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SUSTAINABLE MANAGEMENT OF WATER RESOURCES

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Abstract

The sustainable management of water resources involves the careful stewardship, conservation, and equitable distribution of water to meet current and future needs while preserving the integrity of ecosystems and ensuring social and economic development. Here are some key principles and strategies for sustainable water management: Integrated Water Resource Management, Water Conservation and Efficiency, Protecting Ecosystems, Climate Resilience, Water Governance and Institutions, Investment in Infrastructure and Technology and Cross-Sectoral Collaboration. Sustainable water management requires collaboration and coordination across sectors such as agriculture, energy, industry, and urban development, as water is interconnected with various aspects of socio-economic development. Integrated planning and decision-making processes can help balance competing water demands and identify synergies and trade-offs among different sectors. By adopting these principles and strategies, communities, governments, and organizations can work towards ensuring the sustainable management of water resources, safeguarding water security, supporting ecosystem health, and promoting equitable access to clean and reliable water for present and future generations.

Key words: *management, resources, sustainable, waters.*

INTRODUCTION

Water is essential and vital for sustaining human life on earth. Water is one of the most precious natural resources, vital for human survival and for maintaining any form of socio-economic activity. Although about 71% of the earth is covered by water, only 3% of the world's water is fresh water, and two-thirds of this water is hidden in glaciers that are frozen or unavailable for use. In addition, most people in the world do not have clean and safe drinking water (Mezni et al., 2022; Popa et al., 2022). The world's drinking water resources are under increasing pressure.

Even though the total amount of water in the world remains the same, we see a constant deterioration of water quality, aquatic ecosystems and the environment of watercourses and reservoirs (Zyder et al., 2023). The purpose of this article is to highlight the critical need for sustainable management of water resources considering increasing demand, impacts of climate change and pollution. Once perceived as limitless, this invaluable resource is now understood to be finite and increasingly scarce.

Water resources management involves the monitoring and management of water quality as well as the monitoring and management of water quantity (Zoga et al., n.d.-a). Water resources were and are resources for society, regardless of region, with a direct economic value using water for drinking, agriculture, transport, obtaining energy. According to national legislation, water is a renewable, vulnerable and limited natural resource, an indispensable element for life and society, a determining factor in maintaining the ecological balance, a raw material for productive activities, a source of energy and a means of transport, a heritage natural, which

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must be protected, treated and defended as such, being part of the public domain of the state, and any natural or legal person has the right to use water Constantin et al. (2009).

Proper water and wastewater management is essential for a healthy society, prosperous economy and a sustainable environment.

MATERIALS AND METHODS

The Mendeley platform was used as the search engine to define the subject of this review article. The first search using the keyword water resources provided 3,162 relevant results for the last two years (2023 and 2024). The flow of bibliographic references could provide a wide range of information to ensure the accuracy of the review article.

A second search using the keywords agriculture, energy, industry and urban development:

1. water resources and agriculture provided 407 results;
2. water resources and energy provided 688 results;
3. water resources and industry provided 337 results;
4. water resources and urban development provided 100 results;
5. conservation of water resources - 20 results.

The above search provides new ideas such as definition, conception, strategy, implementation, objectives, principles and indicators of the sustainable management of water resources in the world, but a single work is missing to incurporate and unify all these scattered information found in different references bibliographic. Thus, the work develops the following key areas (areas): integrated management of water resources, water conservation and efficiency, ecosystem protection, water governance and institutions, investments in infrastructure and technology and intersectoral collaboration.

RESULTS AND DISCUSSIONS

1. ***Integrated management of water resources.***
The integrated management of water resources is exposed to the effects of several risks: climatic, socio-economic and political. Integrated Water Resources Management is a methodology that can help countries in their efforts to deal with water problems in a sustainable and cost-effective way (TAC-Documente informative nr. 4 Managementul integrat al resurselor de apă, n.d.).

Climate change is currently one of the biggest risks for many countries around the world and for the agricultural sector (El Ouadi & Ouarda, 2023). Climate change itself can best be described as the average change in weather. Although climate is intertwined and closely related to weather, there are important differences.

A common distinction is the difficulty scientists have in predicting the weather for a few weeks, while confidently predicting the climate 50 years from now (Banouar & Bouslihim, 2024).

Both inter- and intra-annual rainfall variability affects the outcome of cropping systems during any season. Increasing climate variability will jeopardize the sustainability of agricultural production (Boutracheh et al., 2024).

