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Presented by

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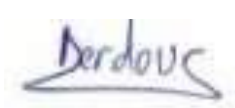
**A MULTI-CRITERIA DECISION SUPPORT FRAMEWORK FOR
SUSTAINABLE WATER RESOURCES MANAGEMENT: A CASE
STUDY OF SOUK-AHRAS REGION - ALGERIA.**

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DECLARATION

I, Ibtissem Derdous hereby declare that this thesis represents my personal work, realized to the best of my knowledge. I also declare that all information, material and results from other works presented here, have been fully cited and referenced in accordance with the academic rules and ethics.

A handwritten signature in blue ink that reads "Derdous". The signature is written in a cursive style with a long horizontal stroke at the bottom.

Derdous Ibtissem

Date: 14/04/2024

CERTIFICATION

This thesis has been submitted with my approval as the supervisor.

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A small, square image showing a handwritten signature in dark ink on a light-colored background. The signature appears to be 'A. Bouamrane'.

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Thank you.

List of Abbreviations

AGIRE	National Agency for Integrated Water Resources Management.
AHP	Analytic Hierarchy Process.
ANP	Analytic Network process
CI	Coherence Index.
CR	Consistency Ratio.
DMs	Decision Makers.
FAO	Food and Agriculture Organization.
IWRM	Integrated Water Resources Management.
MADM	Multi-Attribute Decision Making.
MCDM	Multi-Criteria Decision Making.
MRE	Minister of Water Resources.
MODM	Multi-Objective Decision Making
SWOT :	Strength,Weakness,Opportunity,Threat

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Abstract

This study assesses the sustainability of current water resources management practices in the region of Souk-Ahras in northeastern Algeria through an integrated approach. This approach combines survey investigation, Analytic Hierarchy Process (AHP), and SWOT analysis. Initially, the study evaluates sustainability dimensions of water resources management using a set of criteria and sub-criteria. AHP is then used to prioritize these dimensions, criteria, and sub-criteria based on their pairwise comparisons according to expert judgments. Results highlight the importance of political commitment, early warning systems, and water quality compliance in effective water resources management. Combining survey findings and AHP analysis reveals Strengths, Weaknesses, Opportunities, and Threats (SWOT) in existing practices. Identified weaknesses include non-conforming water quality, inadequate water services, and funding insufficiency. In contrast, strengths comprise strong political will, significant women's participation, and affordable water services. Threats focus on drought, climate change, and agricultural impacts, while opportunities underscore effective wastewater repurposing. Overall, this study provided valuable insights for decision-makers and stakeholders to enhance water management policy and improve the sustainability of water resources in the region of Souk-Ahras.

Keywords: water resources management, sustainability assessment, Analytic Hierarchy Process (AHP), SWOT analysis, survey investigation.

1. INTRODUCTION

1.1. Background

The water stress problem, which currently affects most of the countries in the Mediterranean, is a shared concern among all of the countries in the basin. Climate change, as well as the region's predicted increase in population and urbanization, will only make the problem worse. Algeria is typically categorized as a dryland in which the climate ranges from semi-arid in the north to arid conditions in the south with persistent water stress issue. There are an estimated 19.2 billion cubic meters of mobilizable water resources in Algeria (Drouiche et al, 2011).

While Algeria faces the classification of being 14th among water-poor countries, reports suggest that resource insufficiency is often a result of mismanagement rather than scarcity (Drouiche et al. 2012). The demand for water is increasing, necessitating suitable management strategies to meet the growing needs of the population and ensure the adequacy of water resource management.

The nation's primary source of water, providing about 66% of the nation's yearly water requirements, is groundwater (ADE, 2011). Though less constant and more inequitably distributed, surface water resources are nevertheless substantial. Only roughly 17% of Algeria's annual water needs are met by the more than 100 surface water dams that have been built (MRE, 2011). In unconventional resources like desalination and wastewater reuse, the remaining water needs are satisfied (Drouiche et al. 2012). With an average water supply of around five hundred cubic meters per person per year, Algeria is among the world's poorest nations in terms of freshwater availability, according to the United Nations Organization FAO (Falkenmark & Lundqvist. 1998).

The sector of water resources in Algeria is being digitalized, offering creative ways to recycle and use resources sustainably. Though they address issues with both amount and quality of water, the primary goals of the initiative continue to be centered on equity and efficiency in water distribution and utilization.

With the adoption of the Integrated Water Resources Management (IWRM) principles in 2000, the Algerian government made significant strides toward ensuring sustainable management of its water resources. This kind of management policy offers a conceptual foundation for the government. Additionally, it seeks to infuse water management with a decentralized democratic component, emphasizing stakeholder participation and lowest-level decision-making. Nevertheless, in spite of all the notable advancements in Algeria's

management of water resources, this field continues to face challenges and concerns, including water leak the effects of soil erosion, water pollution, and recurring drought conditions. The nation is also dealing with a host of other environmental issues, including desertification, air pollution, resource depletion, uncontrollable solid waste, and climate change. Accordingly, the proposed work aims at developing a methodological Decision-Making (MCDM) support approach for assessing the sustainability of water resource management at a regional level. This approach considers multiple quantitative and qualitative indicators along with the analytic hierarchy process (AHP) to provide a robust support for the decision-making process.

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1.2. Problem Statement

Souk-Ahras region in northeastern Algeria is impacted by a variety of water resource-related issues, which constitute a significant constraint for the region's development, particularly in the agricultural sector.

The aforementioned issues pertain to diverse facets of water quality, infrastructure, financial sustainability, the impacts of climate change and governance. These problems consist of:

- Poor water quality due to a high level of pollution from home and industrial wastewater outflow. This has been related to insufficient facilities for treating wastewater (Mellahi, Dhaouadi et al. 2021).
- Unbalanced budgets in the water supply and sanitation sectors as a result of low bill collection and high non-revenue water (Bensoltane, Mohamed Amine, et al. 2021).
- Risks of drought and a shortage of water are rising due to climate change. Water resources are being strained by this (Khoualdia et al. 2023).

- The infrastructure problem associated with water treatment, since the current facilities are antiquated and ineffective at meeting drinking water standards. Because of this insufficiency, treated water does not meet the standards, endangering the public's health (Bensoltane, Mohamed Amine, et al. 2021).

1.3. Relevance of the study

This study's relevance lies in its comprehensive examination of various aspects of water resources management. It employs a variety of quantitative and qualitative indicators that represent the economic, environmental, technical, and social dimensions of sustainability. This multi-dimensional analysis enables the identification of both strengths and weaknesses within current water management practices, while also presenting suitable alternative solutions. As a result, this work contributes to the limited body of research that conducts a thorough and in-depth assessment of water resources management sustainability. Its main purpose is to provide an effective decision-making tool for enhancing water resource management, improving the quality of water services, and preserving water resources and the environment.

1.4. Research questions

1. To what extent does ineffective collaboration between organizations limit the accomplishment of IWRM and sustainability goals?
2. What are the key obstacles impeding effective implementation of IWRM principles and sustainable practices?
3. How do current water quality, water quantity, and ecosystem conditions compare to sustainability objectives and standards?
4. What is the level of public awareness, involvement, and acceptance of sustainability efforts and economic instruments?
5. What technological and infrastructure innovations could strengthen sustainable water management?

1.5. Working hypothesis

In this study, will test the following hypotheses:

- Water resources management in Algeria is facing numerous challenges and obstacles, this situation is expected to intensify in light of climate change and increasing anthropogenic pressures.

- The current water resource management practices are far from their optimal potential due to the lack of financial autonomy and public inclusion.
- There are significant differences in the levels of commitment to sustainable water management and the nature of obstacles faced by different stakeholders and across various geographic regions.
- The points of strength and weakness in the current water management practices can be identified by combining multisource data collected from different agencies, questionnaires and field surveys.

1.6. Objectives of the study

Main Objective:

The primary objective of this research is to develop a decision support tool based on a multi-criteria analysis approach to improve water resources management in the region of Souk-Ahras.

Specific Objectives

- Acquire direct insights into the implemented water resources management strategy in the study area.
- Assessing the sustainability of the current strategy by taking into consideration the economic, environmental, technical, governance and social dimensions of sustainability.
- Identifying and addressing the points of weakness in water resource management within the watershed.
- Promoting the implementation of the integrated water resources management (IWRM) approach to enhance the conservation of water resources and the protection of ecosystems and the environment.

1.7. Thesis organization

This thesis unfolds across five chapters, each exploring a key aspect of the research:

- ✓ The thesis commences with a focused introduction that delves into water resource management, stressing sustainable practices, their challenges, and the potential of Multi-Criteria Decision Making (MCDM) to improve sustainability efforts.
- ✓ The second chapter examines the decision support systems currently in use for water resources, highlights Multi-Criteria Decision-Making (MCDM) approaches that are

pertinent to water management objectives, examines case studies, points out gaps in the literature, and makes recommendations for future research to improve decision-making processes.

- ✓ Chapter three focuses on the proposed approach which integrates Survey investigation, “Analytic hierarchy process (AHP) and SWOT analysis, along with the data requirements, presentation of the area under the study and current water management strategy.
- ✓ Chapter four presents the assessment outcomes of current water management practices in the Souk-Ahras region. It will also explore the implications of these findings for sustainable water resource management.
- ✓ Chapter five provides a summary of the thesis's key results as well as recommendations for further study and the use of the MCDM support tools.

