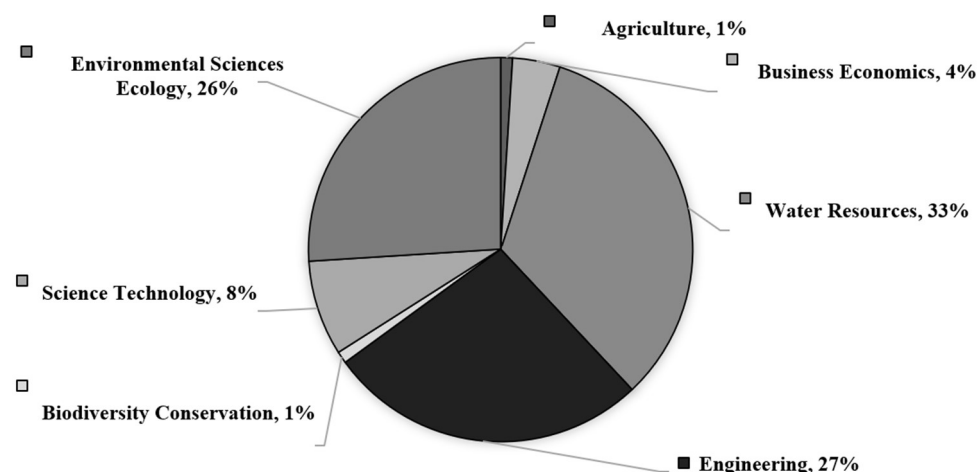


Figure 8. Distribution of publications by the research field. Note: Some papers may span multiple subject areas (two or three) simultaneously (based on data from ScienceDirect, Scopus, and Web of Science Core Collection), so it is not possible to clearly associate these papers with a specific field. Accordingly, each publication was counted separately for each subject area. The total of 60 publications was used to calculate the percentage distribution across subject areas.

The geographic distribution of publications is shown in Figure 9. Geographically, most papers on HWSM originated in Israel (12), the USA (10), China (4), Saudi Arabia (4), and Brazil/Greece/Germany (3 each). The predominance of publications from these countries

may be explained by national policies promoting water security research, significant water scarcity problems, and significant investments in innovative water technologies.