Current approaches to the problem of water quality in the world, especially those in the EU and the US, are based on the application of integral analysis, including all river basins (Zoga et al., n.d.-b.). The European approach was implemented through the Water Framework Directive (Directive, 2000/60/EC) integrating many previous directives. The Water Framework Directive contains a series of recommendations that Member States should implement in their regulatory framework to achieve the objective - "good water quality". These recommendations relate to water quality standards as well as effluent discharge limitations.

Adaptive water resource management has been suggested as a strategy to better coordinate surface water and groundwater resources (ie, conjunctive water use) to address drought (Josef et al., n.d.).

For areas at risk, alternative water sources have been identified as important options to maintain water supply security in the coming years, alongside centralized surface water and desalinated water sources.

This could help not only to identify the potential of existing rainwater and recycled water supply systems to reduce drinking water demand and return water to the environment, but also to identify additional opportunities at different parts of the water cycle and planning scales (Figure 1) (Ashbolt & Kularathna, 2023).

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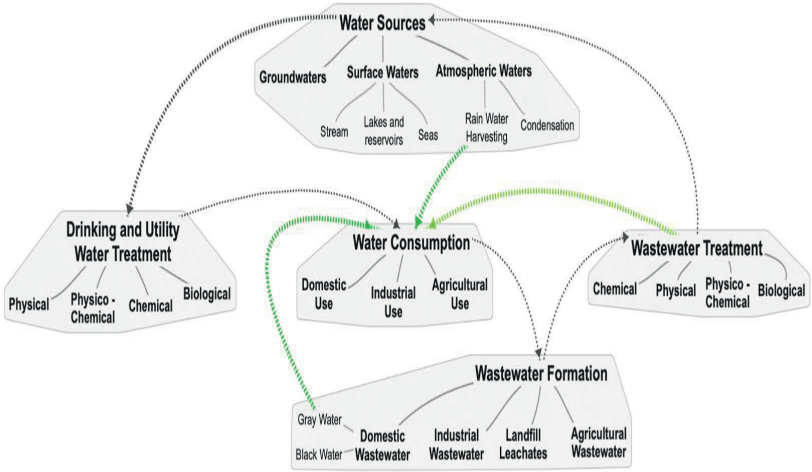

Figure 1. Urban water cycle and CE pathways (green arrows)

2. ***Water conservation and efficiency***. Water security is a broad concept that encompasses ensuring the sustainable use of water resources, providing accessible services for all and mitigating water-related risks in the context of continuous change - the objective being to build a better future from the point of view of the security of water resources for people, economy and environment in the context of global changes. Using water only when needed and in the right amount is the most effective strategy. It is essential to choose the best technology for a job to save water (Kalyanapu et al., 2023).

In the coming decades, climate change issues, increasing constraints on water resources, population growth and natural hazards will force hydrologists around the world to adapt and develop strategies to maintain security related to water resource management (Ghobadi & Kang, 2023). Effective management of water resources is essential for promoting sustainable development, reducing water-related conflicts and protecting aquatic ecosystems (Kamyab et al., 2023).

3. ***Protecting ecosystems***. Aquatic ecosystems are generators of goods and services. A general classification of the services provided by aquatic ecosystems is presented in Table 1 (Durabil Al Apelor, n.d.).

Ecosystems depend on water flows, seasonality and water level fluctuations, both surface and underground, and on water quality as a fundamental element. Water and land management must ensure that fundamental ecosystems are preserved and that adverse effects on other natural resources are considered and where possible ameliorated when management and development decisions are made (TAC-Documente informative nr. 4 Managementul integrat al resurselor de apă, n.d.).

Tabel 1. Services generated by aquatic ecosystems

		Supply services:
		- Food
		- Water
		- Wood
		- Combustible
		Regulation services:
Support services:		- Climate stabilization
- Nutrient cycle		- Flood control (storage and retention)
- Ground		- Retention of nutrients
- Primary producers		- Water processing (detoxification).
		Socio-cultural services:
		- Spiritual, religious and cultural heritage
		- Education
		- Recreation and ecotourism
		- Landscaping and leisure

The complex interactions between human society and water resource systems, as well as the rapid growth of water resource use, forces many countries to face the task of reaching higher levels in water management planning and control of ongoing hydrological processes (Banouar & Bouslihim, 2024).