2. LITERATURE REVIEW

2.1 Introduction

Effective management of water resources is a significant concern, especially in areas experiencing water scarcity and drought challenges (Bousmaha & Boulkaibet. 2020).

This chapter centers on the administration of water resources in Algeria, a nation facing ongoing challenges with water scarcity due to irregular rainfall and drought conditions. The key components discussed in this chapter include:

1. An overview of the water resource management situation in Algeria
2. A discussion of the regulatory aspects and organizational framework for water resource management in Algeria.
3. An introduction to multi-criteria decision-making (MCDM) techniques, which are widely used in water resource management .
4. An examination of the limitations and potential improvements for these MCDM techniques and other sustainability assessment methods in the context of water resource management.

In conclusion, the objective of this chapter is to offer a thorough insight into the water resource management difficulties encountered by Algeria, as well as the decision-making techniques and approaches utilized to effectively and sustainably tackle these challenges.

2.2 An overview of water resource management in Algeria

Algeria has a persistent water scarcity that has been made worse by erratic rainfall and drought, making the management of the country's water resources crucial. Drought was the primary cause of Algeria's disastrous water resource situation in 2000 and 2001, which prompted the government to give this important area top priority. As a result, Algeria has made useful institutional, legislative, and technological preparations for the prudent management of its water resources in order to get past decades-long disparities. Still, the situation with regard to water supplies is concerning and the anticipated outcomes are not yet sufficient. It is therefore necessary to implement innovative methods and effective strategies for managing the nation's water legacy within the framework of a good governance of water resources policy. This entails coordinated management of all planning and economic operations as well as communication among various stakeholders (Bousmaha & Boulkaibet. 2020).

Algeria's water resources include a number of dams that are vital for irrigation, flood control, water storage. Because of a number of variables, including drought and global warming, the nation must manage its groundwater resources as well as its surface water resources, which include rivers, lakes, and reservoirs. Water resource development and planning, water reclamation and purification, and national water policy have all been addressed by the government, the public and private sectors, and policymakers through a variety of methods (Neama, Mennat Allah, et al. 2020).

The estimated annual renewable water resources of Algeria are 19 billion cubic meters, less than the 500 cubic meters per capita that is considered the scarcity threshold. Since the nation's water resources are highly variable, concerns about a potential water scarcity must be addressed using sustainable management techniques. Even with advancements in sanitation and water delivery, issues with water storage capacity and management effectiveness persist (Talbi & Al Any. 2022).

To summarize, the management of Algeria's water resources is a crucial concern, and the nation has taken steps to tackle this issue by instituting diverse institutional frameworks and techniques. But in order to guarantee the availability and quality of the water supply, more effective and sustainable management techniques are required. The condition of water resources is still a worry.

2.3 Regulatory Aspects:

2.3.1 Ministry of Water Resources

The primary responsibility of the Minister of Water Resources (MRE) is to develop and carry out the country's water policy. Within this framework, the Ministry of Water Resources holds the responsibility of establishing the institutional framework necessary to enhance the management of public water services, which includes fostering public-private partnerships. A consultative body known as the National Water Council ensures institutional consultation with the industries directly involved (Dissertation, Tlemcen Unuversity).

2.3.2 Governmental establishments

Public institutions were subject to national jurisdiction under the MRE in 2001 as a result of institutional reforms.

➤ **Algerian Agency for Integrated Water Resources Management (AGIRE):**

Since Integrated Water Resources Management (IWRM) was approved at the 1992 United Nations Conference on Environment and Development, the Algerian government has taken the initiative to put it into practice. This method sees water as a limited, sensitive, and non-renewable natural resource as well as a national treasure.

Algeria created committees and agencies to supervise the management of water resources after dividing its land into five major hydrographic basins in 1996. To further provide financial support for this IWRM effort, a national fund was established. By emphasizing resource preservation and institutional frameworks for integrated water resource management (IWRM), Water Law No. 05-12 of 2005 reinforced the integrated approach to sustainable water resource management even more. This law deals with controlling water withdrawals, protecting water and ecosystems, coordinating water services at the basin level, and allocating resources based on the socioeconomic circumstances unique to each basin.

A strong water information system, integrated planning to address both environmental and human demands, and educational initiatives to improve awareness of water resources and encourage responsible consumption are essential for the effective implementation of IWRM. The purpose of the National Agency for Integrated Water Resources Management (AGIRE), which was founded in December 2014, is to direct, oversee, and assess the work of hydrographic basin authorities. In addition to managing public service obligations related to water data collection, coordinating national water information systems, coordinating studies on IWRM development, advocating for water conservation measures, delineating natural hydraulic public domains, and educating various user groups about water conservation and quality preservation are just a few of AGIRE's duties. (AGIRE)

➤ **Watershed Agencies (ABH):** The Algerian territory is subdivided into 5 major watersheds creating in each of them basin organisms:

Watershed Agencies and Watershed Committees.

A shift from segregated sectoral management to coordinated management at the level of the hydrographic regions was made in 1996 with the establishment of the regional level with the Watershed Agencies (ABH) and the Basin Committees.



Figure. 1 The Five Hydrographic basin in Algeria.

- The main missions of the Watershed Agencies:
 - ✓ Create the water information system within the organization and keep geographic databases and information tools updated.
 - ✓ Develop decision-making tools and establish plans for the management of surface water resources.
 - ✓ Oversee the pricing structure for the use of the public domain's natural hydraulic resources.
 - ✓ Overseeing the funding assistance program for initiatives targeted at water conservation and quality preservation.
- The missions of the basin committee:
 - ✓ Examines the Master Plan for PDARE Water Resources.
 - ✓ Considers everything having to do with the development and management of water resources.
 - ✓ Evaluates activity plans for the quantitative and qualitative preservation of water resources.
 - ✓ Mediates disputes pertaining to deficiencies in the mobilization and distribution of water resources (Abdellah, Bouchedja. 2012).

Master development plan water resources (pdare):

As stipulated in article 56 of the Water Act A "Water Resources Master Plan is produced for each natural hydrographic unit, outlining the strategic decisions for the mobilization, allocation, and use of water resources, including non-conventional waters." endorsed by the Basin Committee and created by the Basin Agency. The strategy for managing mobilized water resources and their allocations is developed, and it establishes the basic guidelines for resource management. (PDARE.1992)

- **National Agency of Dams & large transmission mains Agency (ANBT):** This agency is responsible for the construction and management of dams and water transfers, which are essential for water storage, flood control, electrical generation, and irrigation.
- **Office of national Sanitation (ONA):** Responsible for sanitation and likely involved in the management of wastewater and sewage systems.
- **National Agency of water resources (ANRH):** This organization manages hydraulic resources, which is essential to Algeria's sustainable use of its water resources.
- **Algerian water authority (ADE):** This organization oversees the provision of clean water and sanitation services across the country. Its primary objective is to guarantee that Algerian citizens have access to clean water and proper sanitation facilities.
- **Algerian energy company (AEC):** The Algerian Energy Company (AEC) is a public enterprise spearheading large-scale projects in Algeria's energy and water sectors.
- **National Agency of Irrigation and Drainage (ONID):** This agency is likely responsible for the management of irrigation and drainage systems, which are essential for agricultural water use (Master dissertation, Tlemcen).

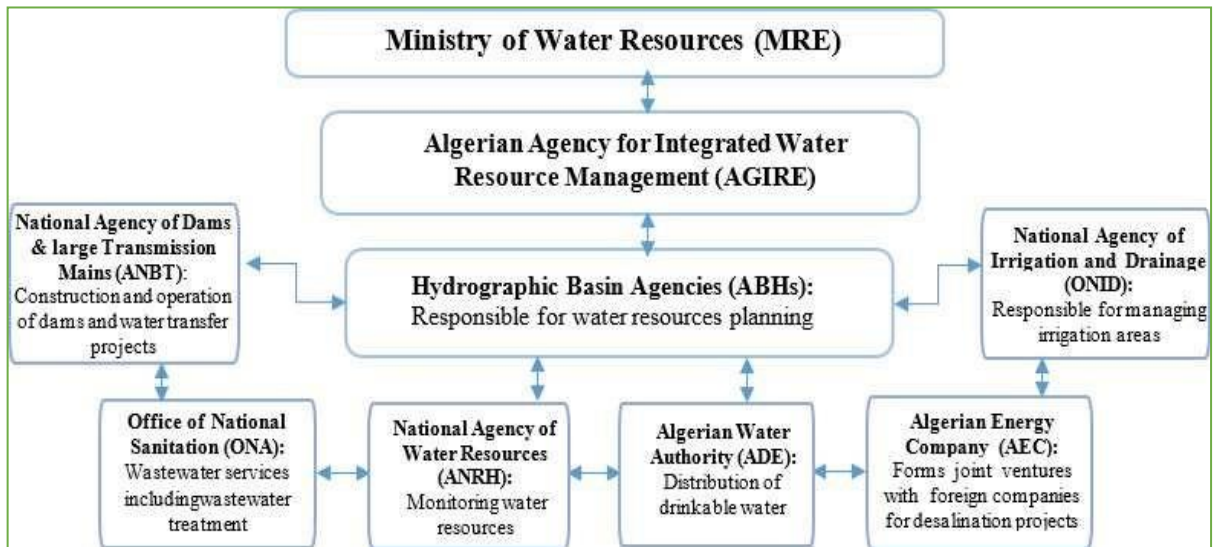


Figure. 2 Main organizations involved in water resource management in Algeria.