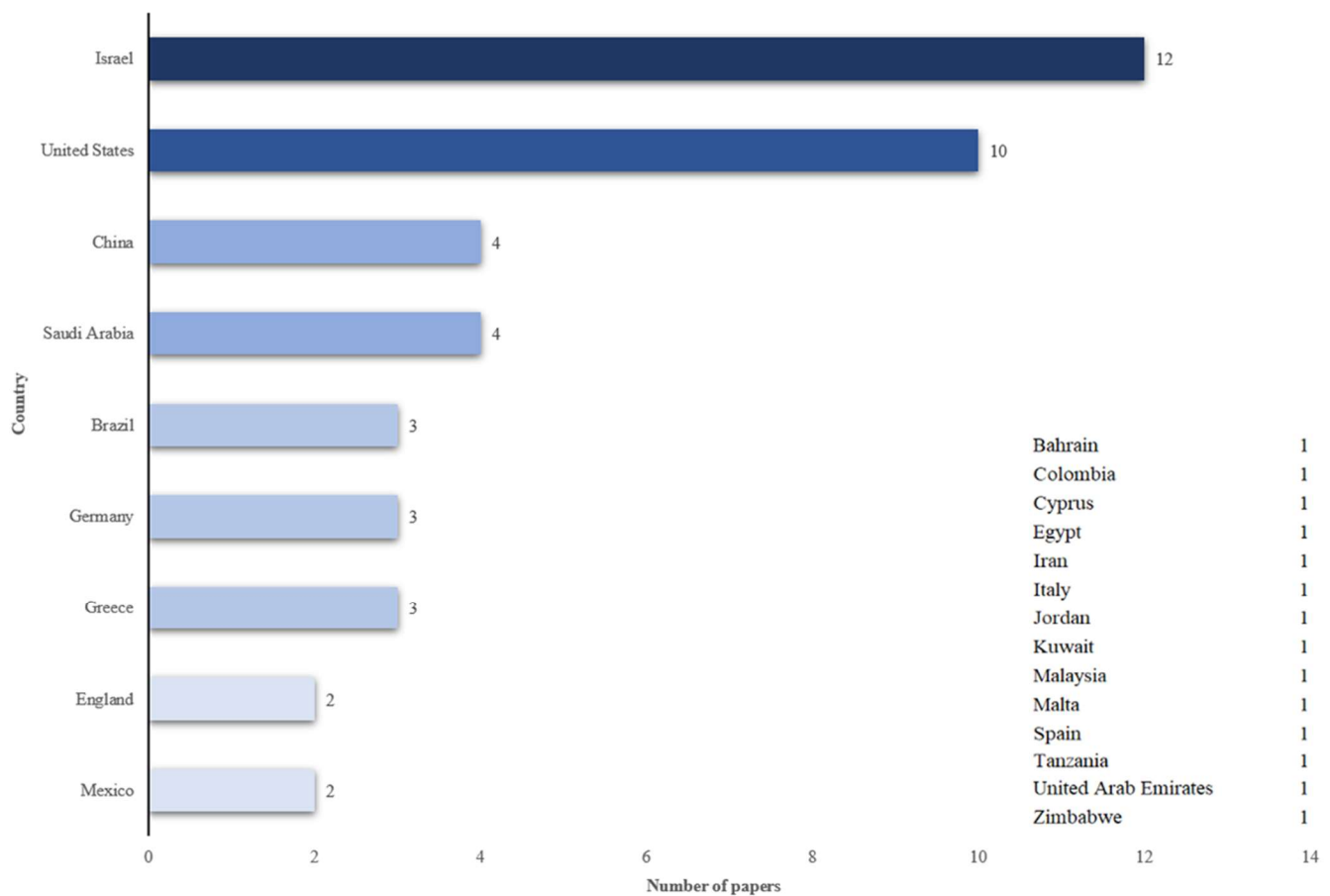


Figure 9. Geographic distribution of publications. Note: The papers under review include 44 relevant publications published between 1999 and 2024, authored by researchers from 23 countries: Bahrain (1.8%), Brazil (5.3%), China (7%), Colombia (1.8%), Cyprus (1.8%), Egypt (1.8%), England (3.5%), Germany (5.3%), Greece (5.3%), Iran (1.8%), Israel (21.1%), Italy (1.8%), Jordan (1.8%), Kuwait (1.8%), Malaysia (1.8%), Malta (1.8%), Mexico (3.5%), Saudi Arabia (7%), Spain (1.8%), Tanzania (1.8%), United Arab Emirates (1.8%), United States (17.5%), and Zimbabwe (1.8%). Some papers included authors from multiple countries (up to four per paper), so each country was counted separately. The total number of country contributions was 57, used to calculate the percentage for each country.

3.5. Water Sources Categorization

Figure 10 categorizes the WSs into two main categories: conventional and non-conventional. Within these categories, groundwater and desalinated water are the most frequently used sources (22% and 18.44%, respectively), while dredging water and distilled water are considerably less frequent (0.71% each). Furthermore, the fact that groundwater and desalinated water are represented close to each other (22% vs. 18.44%) indicates a comparable level of focus in the HWSM literature.

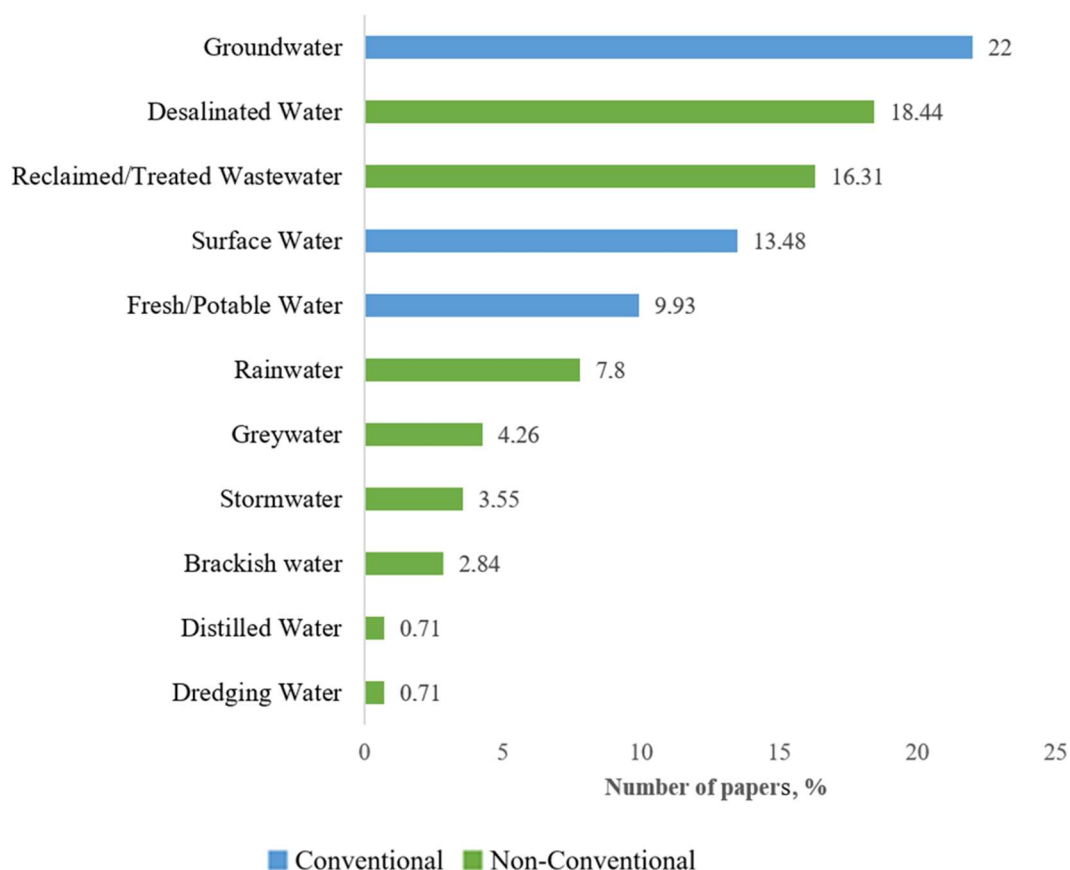


Figure 10. Frequency of use of different water sources in HWSM literature (% out of 44 relevant publications analyzed). Note: For the purposes of the study, stormwater and rainwater are classified as non-traditional sources, as large-scale collection and management practices for them are not widely implemented in many countries, including Israel. Natural springs are included in the Groundwater category, as they represent natural sources of groundwater.

4. Discussion

The main objective of the study was to identify the full range of studies focused on integrating conventional and non-conventional WSs within a single management system. An additional objective was to summarize the current state of knowledge on the classification of conventional and non-conventional WSs. The review helped to identify main conventional WSs (groundwater, surface water, and fresh/potable water—used in cases where studies referred to drinking-quality water without specifying whether it originated from groundwater or surface water) and eight non-conventional alternatives (desalinated water, treated wastewater, greywater, rainwater, stormwater, brackish water, dredging water, and distilled water), commonly used in empirical studies on the management of WSs. The study also enabled us to rank the identified WSs by their frequency of use in the HWSM literature, reflecting the current state of knowledge on both conventional and non-conventional WSs.

Overall, the literature review showed that modern water management strategies increasingly emphasize optimization and circular reuse, rather than water conservation and economics. Moreover, the results indicate a shift away from traditional supply-dominant models towards integrated, cost-effective, and sustainability-oriented approaches that combine multiple WSs and advanced allocation methods, such as multi-objective optimization and dynamic hydroeconomic modeling.