Engineering (or structural) measures such as dams, ponds, reservoirs, diversion channels, pumping stations can reallocate water in terms of time and space and are the operational tools to deal with water-related problems such as floods, drought and water pollution; Complementarily, non-engineering (or non-structural) measures, such as data acquisition, hydrometeorological forecasting, evacuation programs and risk awareness education, are the means to ensure the operation and effective use of engineering measures. The trend of urbanization and unsustainable consumption causes a rapid decrease in the limited water resources, which represent a strategic source of sustainable development of the city (Šulyová & Kubina, 2022).

Since the 1990s, population growth and competition in water use (private commercial water companies, state water distributors, and tourism) have frequently resulted in water access problems for irrigating agricultural communities and private households (Hamdani et al., 2021).

4. ***Water governance and institutions.***Water planning aims to ensure sustainable results for human-technical-ecological systems. The factors that influence water planning are (bio)physical, technological, economic, socio-cultural and political (Rosello et al., 2023).

Water planning must consider the uncertainties of the future. Often, past development strategies are not suitable for planning future water supply and sanitation systems. Climate change and population growth are factors that cannot be controlled. The growing population of the globe also means increasing water consumption in industry, agriculture and energy production.

Increasing flexibility and reducing dependence on external factors in the planning of water systems will improve their response to developments and unforeseen events. Decisions and actions in the field of integrated management of water resources must be taken by all those who may be affected at the most appropriate level (principle of subsidiarity) (Pisleaga et al., 2019).

5. ***Investments in infrastructure***. Investments are needed not only in new infrastructure, but also in the maintenance and operation of existing stock to improve their efficiency and reduce water losses.

Investments in water security face a number of barriers, including (HIGH LEVEL PANEL ON WATER Recommendations Headline Recommendation Report of the High Level Panel on Financing Infrastructure for a Water-Secure World. Water Infrastructure and Investment, n.d.):

- Water is often under-assessed and under-priced, leading to poor cost recovery for investments in this area.
- Water infrastructure is capital intensive, having high sunk costs and a long payback period, requiring a large initial investment.
- Water improvements provide a combination of public and private benefits, such as valuable goods and services and reduced water-related risks. Many of these benefits are difficult to monetize or their positive effects occur outside the investment project.
- The lack of appropriate analytical tools and data for evaluating complex water-related investments and the history of these investments can deter funders.
- Water projects are sometimes too small and too specific, which increases transaction costs and makes it difficult to scale up innovative emerging financing models.

6. ***Technology and cross-sectoral collaboration***. The choice of appropriate water management operations depends mainly on its quality and the hardware capabilities of the water areas. In each zone, water sensors and monitoring hubs collect useful data such as pH, water temperature, turbidity, conductivity, dissolved and chemical oxygen demand, NH_3–N, hardness, solids, chloramines, the number of sulfates, electrical conductivity, organic carbon, trihalomethanes, potability, etc.

Using this real-time data, managers of distributed autonomous services can decide on appropriate water management policy (Mezni et al., 2022).

Pollution limits for wastewater treatment plants of all types are constantly being tightened, which increases the already high costs of their operation and often adds to the increased prices for wastewater. One of the possible solutions to reduce these costs, or at least maintain them at the current level, is to invest in new technologies that allow reaching tighter limits at identical or lower costs (Zyder et al., 2023).

Automation allows farmers to increase efficiency through prudent consumption of resources, making farm management smarter. The use of smart irrigation technology spans a wide range with benefits for consumers (Armando, 2023). An efficient intelligent water management system is a must to avoid the severe repercussions of water scarcity (Mezni et al., 2022).

CONCLUSIONS

Water supply can be improved through management and technological approaches. Water resource management is a multifaceted endeavor that requires careful consideration of numerous environmental, social, and economic factors.

Water management approaches include immediate or future construction activities or those intended for long-term sustainability (Peña-Guzmán et al., 2021). Harnessing water means recognizing and considering all the benefits and risks it provides, including economic, social, ecological and security dimensions, as well as its cultural and religious meanings.

This process promotes efficiency and good practice by highlighting the short- and long-term costs of pollution, waste and misallocation. In this paper, it is highlighted that the lack of water is a major problem in the modern world and a rigorous management of water resources is required throughout the world.

Due to the significant increase in global industrial production and the overexploitation of terrestrial and marine resources, the quality of drinking water has deteriorated considerably.

Also, many water supply systems serving growing human populations are currently facing shortages as many rivers, lakes and aquifers dry up due to global climate change.

Water conservation has become an urgent necessity given the ever-increasing demand of the population for this vital resource, which is increasing by the minute. An adequate management of water resources neutralizes the threats and serious diseases that can be caused to the global population by water scarcity, both in terms of its availability and quality.

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