2.4 Multi criteria decision making tool.

Decision making has been defined differently by various researchers. Harris (1998) formally defines decision making as “the study of identifying and choosing alternatives based on the values and preferences of the decision makers”. "The cognitive process leading to the selection of a course of action among alternatives" is what Lu et al. (2007) define as decision making. These two definitions suggest that decision-making entails decision makers (DMs), options, and transparently and clearly choosing a final solution.

Since the middle of the 20th century, numerous Multi-Criteria Decision Making (MCDM) techniques have been created. Their differences include the quantity and quality of information required, their mathematical features, their ease of use, and the sensitivity analysis tools. Szidarovszky et al. (1986) and Dyer et al. (1992) were among the researchers who examined the development history of these techniques. With the increasing complexity and significance of decision-making problems, these strategies have evolved into helpful decision aids for decision makers (DMs).

Since their introduction in the early 1970s, multi-criteria decision-making (MCDM) techniques have been a potent tool for problem evaluation and handling the process of making decisions based on numerous criteria. It is common for MCDM problems to be highly complicated, but what sets them apart is the requirement for explicit modeling of multiple conflicting criteria and their interactions in order to comprehend the problem and offer a solution.

Organizations and governments can benefit from the efficient use of MCDM techniques in helping to make inclusive, transparent, and objective decisions on sustainable development. Additionally, it can encourage involvement from stakeholders and guarantee that their varied viewpoints and beliefs are considered during the decision-making process.

The multidisciplinary discipline of Operations Research (OR), known as MCDM, employs mathematical techniques that entail the subsequent processes. (Meier and Hobbs, 1994; Carlsson and Fullér, 1996; Yilmaz and Dagdeviren, 2011):

1. Structuring decision processes,
2. Defining and selecting alternatives,
3. Determining criteria formulations and weights.
4. Using value judgments and assessing the outcomes to choose an alternative or make design decisions based on a number of competing criteria.

In general, MCDM methods are divided into Multi-Objective Decision Making (MODM) and Multi-Attribute Decision Making (MADM). The identification of alternatives serves as the primary point of differentiation between the two sets of methodologies (Pohekar and Ramachandran, 2004). Due to its focus on optimal design problems—those involving the simultaneous achievement of many objectives—mathematical programming techniques, which have a sound theoretical foundation, have been extensively investigated in conjunction with MODM (Diakaki et al., 2010). Instead of fixed options, a collection of goal functions is optimized while taking into account a number of restrictions. Hwang and Masud (1979); Lai and Hwang (1996); Ehrgott and Gandibleux (2002) are further references on MODM. Using a specified set of criteria, MADM algorithms assess a group of alternatives and choose the one with the highest score. Typically, the optimal option is chosen by comparing the options in relation to each quality (Wang et al., 2009)

Benjamin Franklin's research on the concept of moral algebra resulted in one of the earliest studies on multi-criteria decision-making. Since the 1950s, a number of empirical and theoretical scientists have worked on MCDM techniques to investigate their capacity for mathematical modeling in order to offer a framework that can aid in organizing decision-making issues and producing preferences from alternatives. Several techniques that are included in MCDM and vary from one another in different ways will be covered in the upcoming sections.

Over the past few decades, various writers have developed or refined a variety of MCDM methodologies. The primary distinctions between these techniques pertain to the degree of algorithmic complexity, the methods employed for weighting criteria, the representation of preferences evaluation criteria, the potential of ambiguous data, and, lastly, the type of data aggregation (Bączkiewicz, et al. 2021). The MCDM techniques have been extensively researched and used in a variety of domains, such as sustainability, engineering, economics, and social sciences.

Furthermore, each type of MCDM has unique benefits and drawbacks that should be discussed in detail depending on the approaches used. For instance, depending on the type of decision-making problem, MCDM contains many components and ideas. The primary ones are listed below:

- ✓ Alternatives are “different possible courses of action”
- ✓ The attribute is defined as “a measurable characteristic of an alternative”
- ✓ Aggregation refers to “considering the performances of an alternative on the specific criteria for deciding on the alternative”
 - Decision variables are defined as “components of alternatives’ vector”
- ✓ Decision space is represented as “feasible alternatives”
- ✓ Measures are defined as “elements utilized to quantify an alternative to its attribute by assigning to the attribute numbers or symbols”
- ✓ Criteria are defined as “tools for evaluating and comparing alternatives from the viewpoint of the consequences of their selection”
- ✓ Preferences are defined as “how an alternative fulfills the need of a decision-maker regarding a given attribute”
- ✓ Decisions are different based on the type of problem that can include choice, ranking, and sorting problems (Habenicht, W et al, Trendowicz, et al. 2002)

2.5 MCDM models used in water management:

Multi-criteria decision making (MCDM) methods have been widely used in water management to evaluate and prioritize different alternatives based on multiple criteria. Some of the MCDM models that are used in water management include:

Analytic Hierarchy Process (AHP): The Analytic Hierarchy Process (AHP) is a popular Multi-Criteria Decision-Making (MCDM) technique that entails dividing a difficult decision into a hierarchy of criteria and sub-criteria, after which the options are

assessed according to how well they meet each criterion (Saaty, 2008). By enabling decision-makers to methodically assess and rank options according to how well they perform in relation to each criterion and sub-criterion, AHP offers an organized approach to decision-making. Making well-informed decisions is made easier by this hierarchical structure, which allows relative weights to be assigned to the criteria. The method's broad acceptance in a variety of disciplines, including engineering, management, environmental sciences, and urban planning, is partly due to its capacity to handle both quantitative and qualitative data. In the first study examined in this section, Zeng et al, (2007) proposed an innovative framework for choosing the most adequate wastewater treatment process through combining AHP and gray relational analysis (GRA) models. AHP was employed to effectively manage various criteria and goals during the decision-making process, while GRA was used to examine unclear interactions between a key element and all other factors in a system. Likewise, Grimaldi et al (2020) developed an AHP-based decision support system designed to water managers in order to find and rate the best solutions for water delivery in emergencies. The proposed system allowed for the inclusion of elements that are frequently disregarded by other methods and instruments, such as social impacts, into the decision-making process as well as the integration of scientific and specialized knowledge. In the third example, Calizaya et al (2010) proposed the use of AHP for identifying the best solutions for existing problems and enhancing interaction with stakeholders in order to reach a sustainable strategy for water resources management in Bolivia.

Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE): The Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE) is used to rank options according to how well they perform across a range of criteria (Brans & Vincke, 1985). PROMETHEE entails evaluating each option in relation to all others and allocating preference values in accordance with the standards. With consideration for the relative weight of each criterion, the technique helps decision-makers assess and prioritize options based on their overall performance. Numerous domains, such as energy systems analysis, transportation planning, and environmental management, have made extensive use of PROMETHEE. The method's considerable acceptance in practice can be attributed to its versatility in handling many sorts of criteria and its capacity to handle both quantitative and qualitative data. Three noteworthy works investigate sophisticated multi-criteria decision-making strategies for the management of water resources. The paper "Multi-criteria decision making for water

resource management: a case study of the Gediz River Basin, Turkey" first introduces a particular MCDM approach that takes into account social, cultural, and economic aspects as well as uncertainties by applying Possibility Theory. The research highlights the importance of holistic sustainability factors in the management of water resources and provides insights for evidence-based decision-making procedures, politicians' and scientists' cooperation, and managing uncertainty in this area. (Yilmaz et al, 2010). Second, the article "Risk Management of Drinking Water Supply in Critical Conditions Using Fuzzy PROMETHEE V Technique" applies fuzzy PROMETHEE V to assess risks associated with drinking water supplies under critical conditions. The research emphasizes the importance of risk assessment in safeguarding public health and ensures continuous access to clean water. The paper presents PROMETHEE V as a multi-criteria decision-making tool to rate various mitigation methods according to their capacity to reduce risks. Fuzzy set theory is used to handle ambiguity and imprecise data (Ghandi and others, 2020). Finally, the paper "Application of PROMETHEE II Model Technique to Evaluate Water Loss Management Strategies in Water Supply Systems" investigates how multi-criteria decision-making techniques and hydraulic modeling can be combined to improve water loss management practices, with a particular emphasis on Alexandria. The research offers a systematic framework for assessing and prioritizing different possibilities. By using the PROMETHEE II model, it seeks to optimize decision-making processes connected to water loss reduction measures. The use of PROMETHEE II in this situation indicates how well it works to address the complicated issues that water utilities encounter, which eventually leads to the development of more effective and sustainable water resource management techniques. Together, these studies show how important it is to use sophisticated multi-criteria decision-making methods to enhance water resource management procedures (Mathyea et al, 2023).

Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS):

Ranking alternatives according to how far they are from the best and worst solutions is the basis of the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), a Multi-Criteria Decision-Making (MCDM) technique (Hwang & Yoon, 1981). A solution that maximizes benefits and reduces costs is ideal; conversely, a solution that maximizes costs and decreases benefits is bad. Considering the relative weight of each criterion, TOPSIS helps decision-makers assess and prioritize options based on their overall performance. The method has been widely used in a variety of sectors, including engineering, management, and environmental sciences, due to its

capacity to handle both quantitative and qualitative data as well as its simplicity and convenience of use (Mardani et al., 2015; Tzeng & Huang, 2011). The use of the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) to handle problems with water resource management in various settings is illustrated by two recent studies. First study, "Using Improved TOPSIS and Best Worst Method in prioritizing management scenarios for watershed management in arid and semi-arid environments," published in June 2021, suggests a novel way to integrate two multi-criteria decision-making methods (Best Worst Method and Improved TOPSIS) to prioritize management scenarios in drylands (Alvandi, Ehsan, et al, 2021). The second study, "Evaluation of the water resource carrying capacity in Heilongjiang, eastern China, based on the improved TOPSIS model", explores the region's water management issues in depth and provides a thorough assessment of the its water resource carrying capacity. Both studies assess and rank management strategies using the Improved TOPSIS model, providing insightful information about how best to distribute water, improve conservation efforts, and advance sustainable water resource management techniques that are suited to the unique requirements and limitations of the different regions. In conclusion, these researches provide important information to help defensible decision-making and enhance the management of water resources in areas around the world confronting comparable difficulties (Lv, Bo, et al. 2023).

Elimination and Choice Expressing Reality (ELECTRE): To rank alternatives and allocate them to distinct preference classes based on their performance on several criteria, one popular Multi-Criteria Decision-Making (MCDM) methodology is the Elimination and Choice Expressing Reality (ELECTRE) method. With ELECTRE, decision-makers can communicate their preferences in a non-quantitative way and are not required to employ a compensating model. Figueira, Greco, and Ehrgott (2005) describe the methodology, which entails evaluating each alternative against a set of reference alternatives and classifying them into distinct preference classes according to how well they meet the criteria. Thanks to its capacity to handle imprecise and qualitative data well, ELECTRE has been used extensively in a variety of sectors, including finance, environmental management, and engineering (Rangel, Gomes, & Moreira, 2009). A number of studies that use the ELECTRE approach to address difficult decision-making problems in a variety of disciplines have been published recently. The paper "A New ELECTRE-Based Method for Group Decision-Making with Complex Spherical Fuzzy Information" in particular presents a novel

strategy to deal with the challenge of group decision

making when dealing with complex and uncertain data that is represented by spherical fuzzy sets (SFS).

This methodology extends the possibilities of uncertainty representation and enhances multi-criteria decision analysis (MCDA) through the development of generalized spherical fuzzy numbers (GSFNs) and the Generalized Spherical Fuzzy ELECTRE III (GSFEIII) method. Comparably, the paper "ELECTRE III for Strategic Environmental Assessment: A "Phantom" Approach" delves into the use of ELECTRE III in SEA with the goal of enhancing assessment instruments and methods for better environmental assessment decision-making. The study, which mainly focuses on the Italian scenario, shows how ELECTRE III might improve the methods and instruments used for SEA project evaluation. Finally, a multi-objective optimization approach using the ELECTRE method is presented in the study "A multi-objective optimal allocation of treated wastewater in urban areas using leader-follower game" to allocate treated wastewater in urban districts while taking social, environmental, and economic factors for sustainable wastewater management practices into account. In order to promote more sustainable and effective wastewater management methods, the article shows how successful the ELECTRE approach is at allocating treated wastewater in urban areas. Collectively, these studies highlight how flexible and useful the ELECTRE approach is for addressing difficult issues in today's world, including wastewater management, environmental evaluation, and collective decision-making.

2.6 Limitation of Multi-Criteria Decision-Making techniques:

Popular Multi-Criteria Decision-Making (MCDM) techniques have limits that have been highlighted by recent research, offering practitioners insightful information on how to improve their selection procedures. The Analytic Hierarchy Process (AHP) has come under fire for relying too much on subjective assessments, which can lead to biases and inconsistencies in the framework used for making decisions (Kaya & Kahraman, 2020). Moreover, AHP becomes more difficult to apply in practical settings when dealing with a large number of criteria and choices (Kaya & Kahraman, 2020). It has been discovered that the Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE) is sensitive to the choices made for preference functions and ranking algorithms, resulting in uneven results (Kaya & Kahraman, 2020). PROMETHEE also has trouble communicating trade-offs between criteria, which makes it difficult to understand

how different elements relate to one another (Kaya & Kahraman, 2020). According to Kaya and Kahraman (2020), there is a possibility that the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) will contain errors as a result of incorrect criterion normalization, leading to uneven outcomes. Similarly, TOPSIS has been criticized for not appropriately representing criteria trade-offs, which makes it difficult to assess the relative importance of each component (Kaya & Kahraman, 2020). Elimination and Choice Expressing Reality (ELECTRE) has been noted to provide considerable difficulties due to its complex architecture and the high level of knowledge needed to carry it out effectively (Kaya & Kahraman, 2020). Furthermore, ELECTRE is susceptible to changes in threshold settings and reference alternatives, which may jeopardize the accuracy of the result (Kaya & Kahraman, 2020). Through awareness of the constraints associated with each MCDM approach, practitioners can more effectively modify their studies to satisfy the needs of their unique project objectives. By having this insight, decision-makers may make sure they choose the best instrument for the job at hand, which will improve the efficiency and caliber of their decision-making procedures.

2.7 Sustainability assessment methods:

The scientific literature states that numerous sustainability assessment methods have been widely used to enhance decision-making for challenges relating to the management and planning of water resources, for instance:

(1) Cost-benefit analysis (CBA) is an economic evaluation technique that traditionally focuses on quantifiable economic factors, often-monetary costs and benefits. When assessing the financial viability of various water management initiatives or regulations, such as water supply and wastewater treatment facilities, cost-benefit analysis, or CBA, is employed. To ascertain which option offers the most net benefit to society, it entails calculating the costs and benefits connected with each option and comparing them (Boardman, A. E., et al. 2020).

For example, a study applied cost-benefit analysis to assess global pathways to water sustainability, emphasizing the linkages between implementing Integrated Water Resource Management (IWRM) and achieving improved environmental outcomes. Key findings were that IWRM led to a better environmental management, including water quality, pollution reduction, and ecosystem health. In most cases, IWRM benefits outweighed costs, positioning it as an effective sustainability approach (Bilalova et al, 2023).

(2) Life cycle assessment (LCA) can be used to assess the environmental sustainability of water resource management practices. Water management projects and policies, including water supply and wastewater treatment systems, are assessed for their environmental effects using life cycle assessment (LCA). In order to find areas for improvement, it entails quantifying the environmental impacts related to every phase of the project or policy's life cycle (International Organization for Standardization 2020). For instance, a recent study discussed suggested using a comprehensive assessment tool called life cycle sustainability assessment (LCSA) to evaluate the sustainability of water sector resource recovery solutions. The analysis brought to light three key features of these solutions: their potential to benefit natural ecosystems through nutrient and water recovery, the need to account for off-site impacts in LCSA frameworks, the capability to improve local environmental sustainability. The authors demonstrated application of an LCSA method using a case study of a resource recovery installation in the Netherlands. Overall, the review emphasized that LCSA enables robust quantification of sustainability for water reuse systems (Bhambhani et al. 2022).

(3) Triple bottom line (TBL) provides a method for presenting sustainable water resources management assessment frameworks with associated indicators and benchmarks, showcasing recent efforts to integrate social equality, environmental sustainability and economic viability factors in water resource assessments. Environmental, social, and economic factors are the three perspectives from which the triple bottom line (TBL) in water management assesses the sustainability of various water management initiatives or policies. In order to strike a balance between environmental, social, and economic factors, it entails assessing how the project or policy will affect each of these aspects (Savitz, A. W., & Weber, K. (2019). *The triple bottom line: How today's best-run companies are achieving economic, social and environmental success – and how you can too* (John Wiley & Sons). Recent research reviewed 17 sustainable water resource management frameworks (SWRM-AFs) for arid and semi-arid regions. Shared components were identified, covering indicators for social, environmental, and economic sustainability. Social metrics evaluated equitable access and cultural preservation, while environmental indicators targeted ecosystem sustainability. Economic factors balanced infrastructure financing and cost recovery. Integration of these dimensions supports holistic water management strategies for arid regions. The study's findings influenced further research connecting frameworks to outcomes and their application in specific countries (Alsaeed et al. 2022).

(4) Integrated assessment (IA) provides an overview of water resources planning and management, ensuring sustainable water supplies. Various water management projects and policies are assessed for sustainability from a variety of perspectives, including institutional, social, environmental, and economic, using integrated assessment (IA). To assess the effects of a project or policy on every aspect of sustainability and to assist in the decision-making process, it entails integrating several models and data sources. (Cash, D. W., Clark, W. C., Alcock, F., Dickson, N. M., Eckley, N., Guston, D. H., Jäger, J., & Mitchell, R. B. (2003). Knowledge systems for sustainable development. *Proceedings of the National Academy of Sciences*, 100(14), 8086-8091). Findings from a recent study highlight essential components of integrated water resources planning and management for securing sufficient, cost-effective, and sustainable water supplies. This involves coordinating the development, allocation, and quality management of both surface and groundwater sources to address the needs of both human communities and the environment. Current frameworks further advance these principles by integrating sustainability indicators that span social, economic, and environmental dimensions. (Loucks, 2017).