As mentioned earlier, scholars have investigated water management issues from different perspectives, and several review papers have been published to date [34–38,60]. Of these, only one review [38] used the PRISMA methodology to review integrated water management and analyze how “Water–Energy–Food” nexus approaches have been implemented to support sustainable water management.

The results of our analysis are partly consistent with those presented by Gárate-Ríos et al. [34], who identified an urgent need for new management paradigms that integrate economic, social, and environmental components. Similarly, the results presented by Dinar [60] demonstrate that addressing interrelated water resource challenges can be achieved through an integrated water resources management system that integrates the entire set of water types, including surface water, groundwater, reclaimed wastewater, and desalinated water.

Nonetheless, unlike previous literature reviews on water management, which focused on collaboration and interaction among different stakeholders, economic and modeling approaches, planning, water quality, and the implementation of sustainable development elements [34–38,60]. This review aimed to identify the full range of studies focused on integrating conventional and non-conventional water sources within a single management system.

The current study shows a relatively balanced distribution between conventional and non-conventional WSSs, with a slight tendency toward non-conventional sources in the recent literature.

The results highlighted by this literature review show that atmospheric water harvesting remains largely overlooked despite its long-term potential and importance. Furthermore, other important WSSs, such as dredging and distilled water, appear in ~1% of the studies included in this literature review.

Although 57% of the studies focused on WS management at the country level and 43% on city-level management, this distribution suggests that the literature covers different spatial resolutions. Given that many water challenges and innovations arise in urban areas, the city-scale perspective remains an essential dimension for further research.

Another noteworthy result of this study is that Israel is frequently highlighted in the reviewed literature as demonstrating a particularly diverse and potentially sustainable water supply system, integrating the largest number of both conventional and non-conventional WSSs—eight out of eleven—under a single management system (Table 1). As reflected in our results (Figure 9 and Table 1), Israel’s experience is often cited as a global pioneer, combining desalination, wastewater reuse, and conventional WSSs into one of the most advanced hybrid frameworks worldwide.

In addition to Israel, Brazil also stands out as a highly diverse country, combining conventional WSSs with numerous non-conventional alternatives such as treated wastewater, greywater, and rainwater. Kuwait is a contrasting example, as its extremely limited natural resources mean it relies heavily on energy-intensive technologies such as desalination and distillation.

Surprisingly, while Australia represents a leading case in non-conventional water adoption, particularly during the Millennium Drought [61], it was not highlighted in our PRISMA screening process. This is because many Australian studies focused on a single non-conventional source rather than the management of hybrid water systems that include both conventional and non-conventional sources. This explains their limited representation in the final sample.

Table 1. Diversity of water sources integrated into management systems (based on reviewed studies).

Nº	Water Type	Water Source	Country
1	Conventional	Groundwater	Brazil, China, Crete, East Africa, Egypt, Greece, Iran, Israel, Italy, Jordan, Kuwait, Malta, Saudi Arabia, UAE, USA
2		Surface Water	Brazil, China, Crete, Greece, Iran, Israel, Jordan, Malaysia, USA
3		Fresh/Potable Water	Brazil, China, Colombia, Greece, Israel, Mexico, Northern Europe, Republic of South Africa, UAE, USA
4	Non-Conventional	Desalinated Seawater	Brazil, Crete, Egypt, Greece, Israel, Italy, Jordan, Kuwait, Malta, Saudi Arabia, UAE, USA
5		Brackish water	Crete, Israel, UAE
6		Reclaimed/Treated Wastewater	Brazil, China, Crete, Gaza Strip, Iran, Israel, Malaysia, Mexico, northern Europe, Saudi Arabia, UAE, USA
7		Rainwater	Brazil, China, Colombia, East Africa, Greece, Israel, Mexico, Republic of South Africa
8		Greywater	Brazil, Colombia, Israel, Mexico, Republic of South Africa
9		Stormwater	East Africa, Northern Europe, Republic of South Africa, USA
10		Dredging Water	China
11		Distilled Water	Kuwait

Note: The table summarizes how WSs and management systems are depicted in the reviewed studies (1999–2024), which may differ from real-world configurations; the table provides details on the geographical distribution of studies using each WS, facilitating the identification of regional trends and preferences.

Regional patterns are also evident: while Latin America and sub-Saharan Africa place particular emphasis on rainwater harvesting, non-traditional sources such as greywater and treated wastewater predominate in the Middle East. This distribution highlights the adaptability of water management strategies to local conditions, highlighting the importance of household water management (HWSM) as a framework for integrating heterogeneous WSs.

Climate pressures and water scarcity are among the primary reasons for integrating non-conventional sources within HWSM. Similarly, cost considerations—including the energy requirements of desalination and wastewater treatment—are recurring themes in the reviewed literature. Our review complements this existing work by focusing on how these factors interact within the broader hybrid system perspective, highlighting integration strategies rather than analyzing each factor in isolation.

This review also shows that the research gaps in HWSM arise from three main causes: (1) disciplinary fragmentation, where engineering, economics, and environmental studies are developing separately; (2) governance and institutional barriers that limit cross-sector integration; and (3) the relatively recent adoption of non-conventional sources, which necessitate the development of integrated management frameworks. Addressing these challenges requires integrated frameworks that combine hybrid WSs, stronger governance frameworks to improve coordination, and interdisciplinary collaboration to better align technical, economic, and environmental perspectives.

In particular, the study refined eleven operational categories for classifying WSs, grouped into two aggregated groups—conventional (groundwater, surface water, and fresh/potable water)—used in cases where studies referred to drinking-quality water

without specifying whether it originated from groundwater or surface water) and non-conventional (desalinated water, treated wastewater, gray water, rainwater, stormwater, brackish water, dredging water, and distilled water). This outcome represents a more detailed categorization than that presented by Dinar [60], who identified a set of water types that included surface water, groundwater, reclaimed wastewater, and desalinated water.