(5) Multi-Criteria Analysis (MCA) is a framework for systematically evaluating and ranking decision options across multiple, often conflicting objectives. MCA facilitates transparent assessment and comparison of trade-offs by scoring alternatives based on a range of quantitative metrics and qualitative criteria. Key features include consolidating diverse priorities into a single process; allowing both objective and subjective inputs; and supporting complex decisions through structured analysis (Hajkowicz and Collins, 2007).

3. METHODS AND MATERIAL

3.1. Introduction

Water resources in Algeria are limited, delicate, and unevenly distributed across different time periods and geographical areas. Over the past two decades, these resources have been adversely impacted by drought, pollution, and suboptimal governance practices. Algeria's water potential is estimated at 19 billion cubic meters annually, which equates to around 600 cubic meters per inhabitant per year. Consequently, Algeria falls within the classification of nations grappling with water scarcity, as delineated by the World Bank's threshold of 1,000 cubic meters per inhabitant per year. (Messahel & Mekki. 2008)

In the initial segment of this chapter, we will explore the following, we will explore the following key points:

1. Offering a comprehensive overview of the research site, and outlining its water resources.
2. Providing a thorough examination of the various aspects of sustainable water resource management.
3. Emphasizing the significant water sustainability issues facing the Souk-Ahras region, stemming from a variety of contributing factors.
4. Highlighting the urgent need for integrated water resource management in the Souk-Ahras area to address these challenges effectively.

3.2. Presentation of the case study: Souk-Ahras region.

3.2.1. Description of the study area.

The study area is situated in the eastern region of Algeria, which is known for its high susceptibility to landslides. Specifically, the Souk-Ahras area is positioned between 36°17.1834' N latitude and 7°57.0666' E longitude. (Gueraidia, N, et al. 2023) This mountainous area features rugged terrain and is bordered by:

- ✓ El Tarf and Guelma to the north,
- ✓ Oum El Bouaghi to the southwest,
- ✓ and Tebessa to the south,
- ✓ with the Tunisian border lying to the east.

The region is characterized by a depression surrounded by forested mountains, which are intersected by the Mjarda valley. Souk-Ahras province covers an area of 4360 km² and is

subdivided into 10 districts and 26 municipalities, with a population of 453,917 individuals, accounting for 0.18% of the total national territory.

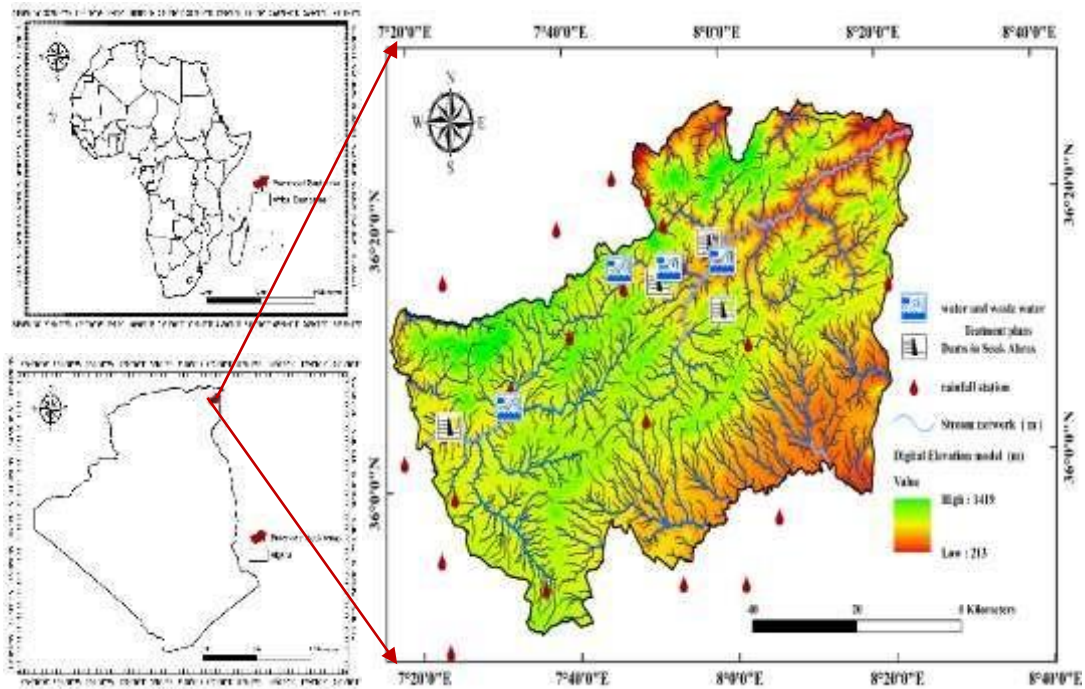


Figure. 3 localisation of Souk-Ahras city region.

3.2.2. Hydrographic networks

The hydrographic system extensively covers the entire region of Souk-Ahras. The limited water availability can be attributed to a combination of inadequate precipitation levels and insufficient water recovery and storage infrastructure. The region is intersected by three major wadis with varying flow rates influenced by climatic fluctuations (Barour, 2014):

- Oued Mellegue: with a basin area of 1442 km² and an average flow of 210 million m³/year.
- Oued Medjerda: with a basin area of 1377 km² and an average flow of 400 million m³/year.
- Oued Echaref: with a basin area of 1040 km² and an average flow of 99 million m³/year.

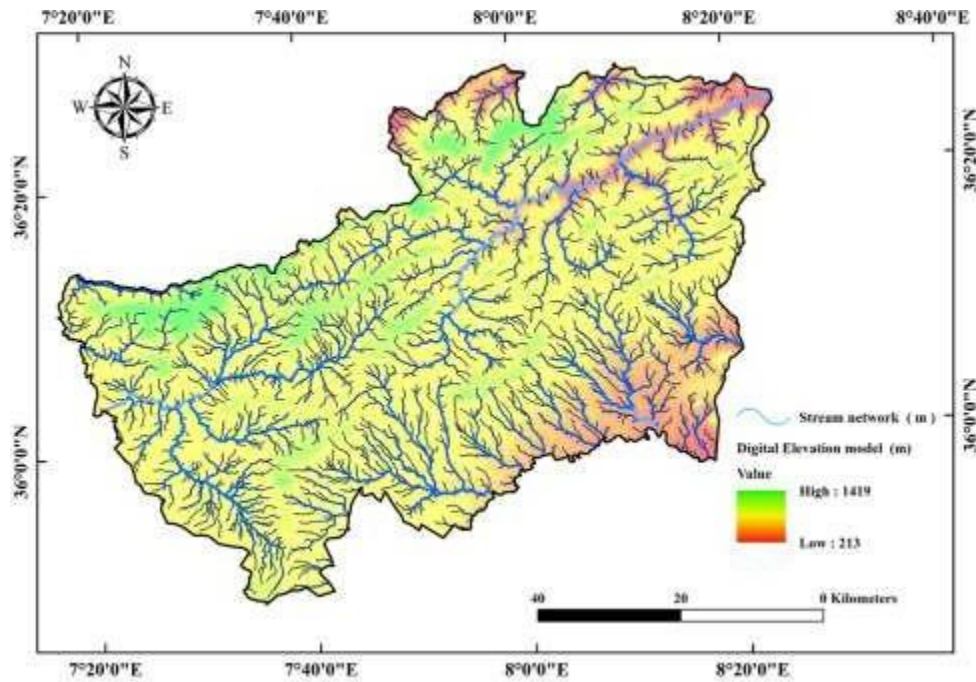


Figure. 4 Hydrological map of study area.

3.2.3. Water resources.

The primary water source for the municipality of Souk-Ahras is the Ain Dalia Dam, a surface water reservoir established in 1987 with a storage capacity of 70 million cubic meters. By 2015, the dam contained 53 million cubic meters of water, which is utilized by a water treatment facility generating 33,700 cubic meters per day. Furthermore, supplementary surface water is obtained from infiltrations at the base of the dam, which are collected and transferred to the urban area through pumping mechanisms. (Bensoltane, M. A. 2019)

Groundwater reserves serve as a complementary source to surface water supply. The M'Riss Aquifer located to the north of the city exhibits restricted availability and quality, featuring three boreholes - two of which contribute water to reservoirs, while one was decommissioned in 2018 due to substandard water quality. Conversely, the Taoura Aquifer situated to the south in proximity to the Tunisian border holds regional significance, with the identification of 15 boreholes, of which 3 are designated for the Souk-Ahras area. (ADE 2015)

The Ain Dalia Dam functions as the main water source, with the groundwater from M'Riss and Taoura serving as the initial sources prior to the dam's construction. These sources now serve as alternative and supplementary water supplies as required (Bensoltane, M. A. 2019).

Table 1 : Water resources AT Souk-Ahras region((Ministère des Ressources en Eau, 2020).