The present analysis also helped to rank the WSs by their frequency of appearance in the reviewed literature, showing that groundwater and desalinated water are the most frequently used sources (22% and 18.44%, respectively), while dredging water and distilled water are considerably less frequent (0.71% each). In contrast to the pattern presented by Saleh et al. [62], where groundwater and treated wastewater are the most and least frequently used sources, with 51% and 9%, respectively.

The methodological approach can explain the differences in findings. Previous studies have often used literature review approaches without determining formal criteria for selecting relevant studies, which increased the risk of selection bias. In contrast, our study applied the PRISMA methodology, using the Covidence tool for screening and data extraction procedures [45]. Thus, the PRISMA method reduces potential selection bias and enhances the reliability of the findings [43] compared to other methods such as content analysis [39] or citation clustering [41], which may overlook key bibliographic information due to the absence of study-section protocols.

5. Conclusions

This systematic review, conducted in accordance with the PRISMA methodology, identified and analyzed existing research on HWSM. The review clarified the classification of WSs, distinguishing the main conventional types—groundwater and surface water—from eight non-conventional alternatives, including desalinated water, treated wastewater, gray water, and rainwater. The analysis revealed that non-conventional WSs are now more frequently discussed in the literature than conventional ones, indicating a significant shift in water management practices. Modern water strategies increasingly emphasize optimization and reuse, particularly in high-income, water-scarce regions. Overall, the findings reveal a shift away from traditional supply-dominant models toward integrated, cost-effective, and sustainability-driven approaches that combine multiple sources and advanced allocation techniques.

Several limitations of the present study should be noted. First, the systematic review covers the period from 1999 to 2024. Second, the literature review only includes original articles published in English. However, our study excludes “grey literature” (e.g., government reports, policy statements, professional newsletters, issues papers), focusing on articles published in peer-refereed scientific journals that appear in ScienceDirect, Scopus, and Web of Science Core Collections databases. Finally, only one specific research area was analyzed—management of conventional and non-conventional WSs. It should also be noted that certain global leaders in non-conventional water adoption, such as Australia, are underrepresented in the final sample, as many of their contributions emphasize single-source strategies rather than integrated hybrid systems. Future research should prioritize the evaluation of current knowledge in managing conventional and non-conventional WSs, with a focus on the sustainability and flexibility of WS management.

Author Contributions: Conceptualization, M.H. and O.D.; methodology, O.D.; software, O.D.; validation, O.D.; formal analysis, O.D.; data curation, M.H.; writing—original draft preparation, O.D.; writing—review and editing, M.H.; visualization, O.D.; supervision, M.H. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest: The authors declare that they have no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

HWSM	Hybrid Water Systems Management
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
UN	United Nations
WSs	Water Sources
VOSviewer	Visualization of Similarities Viewer

Appendix A

Table A1. Search Query Strings Used for “Scopus”, “Web of Science” and “ScienceDirect” Database Searches.

Database Name	Suggested Query Strings for Search
Scopus	TITLE-ABS-KEY (“Water Source” OR “Conventional water” OR “Non-conventional water” OR “Water Supply System” OR “Water Resource System”) AND (“Surface water” OR Groundwater OR “Brackish water” OR Effluent OR Greywater OR “Reclaimed wastewater” OR “Harvested rainwater” OR “Harvested stormwater” OR “Atmospheric Water” OR “Desalinated water” OR “Urban runoff”) AND NOT (Health OR Biodiversity OR Climate OR Educat OR Culture OR Energy OR Hydrodynamic OR Ecology) AND DOCTYPE (ar OR re) AND (PUBYEAR > 1999 AND PUBYEAR < 2024) AND (LIMITTO (LANGUAGE, “English”))
Web of Science Core Collections	# 1 (TS = (“Water Source*” OR “Conventional water*” OR “Non-conventional water*” OR “Water Supply System*” OR “Water Resource System*”) AND LANGUAGE: (English) AND DOCUMENT TYPES: (Article)) # 2 (TS = (“Surface water*” OR Groundwater* OR “Brackish water*” OR Effluent OR Greywater OR “Reclaimed wastewater” OR “Harvested rainwater” OR “Harvested stormwater” OR “Atmospheric Water*” OR “Desalinated water*” OR “Urban runoff*”)) AND LANGUAGE: (English) AND DOCUMENT TYPES: (Article)) # 3 # 2 AND # 1 # 4 (TS = (Health* OR Biodiversity OR Design* OR Climate OR Educat* OR Culture* OR Energy* OR Hydrodynamic* OR Ecology)) AND LANGUAGE: (English) AND DOCUMENT TYPES: (Article)) # 5 (# 3 NOT # 4) AND LANGUAGE: (English) AND DOCUMENT TYPES: (Article)
ScienceDirect	Find articles with these terms: (“Water Source” OR “Conventional water” OR “Non-conventional water” OR “Water Supply System” OR “Water Resource System”) Year: 1999–2024 Title, abstract, keywords: NOT (Health OR Biodiversity OR Climate OR Educat OR Culture OR Energy OR Hydrodynamic OR Ecology) Title: (“Surface water” OR Groundwater OR “Brackish water” OR Effluent OR Greywater OR “Reclaimed wastewater” OR “Harvested rainwater” OR “Harvested stormwater” OR “Atmospheric Water” OR “Desalinated water” OR “Urban runoff”) Article types: Review articles, Research articles

Note: Wildcards “*” are not supported and a maximum of eight Boolean connectors per field is allowed.

Appendix B

Table A2. Summary of Studies.

Nº	Publication	Topic	Location	Water Source	Main Results
1	Abu Qdais & Batayneh [63]	The role of desalination in bridging the water gap in Jordan	Hashemite Kingdom of Jordan, 2000–2020	Groundwater; surface water; desalinated water	This study assesses Jordan’s water resources, future demand, and the demand-supply gap under two scenarios, exploring desalination as a potential solution. While seawater desalination is currently not cost-effective for domestic use, desalination of brackish water using reverse osmosis is the most practical short-term option.
2	Talaat et al. [64]	The potential role of brackish water desalination within the Egyptian water supply matrix	Egypt, 2001	Groundwater and desalinated water	The study examines challenges in Egypt’s brackish water desalination and presents a case study on reverse osmosis to assess its feasibility as compared to other water supply options. The findings highlight reverse osmosis desalination as a cost-effective solution, supporting the need for large-scale implementation.
3	Voivontas et al. [65]	Water supply modeling towards sustainable environmental management in small islands	Paros, Greece, 2002	Groundwater; surface water; desalinated water and water hauling by ships/fresh water	An optimization model was developed to minimize the Net Present Value of projected water supply costs for the period 2002–2030. The results illustrate that conventional water sources, supplemented by flexible desalination systems to address water consumption peaks, offer the most effective solution for the island of Paros.
4	Al-Ruwaih & Almedeij [66]	The future sustainability of water supply in Kuwait	Kuwait, 2010	Groundwater; distilled water; desalinated seawater	The paper evaluates Kuwait’s water resources to develop an integrated management plan with a focus on sustainability. Given the constraints on conventional and non-conventional water sources amid a growing population, wastewater recycling for irrigation, industry, and other non-potable uses is essential.
5	Al-Katheeri [67]	Towards the establishment of water management in Abu Dhabi Emirate	Abu Dhabi, United Arab Emirates, 2006	Brackish water; groundwater; fresh water; treated wastewater; desalinated water	The need for water management is critical. Adequate storage capacity addresses some of the challenges associated with freshwater supply. The Emirate of Abu Dhabi requires long-term storage capacity equivalent to at least one year’s freshwater demand. One method of increasing this capacity is artificial recharge using surplus desalinated water produced from treated wastewater.
6	Blute et al. [68]	Integration of desalinated seawater into a distribution system.	Carlsbad, California, USA, 2007	Desalinated seawater and surface water	The findings support the sustainable integration of desalinated water alongside conventional sources while ensuring long-term infrastructure reliability.
7	Gikas & Angelakis [69]	Water resources management in Crete and in the Aegean Islands, with emphasis on the utilization of non-conventional water sources	Crete and the Aegean Islands, 2007	Groundwater, surface water, desalinated seawater; reclaimed wastewater and brackish water; rainwater catchment	The study highlights water scarcity in Crete and the Aegean Islands, where limited resources and geographical constraints hinder integrated management. It highlights the potential of non-conventional sources like desalination and wastewater reuse to address shortages. Sustainable water management strategies are crucial for long-term resilience in these regions.

Table A2. Cont.

Nº	Publication	Topic	Location	Water Source	Main Results
8	Lahav et al. [70]	Chemical stability of inline blends of desalinated, surface and ground waters	Israel, 2008	Groundwater; surface water; desalinated water	Simulation results for an Israeli water distribution model demonstrate that desalinated water with low alkalinity causes chemical instability upon mixing, while increasing alkalinity ensures constant calcium carbonate precipitation potential values.
9	Housh et al. [71]	Box-Constrained Optimization Methodology and Its Application for a Water Supply System Model	Israel, 2011	Groundwater and desalinated water	The study presents the search method for box optimization, a heuristic optimization method that outperforms or matches genetic algorithms in benchmark tests and is found to be effective for solving nonlinear water supply system management problems.
10	Housh et al. [72]	Limited multi-stage stochastic programming for managing water supply systems	Israel, 2012	Groundwater and desalinated water	The study proposes a limited multi-stage stochastic programming method that simplifies complex water supply optimization under uncertainty by clustering similar decisions, enabling efficient and scalable decisions.
11	Nápoles-Rivera et al. [73]	Sustainable water management for macroscopic systems	Morelia, Mexico, 2012	Potable water *; rainwater and reclaimed water	The paper presents a mathematical model for sustainable water management, optimizing the distribution and storage of conventional and non-conventional water sources. The model demonstrates that incorporating rainwater and reclaimed water can reduce freshwater consumption and waste while remaining economically viable. The approach highlights the potential of non-conventional water sources in enhancing sustainability.
12	Al-Juaidei et al. [74]	Hydrologic-Economic Model for Sustainable Water Resources Management in a Coastal Aquifer.	Gaza Strip, 2013	Groundwater; treated wastewater and desalinated seawater	The study presents an optimization model for Gaza's water system by balancing groundwater use, desalination, and wastewater reuse. The results show that water reallocation and a 2% annual reduction in agriculture can mitigate groundwater depletion while improving economic viability. Integrating desalination and wastewater reuse increases sustainability, reduces costs, and supports long-term water security.
13	Asefa et al. [75]	A tale of integrated regional water supply planning: Meshing socio-economic, policy, governance, and sustainability desires together	Florida, USA, 2013	Groundwater; surface water, and desalinated seawater	Tampa Bay Water reduced groundwater use by over 50% in under a decade, diversifying supply with groundwater, surface water, and desalinated seawater. Their advanced forecasting and decision-making tools improved lake and wetland levels while ensuring sustainable water availability for 23 million customers.
14	dos Santos & Benetti [76]	Application of the urban water use model for urban water use management purposes	Seara city, Santa Catarina State, Brazil, 2013	Potable water *; greywater; wastewater	This study applies the Urban Water Use model to identify the most effective water management strategies for Seara, Brazil. By evaluating various alternatives, the model highlighted water demand management and decentralized sanitation as the most impactful measures for improving urban water efficiency and sustainability.

Table A2. Cont.