Type of Production	Region	Annual Production used volume (Mm 3)
Groundwater	1- Groundwater :	
	• Taoura	1.30
	• Other	0.65
	Total Forages	1.95
	2-Sources:Sedrata, Mechroha, Hennancha, ...etc.	0.65
	Total Sources	0.65
	Total groundwater	2.60
Surface Water	1- Dam Ain Dalia:	
	• Souk-Ahras	11.38
	• Mechrouha	0.32
	• Sedrata	1.06
	• M'Daourouch	0.63
	• Oude Kbarit	0.14
	• Zouabi	0.07
	Total surface Water	13.60
Total, Mm³		16.20

3.3. Dimensions of sustainable water resources management.

Sustainable water resource management entails the effective utilization and administration of water sources to fulfill long-term societal water supply requirements while safeguarding the integrity of hydrological systems. (Alley, et al. 1999).

3.3.1 Social dimension: Social fairness and community engagement, not simply economic efficiency, must be considered when managing water resources

sustainably. As a basic human right, access to clean water resources must be equitable and reasonably priced (UN, 2010).

- 3.3.2 Economic dimension:** Pricing and market mechanisms in the economy can encourage the more efficient and just distribution of scarce water resources. (Rogers et al. 1998), establishing water prices that fully represent the cost of providing promotes conservation and manages sustainable use. Water can be directed toward higher value uses by allowing the selling of water rights or allocations (Easter et al. 1999). In general, economics gives methods to control water demand and reallocate supply more sustainably, but social aspects must be considered when designing policies (GWP, 2000).
- 3.3.3 Governance dimension:** The management of water resources sustainably depends on effective governance. This comprises inclusive decision-making procedures that involve a variety of stakeholders, integrate across industries, and connect local and federal levels of authority (Pahl-Wostl. 2002).
- 3.3.4 Environmental dimension:** Human water requirements and environmental protection must be balanced in sustainable water management. Freshwater ecosystems and the services they provide can be harmed by overuse and contamination of water supplies. (Vörösmarty et al. 2010). In order to preserve aquatic habitats and species, environmental flows in rivers and groundwater should be used sustainably. Preventative strategies, treatment options, impact analyses, and resource monitoring can all be used to reduce pollution, safeguard ecosystems, and ensure water supplies are available for the foreseeable future (UNESCO. 2022).
- 3.3.5 Technical dimension:** Infrastructure improvements and technological advancements are crucial tools for enhancing the sustainability of water systems. Water networks can be more effectively monitored and operated thanks to technologies like smart meters, remote sensing, and real-time control systems (Gleick. 2018).

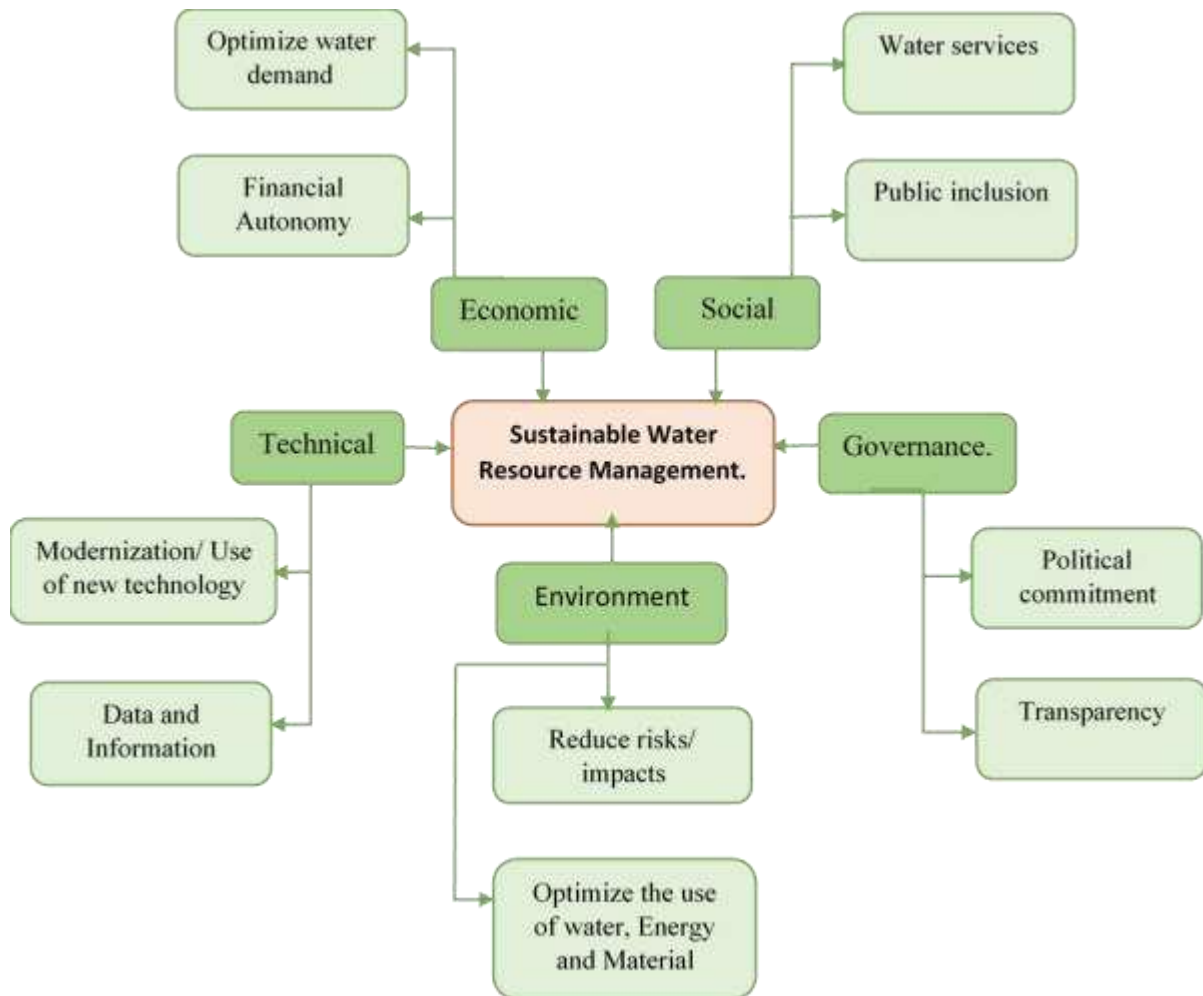


Figure. 5 Flowchart of dimensions of sustainable water resource management.

3.4. Water Resource Sustainability Challenges in the Souk-Ahras Region:

Findings from reputable international evaluations emphasize that the Souk-Ahras area is significantly susceptible to water scarcity due to a mix of restricted renewable resources, excessive exploitation, ineffective utilization, and the effects of climate change. This highlights the urgent requirement for coordinated water resource governance. Several existing challenges are impacting the water sustainability of the Souk-Ahras region, including:

- Research findings indicate that a 15% decrease in precipitation due to climate change would significantly affect the Ain Dalia dam's capacity to fulfill water demand, resulting in an estimated 12 million cubic meters of unmet demand by the year 2037(Ouled Zaoui, S. et al. 2010)
- The imminent water scarcity in Souk-Ahras is consistent with the overarching evaluations of water stress in northeastern Algeria. This area is situated within the

semi-arid to arid climatic regions that encompass a significant portion of Algeria. As per the Food and Agriculture Organization (FAO), Algeria is presently encountering water scarcity, with renewable freshwater resources amounting to approximately 286 m³ per capita annually as of 2017, significantly lower than the recognized threshold of 1,000 m³ indicative of water scarcity. (FAO Aquastat, 2022).

- The excessive utilization of groundwater reserves is a significant concern that exacerbates water scarcity. Research conducted investigating the Taoura aquifer in Souk-Ahras revealed a yearly decrease in groundwater levels ranging from 1 to 3 meters, which was linked to the excessive extraction of water for agricultural purposes. (Kebiri, L. et al. 2021)
- The impact of climate change is anticipated to intensify the challenges associated with water scarcity. Recent findings from the Intergovernmental Panel on Climate Change (IPCC) indicate a projected reduction in precipitation and a heightened occurrence of droughts in the Mediterranean area, encompassing northern Algeria, as a consequence of escalating global temperatures. (IPCC, 2022).

MATERIALS AND METHOD

3.5. Introduction

The idea of managing water resources sustainably highlights the significance of taking both the present and the long term into account. "Sustainable" water resource management refers to the management of a system's water resources to meet changing demands both today and in the future without compromising the system. (Loucks, Daniel P. 2000).

In pursuit of this goal, it is essential to incorporate economic, environmental, technical, governance and social dimensions of sustainability. In our proposed study, we made a concerted effort to integrate these dimensions in our assessment of water management sustainability.

In this section of the third chapter, two distinct methodologies were employed to accomplish the objective of the research:

- ✓ A comprehensive survey will be conducted to gather direct feedback from stakeholders such as water authorities and agricultural communities. This survey aims to assess the efficiency of water management techniques, identify future improvements, and uncover key policies and strategies related to water management.

- ✓ Utilizing the Analytical Hierarchy Process (AHP) which involves the prioritization of different dimensions of water management sustainability and their related indicators.
- ✓ Employing the SWOT analysis to identify key points of weakness, strength, opportunities and threats regarding current water management practices on the study area.