Nº	Publication	Topic	Location	Water Source	Main Results
15	Behzadian & Kapelan [77]	Advantages of integrated and sustainability-based assessment for metabolism based strategic planning of urban water systems	City of northern Europe, 2010–2014	Potable water *; stormwater; wastewater, and water recycling	This paper compares traditional water supply planning with an integrated urban water system approach, including potable water, stormwater, wastewater, and recycling. Using the WaterMet model, it finds that strategies like rainwater harvesting and greywater recycling are more effective in integrated systems, emphasizing the need for both conventional and sustainability criteria in long-term urban water systems planning.
16	Ward & Becker [78]	Cost of water for peace and the environment in Israel: An integrated approach	Israel, 2012	Potable water *; Marginal saline water and desalinated sea water	The optimization model shows that integrated water resources management and desalination can ensure cost-effective water distribution in Israel, supporting both peace efforts and environmental goals.
17	Al-Zahrani et al. [79]	Multi-objective optimization model for water resource management	Riyadh city, Saudi Arabia, 2015	Groundwater; desalinated water and treated wastewater	A multi-objective goal programming model was developed for water distribution from multiple sources (groundwater, desalinated water, and treated wastewater) to multiple users (domestic, agricultural, and industrial sectors). The results show that desalinated water supply and treated wastewater reuse need to be increased to meet projected volumes during 2015–2050.
18	Luckmann et al. [80]	Modeling economy-wide linkages of wastewater use	Israel, 2004	Potable water *; reclaimed wastewater and brackish water	A Computable General Equilibrium model reveals that the decline in potable water increases the demand for reclaimed wastewater, supports pricing strategies, and shows limited substitution when recycling is already high.
19	Zavala et al. [81]	Potential of Rainwater Harvesting and Greywater Reuse for Water Consumption Reduction and Wastewater Minimization	Monterrey, Mexico, 2015	Potable water *; rainwater and greywater	The results showed that water consumption could be reduced by 48% and wastewater generation could be minimized by 59%. Integrating rainwater harvesting with greywater treatment and reuse would not only reduce potable water consumption and wastewater treatment needs but would also contribute to significant savings for water users and water and wastewater system operators.
20	George et al. [82]	Effects of two different water sources used for irrigation on the soil geochemical properties	Kuala Lumpur, Malaysia, 2016	Treated wastewater and surface water	This study examined the impact of treated wastewater and lake water irrigation on soil geochemistry and Lohan guava quality. Treated wastewater met irrigation standards, while lake water fell short. Water sources significantly affected soil properties and fruit quality, with irrigation quality positively influencing fruit attributes and consumer acceptance.
21	Nel et al. [83]	Supplementary household water sources to augment potable municipal supply in South Africa	Western Cape, Republic of South Africa, 2016	Potable water *; greywater, rainwater and stormwater	This study examines groundwater abstraction, rainwater harvesting, and greywater reuse as household water sources in South Africa. The proposed end-use model estimates a 55–69% reduction in municipal water demand when these sources are maximally used. While they help alleviate supply pressures, their integration complicates water planning and management, requiring further research.

Table A2. Cont.

Nº	Publication	Topic	Location	Water Source	Main Results
22	Porse et al. [84]	Systems Analysis and Optimization of Local Water Supplies in Los Angeles	Los Angeles, USA, 2016	Potable water *; wastewater, and stormwater	The network flow model was developed to explore management trade-offs between engineering, social, and environmental systems. With aggressive regional demand, increased stormwater capture (300%), and prioritized reuse of water from existing facilities, imported water supplies can be reduced by 30% while maintaining landscapes, economic productivity, and groundwater resources. Further reductions in imports (40–50%) are possible through additional reuse, recharge, conservation, and access to groundwater.
23	Reznik et al. [27]	Agricultural reuse of treated wastewater in Israel	Israel, 2016	Groundwater; desalinated water; treated wastewater and brackish water	The study identified that agricultural reuse of treated wastewater is an optimal water management strategy under water conditions, mainly as a cost-effective way to transfer freshwater from the agriculture to the urban sector.
24	Ao et al. [85]	Replenishment of landscape water with reclaimed water	China, 2013–2015	Surface water; potable/urban water *; reclaimed water	With urban water shortages, reclaimed water (RW) is increasingly used for landscape water replenishment. A mathematical model analyzed its impact on water quality in a northwest Chinese city. While RW's higher nutrients may boost algae growth, its lower suspended solids improve water clarity. Simulations using MIKE 3 showed that with optimal RW use, inflow needs decreased. A water supply scheme of RW replenishment for the surface water body (with water transparency as the control indicator) was proposed.
25	Podda et al. [86]	Blending between desalinated water and other sources	Italy, 2017	Groundwater and desalinated water	A comprehensive blending tool, integrated with a hydrogeological dynamic verification tool, was developed by Lotti Ingegneria, Italy. Based on a database of groundwater and blending points (desalinated water and groundwater), the tool monitors and controls desalinated water blending in real time to ensure optimal water quality.
26	Tsur & Zemel [87]	Water policy guidelines: A comprehensive approach	Israel, 2017	Groundwater; surface water; desalinated water and recycled water	The study models the optimal allocation of water and investment between sources and sectors, showing that infrastructure must quickly reach efficient (turnpike) paths and then stabilize, with implications for pricing, processing, and desalination times.
27	Aparicio et al. [88]	Agricultural irrigation of vine crops from desalinated and groundwater	Siggiewi, Malta, 2018	Groundwater and desalinated water	Two irrigation scenarios were considered: groundwater irrigation or “do nothing” versus “use of non-conventional water” by blending water from a small desalination plant and groundwater. Blending desalinated water with groundwater improves water availability, quality, and farm profitability. The study finds desalination to be the best non-conventional water option, with a small reverse osmosis plant (120 m ³ /day) supporting irrigation needs profitably from a minimum area of 1 ha.

Table A2. Cont.

Nº	Publication	Topic	Location	Water Source	Main Results
28	Porse & Pincetl [89]	Effects of Stormwater Capture and Use on Urban Streamflows	Los Angeles, USA, 2017	Groundwater, surface water; recycled water, and stormwater	Using a simulation and optimization model for regional urban water management, the potential impact of increased stormwater was captured and infiltration on urban flow was analyzed. Results show that for many watersheds in Los Angeles, further increases in stormwater capture and use would significantly reduce urban flow. The results illustrate the potential tradeoffs in water supply, river flows, and aquatic habitat that must be considered when attempting to increase local water use by increasing stormwater.
29	Qi et al. [90]	Making Rainwater Harvesting a Key Solution for Water Management	East African Rift System, East Africa, 2018	Groundwater; rainwater; stormwater	This paper presents an expansion of the original Kilimanjaro Concept by incorporating Chinese experience to demonstrate the universal applicability of KC for water management. Ongoing efforts to implement the Kilimanjaro Concept in the East African Rift Valley demonstrate that rainwater harvesting is a potential universal solution to meet ever-increasing water needs, while also assisting in groundwater recharge, reducing flooding and soil erosion.
30	Silva et al. [91]	Proposal of integrated urban waters management as a strategy to promote water security	Fortaleza, Brazil, 2018	Surface water; groundwater; rainwater; desalinated water	The study proposes the use of the integrated urban water management model. The model is based on the management of water supply and water demand. The proposed model diversifies supply with surface water, groundwater, rainwater, and desalination, while demand management includes water-saving fixtures and financial incentives. This approach strengthens urban water security through a more resilient supply matrix.
31	Al-Juaidi & Attiah [92]	Evaluation of desalination and groundwater supply sources for future water resources management	Riyadh city, Saudi Arabia, 2017–2019	Groundwater and desalinated water	This paper examines the effectiveness of desalination and groundwater supply on water demand based on the Water Evaluation and Planning model. Without intervention, unmet demand could reach 1076 MCM by 2030. Strategies like water conservation, leak reduction, and recycled water reuse lower future deficits, ensuring a more sustainable supply.
32	Finkelshtain et al. [93]	Substitutability of Freshwater and Non-Freshwater Sources in Irrigation	Israel, 2019	Potable water *; treated wastewater	The simulations indicate that the Israeli quota-exchange policy has increased both agricultural production value and farming profits.
33	Slater et al. [94]	Large-Scale Desalination and the External Impact on Irrigation-Water Salinity	Israel, 2015	Surface water; groundwater; treated wastewater; desalinated water	Using a dynamic hydroeconomic model, the study shows that accounting for irrigation water salinity justifies large-scale desalination in Israel, preventing a 29% drop in farm profits and avoiding significant deadweight losses per hectare.

Table A2. Cont.

Nº	Publication	Topic	Location	Water Source	Main Results
34	Zhang et al. [95]	Numerical Simulation of Multi-Water-Source Artificial Recharge of Aquifer	Mi-Huai-Shun area, China, 2007–2016	Surface water; groundwater; reclaimed water	Artificial recharge helps to solve the problem of water scarcity and groundwater depletion. Numerical simulations in the Mi-Huai-Shun area evaluated a multi-source groundwater recharge reservoir using reclaimed water, treated wetland water, and SNWTP (South–North Water Transfer Project) water. The results showed that groundwater levels recovered, and reserves increased, but chloride levels increased with reclaimed and wetland water. Chloride concentrations in SNWTP water are diluted, highlighting its role in improving water quality.
35	Housh & Aharon [96]	Info-Gap Models for Optimal Multi-Year Management of Regional Water Resources Systems under Uncertainty	Israel, 2020	Surface water; groundwater; desalinated water	The study develops an Info-Gap Decision Theory-based model for managing water supply systems under deep uncertainty, demonstrating its use on the Sea of Galilee system to support robust, long-term planning amid climate change and non-stationary conditions.
36	Gómez-Monsalve et al. [97]	Environmental performance of a hybrid rainwater harvesting and greywater reuse system	Bucaramanga, Colombia, 2021	Potable water *; greywater and rainwater	This study compares the environmental performance of a hybrid rainwater harvesting and greywater reuse system with a conventional centralized water system. Using Life Cycle Assessment (LCA) with GaBi software, the study found that the hybrid system saves about 131 m ³ /year of potable water, reducing total consumption by 42.5% and wastewater treatment plant flows by 20%. Furthermore, the hybrid system showed lower environmental impacts.
37	Moradikian et al. [98]	A distributed constraint multi-agent model for water and reclaimed wastewater allocation in urban areas	Tehran, Iran, 2021	Surface; groundwater; reclaimed wastewater	This study develops a Distributed Constraint Optimization (DCOP)-based model for allocating urban water and reclaimed wastewater, balancing stakeholders' conflicting interests. A modified ADOPT algorithm (MADOPT) introduces an agent for monitoring and conservation, incorporating social dynamics. Applied to urban water allocation, MADOPT proves effective for large-scale multi-agent systems, demonstrating how agents' social behaviors influence water use policies.
38	Ribeiro et al. [99]	Diversification of urban water supply: an assessment of social costs and water production costs	Fortaleza, Brazil, 2019	Groundwater; surface water; desalinated water; treated wastewater; greywater; rainwater	This study assesses the economic feasibility of integrating new water sources by analyzing production and social costs. Desalination (USD 0.28/m ³) and industrial reuse (USD 0.57/m ³) are cost-effective, while cisterns and greywater reuse are more expensive. Well water is the cheapest (USD 0.08/m ³). Desalination and industrial reuse are reliable, but tariffs do not reflect their full social costs.

Table A2. Cont.