3.6. Methodologies

The methodology employed in this study incorporates a variety of tools, encompassing both qualitative and quantitative approaches, and is structured into three main sections for analysis.

using the AHP model.

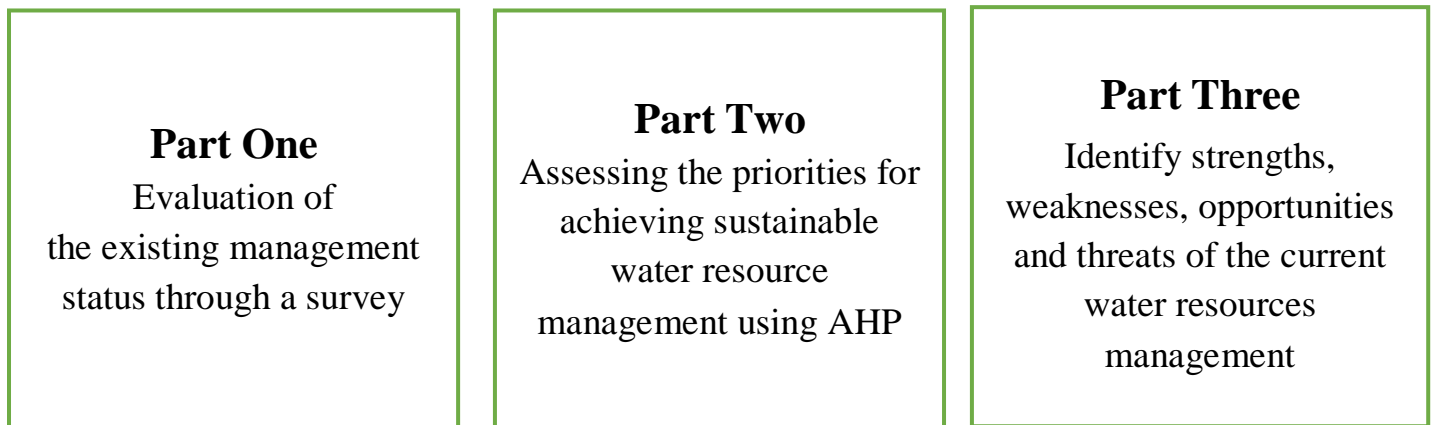


Figure. 6 Flowchart of the three main parts of the followed methodology.

3.6.1. Part one: Assessment of the current state of management using survey.

The objective of the survey is to evaluate the Souk-Ahras region's water resources management system in terms of advantages and limitations. The questions will be structured around various aspects and factors influencing the effectiveness of water resource management. To enable a thorough examination of the current status of water resource management services, representatives and engineers from a range of public water service organizations will respond to these inquiries.

1) Defining survey objectives:

A fundamental step in the survey process is establishing specific study goals, which calls for researchers to agree on well-defined research objectives (Johnson, R et al, 2004).

The objectives of our survey can be summarized as follow:

- ✓ To comprehensively evaluate current water management practices in the region and identify challenges impeding sustainability.
- ✓ To evaluate the level of commitment among stakeholders and determine the effectiveness of collective efforts in sustainable water management.
- ✓ To analyze policy effectiveness and regulatory frameworks.
- ✓ To assess community perception and awareness, the survey aims to understand local attitudes, awareness levels, and involvement in water management.

2) Scale and Type of Questions.

The methodology adopted in this study involved the use of a survey incorporating a “5-point Likert scale “for questioning.

Likert scale:

Likert scale is a popular psychometric instrument used to measure attitudes, views, and perceptions in surveys and questionnaires. Usually, it consists of a sequence of statements or questions where participants indicate how much they agree or disagree using a predetermined scale that goes from highly agree to strongly disagree (Likert, 1932).

The Likert scale with five points includes:

- Strongly Disagree: expressing the least amount of support or agreement with a a statement.
- Disagree: displaying disagreement even though it's not as strong as disagree.
- Neutral: indicating that respondents were neither strongly in agreement nor disagreement.
- Agree: expressing agreement with the statement and endorsing it.
- Strongly Agree: expressing the maximum level of agreement or support for a statement.

1) **Advantages of Likert scale**

The advantages of Likert scales can be summarized as follows (Typeform. 2024):

- ✓ Likert scales yield precise outcomes, enabling a comprehensive comprehension of individuals perspectives regarding a certain subject.

- ✓ The scales make it easier to gather quantitative data, which permits effective statistical analysis and the computation of final scores.
- ✓ Because Likert scales have a closed-ended format, they are easy to use and time-efficient for gathering data from large samples.

Limitations of Likert scales

Among the limitations of Likert scales is the possibility of bias response, in which participants give socially acceptable answers rather than their genuine beliefs or attitudes (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003). Extreme reaction tendencies, acquiescence bias, and social desirability are a few examples of factors that may contribute to bias. Furthermore, Likert scales may find it difficult to accurately identify subtle differences in attitudes if the scale alternatives are unduly limited or broad. Furthermore, using Likert scales to collect self-report data can result in errors because of problems with memory recall and question interpretation. (Oppenheim, 1992; DeVellis, 2017). In order to overcome these constraints, researchers frequently add qualitative interviews or observational studies to Likert scales in order to obtain a more thorough understanding of participants' opinions and behaviors.

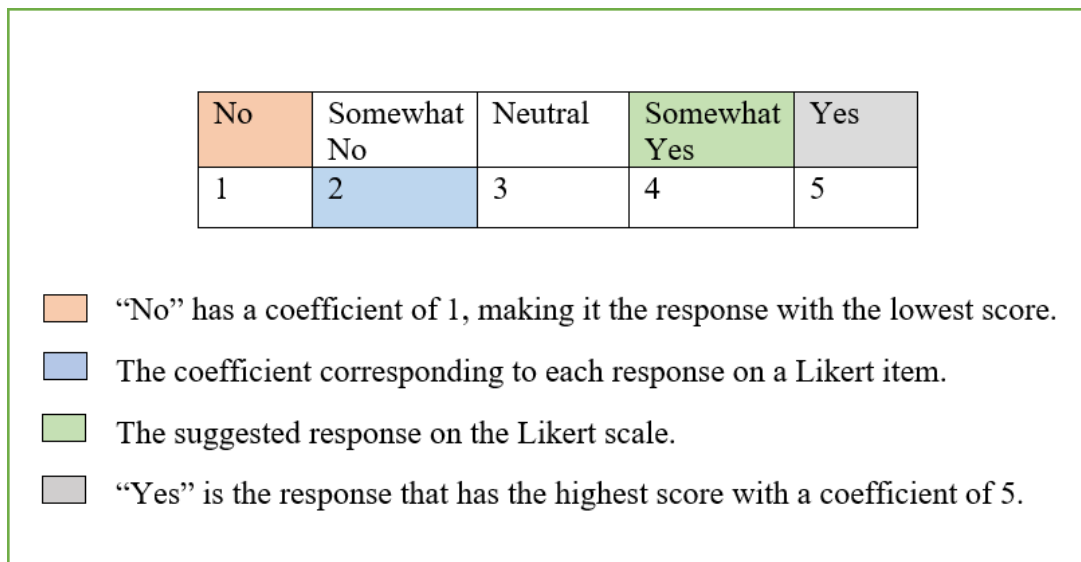


Figure. 7 Presentation of the five-point Likert scale.

d. Survey Design

The process of designing a survey is crucial, in this study the questions were designed using multiple axes and criteria and sub-criteria in relation with the different dimensions of sustainable management of water resources and various water sector's facilities. In total ten

distinct axes were considered in the current survey; these axes were selected because they have a direct link with the final objectives of our investigation.

The various survey axes are presented in the following table:

Table 2:The considered axes within the questionnaire.

The number of the axis	The name of the axis	The number of questions per axis
N°1	Political commitment	06
N°2	Transparency	10
N°3	Public inclusion	07
N°4	Water services	11
N°5	Optimize water demand	09
N°6	Financial autonomy	06
N°7	Reducing Risks and Impacts	09
N°8	Optimize Use of Resources	06
N°9	Data and information	09
N°10	Modernization	10

e. Calculation method

To calculate the score (N_i) on a Likert scale, the following formula is used:

$$N_i = a*1+b*2+c*3+d*4+e*5$$

With:

- a: represent the number of respondents they have chosen the answer « NO »
- b: represent the number of respondents they have chosen the answer « Somewhat NO »
- c: represent the number of respondents they have chosen the answer « Neutral »
- d: represent the number of respondents they have chosen the answer « Somewhat Yes »
- e: represent the number of respondents they have chosen the answer « Yes »

In order to express the score as a percentage representing each axis, we adopted a methodology inspired by prior research (Deng, Xinyang, et al., 2014). This approach involves determining the percentage of a specific axis in relation to the maximum potential score of the axis, which is calculated as: $(a+b+c+d+e) *5$.

Questions design:**Axis N°: 1 Policy Implementation**

Policy implementation in water resources management involves the practical application of policies, plans, and strategies related to water resources. This process includes a range of actions and steps taken by governments, organizations, and interested parties to achieve policy goals and effectively manage water resources. (Biswas, Asit K. 2004)

The objective of this axis is to evaluate the level of political dedication in various aspects of sustainable water resource management, and to be able to:

- ✓ Evaluate the adequacy of actions implemented by policymakers in the execution of Integrated Water Resources Management (IWRM) strategies.
- ✓ Assess the transparency and adaptability of current water policies.
- ✓ Determine the extent of governmental commitment towards implementing local legislations that relate to water issues.