Nº	Publication	Topic	Location	Water Source	Main Results
39	Zafeirakou et al. [100]	Water resources management in the framework of the circular economy for touristic areas in the Mediterranean	Sifnos Island, Greece, 2021	Groundwater; natural springs; rainwater, and desalinated water	The study compares Sifnos's water management model to Singapore's, as both use rainwater and desalination. Sifnos relies on groundwater, springs, cisterns, reservoirs, and desalination. The study aims to improve sustainability over 20 years by incorporating wastewater reuse for irrigation, firefighting, and potential potable use. The findings offer a framework for water autonomy that could be applied to other islands and coastal tourism areas.
40	Gilboa et al. [101]	Assessing water use and reuse options—a holistic analysis of a Model City, coupling dynamic system modeling with Life Cycle Assessment	Future Model City under typical Israeli conditions, 2022	Potable water *, rainwater, greywater, and treated wastewater	A dynamic model was developed to assess water reuse in an urban system, integrating Life Cycle Assessment and Life Cycle Costing. The model compares six scenarios using different water sources (potable, rainwater, greywater, and treated wastewater) for a future city under Israeli conditions. The results show that using treated greywater or treated wastewater for non-potable uses is the most economical. The business-as-usual scenario, relying solely on potable water, has the highest environmental impacts.
41	Hendrickson et al. [102]	Optimizing desalination for regional water systems	Israel, 2022	Surface water; groundwater; desalinated water	The study applies two-stage optimization and multi-criteria decision analysis to the Israeli water system, showing how desalination can be effectively integrated under uncertainty by balancing early production decisions with flexible supply allocation and stakeholder benefits.
42	Housh [103]	Optimizing bilinear multi-source water supply systems using mixed-integer linear programming approximations	Israel, 2020	Surface water; groundwater; desalinated water	The study proposes MILP-based formulas for optimizing multi-source water supply management, demonstrating that they effectively solve the complex model of the Israeli water supply system and allow for optimal use of both conventional and non-conventional water sources.
43	Abbasmiri et al. [104]	Quantitative and qualitative management of water resources with the use of treated wastewater	Tehran, Iran, 2023	Groundwater and treated wastewater	An optimization model for the joint use of treated wastewater and groundwater was used to allocate traditional and non-traditional water resources. The model results showed that the volume of water withdrawal for irrigation would be reduced if the Rei treatment plant and irrigation and drainage network were built. The results show that under existing conditions, the net benefit of the system would decrease in search of an optimal economic and environmental state.

Table A2. Cont.

Nº	Publication	Topic	Location	Water Source	Main Results
44	Shi et al. [105]	Optimal Allocation of Water Resources in Ordos City Based on the General Water Allocation and Simulation Model	Ordos City, the Inner Mongolia Autonomous Region, China, 2010–2021	Surface water; groundwater; dredging water; reclaimed water; and rainwater	This study develops a multi-objective model to optimize water resource allocation for Ordos City. The model forecasts water shortages in specific districts by 2025 and 2030, especially during agricultural use, but shows a shift from groundwater to surface and unconventional water sources, improving efficiency and reducing overexploitation. As a result, the regional water supply structure was optimized, with groundwater decreasing from 49.08% in 2025 to 43.35% in 2030, while surface water and unconventional water proportions increased.

Note: * Fresh/Potable water: refers to cases where studies reported drinking water quality without specifying its source (groundwater or surface water).

Appendix C

Table A3. Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews (PRISMA-ScR) Checklist.

Section and Topic	Item #	Checklist Item	Location Where Item Is Reported
TITLE			
Title	1	Identify the report as a systematic review.	See p. 1
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	See p. 1
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	See pp. 1–4
Objectives	4	Provide an explicit statement of the objective(s) or question(s) addressed in the review.	See p. 3
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how the studies were grouped for the syntheses.	See p. 5, 2nd paragraph
Information sources	6	Specify all databases, registers, websites, organizations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	See p. 6, 1st paragraph
Search strategy	7	Present the full search strategies for all databases, registers, and websites, including any filters and limits used.	See pp. 5–7
Selection process	8	Specify the methods used to decide whether a study met the review inclusion criteria, including how many reviewers screened each record and each report retrieved, whether they worked independently and, if applicable, details of automation tools used in the process.	See p. 6, 4th and 5th paragraphs
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes to obtain or confirming data from study investigators, and, if applicable, details of automation tools used in the process.	See p. 7, 2nd paragraphs
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g., for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	Reported in Figure 2
	10b	List and define all other variables for which data were sought (e.g., participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	-

Table A3. Cont.

Section and Topic	Item #	Checklist Item	Location Where Item Is Reported
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of the automation tools used in the process.	See p. 4, 1st paragraphs
Effect measures	12	Specify for each outcome the effect measure(s) (e.g., risk ratio, mean difference) used in the synthesis or presentation of results.	-
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g., tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item # 5)).	See p. 6, 4th and 5th paragraphs
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling missing summary statistics, or data conversions.	-
	13c	Describe any methods used to tabulate or visually display the results of individual studies and syntheses.	See p. 7, 2nd paragraph
	13d	Describe any methods used to synthesize the results and provide a rationale for the choice(s). If a meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	-
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g., subgroup analysis, meta-regression).	-
	13f	Describe any sensitivity analyzes conducted to assess robustness of the synthesized results.	-
Reporting bias assessment	14	Describe any methods used to assess the risk of bias due to missing results in a synthesis (arising from reporting biases).	-
Certainty assessment	15	Describe any methods used to assess the certainty (or confidence) in the body of evidence for an outcome.	See p. 4, 1st paragraphs
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow chart.	Reported in Figure 3
	16b	Cite studies that might appear to meet the inclusion criteria, but were excluded, and explain why they were excluded.	-
Study characteristics	17	Cite each included study and present its characteristics.	Reported in Appendix B
Risk of bias in studies	18	Present evaluations of risk of bias for each included study.	See p. 5, 1st and 2nd paragraphs
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate), and (b) an effect estimates and its precision (e.g., confidence/credible interval), ideally using structured tables or plots.	See pp. 7–13
Results of syntheses	20a	For each synthesis, briefly summarize the characteristics and risk of bias among contributing studies.	-
	20b	Present results of all statistical syntheses conducted. If a meta-analysis was done, present for each the summary estimate and its precision (e.g., confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	-
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	-
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	-
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	See p. 5, 2nd paragraph
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	-

Table A3. Cont.

Section and Topic	Item #	Checklist Item	Location Where Item Is Reported
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	See pp. 13–16
	23b	Discuss any limitations of the evidence included in the review.	See p. 16, 6th paragraph
	23c	Discuss any limitations of the review processes used.	See p. 16, 6th paragraph
	23d	Discuss implications of the results for practice, policy, and future research.	See p. 16, 6th paragraph
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	-
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	-
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	-
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	See p. 17
Competing interests	26	Declare any competing interests of review authors.	See p. 17
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	See p. 17

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