Table 3: Representation of the details of the Political commitment axe

Axis N°: 1	Number of Questions	Number of respondents
Political Commitment	6	15

The questions related to this axe are presented in the following figure:

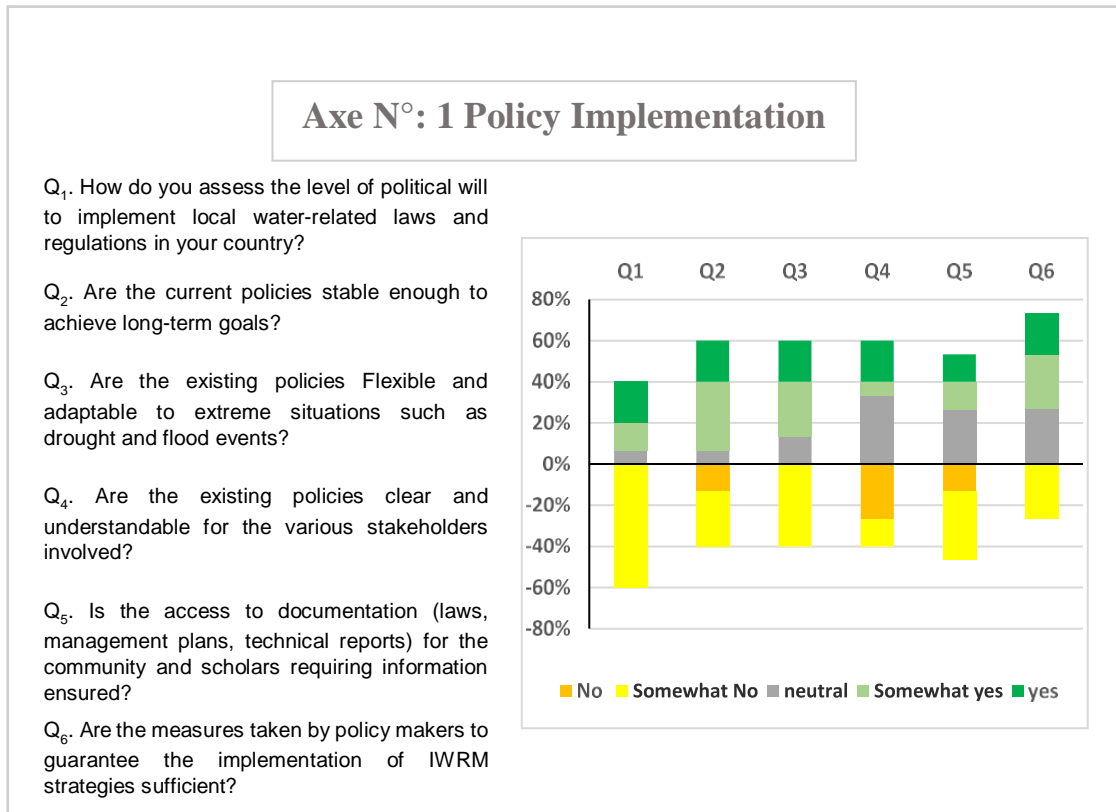


Figure. 8 Presentation of the questions related to the axe Policy Implementation.

Axis N°: 2 Transparency

Transparency in the management of water resources involves the open dissemination of pertinent information, data, policies, and decision-making procedures to various stakeholders. This practice fosters public confidence by demonstrating equitable and accountable decision-making processes. Transparency plays a pivotal role in holding decision-makers responsible and fostering stakeholder engagement by accommodating a range of viewpoints. Moreover, it facilitates the monitoring and assessment of water resource management strategies to highlight areas necessitating enhancement and to facilitate conflict resolution through the establishment of a consensus among stakeholders. (Akhmouch, Aziza, et al. 2016)

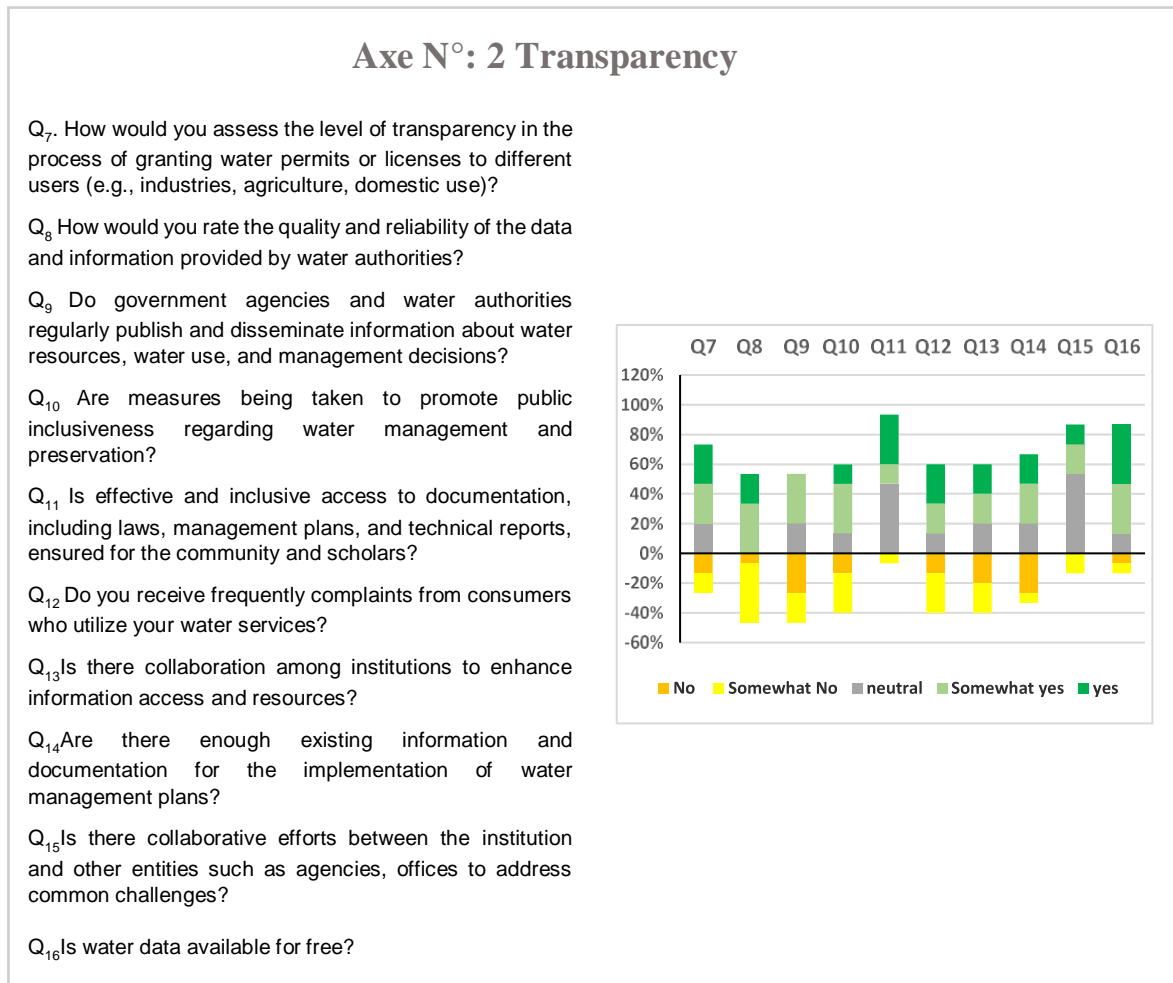
The objective of this axis can be summarized as follows.:

- ✓ Examine the availability and accessibility of water data.
- ✓ Evaluate the level of collaboration among institutions in addressing challenges related to water management.
- ✓ Assess the quality and reliability of data sourced from water authorities.

Table 4: Representation of the details of the Transparency axe.

Axis N°: 2	Number of Questions	Number of respondents
Transparency	10	15

The questions related to this axe are presented in the following figure:

**Figure. 9** Presentation of the questions related to the axe Transparency.

Axe N°: 3 Public Inclusion

The concept of public participation in water resources management involves engaging the public, communities, and relevant stakeholders in the decision-making processes concerning water planning, management, and policies. This principle is underscored as a fundamental aspect by prominent entities such as the Global Water Partnership to enhance the efficiency and sustainability of water management. Public inclusion facilitates the making of well-informed decisions, heightens awareness and approval, ensures fair management practices,

fosters transparency, accountability, and acknowledges a variety of viewpoints. It is a crucial element for achieving integrated, participatory, and effective water resources management (Solanes, M, and Fernando Gonzalez ,V. 1999).

This axis's goal can be summed up as follows:

- ✓ Evaluate the degree of support for women's participation in water management programs.
- ✓ Analyze the extent of community engagement in the formulation of policies.
- ✓ Assess the effectiveness of initiatives aimed at promoting public engagement in water resource management and preservation.

Table 5: Representation of the details of the Public inclusion axe.

Axis N°: 3	Number of Questions	Number of respondents
Public Inclusion	7	15

The questions related to this axe are presented in the following figure:

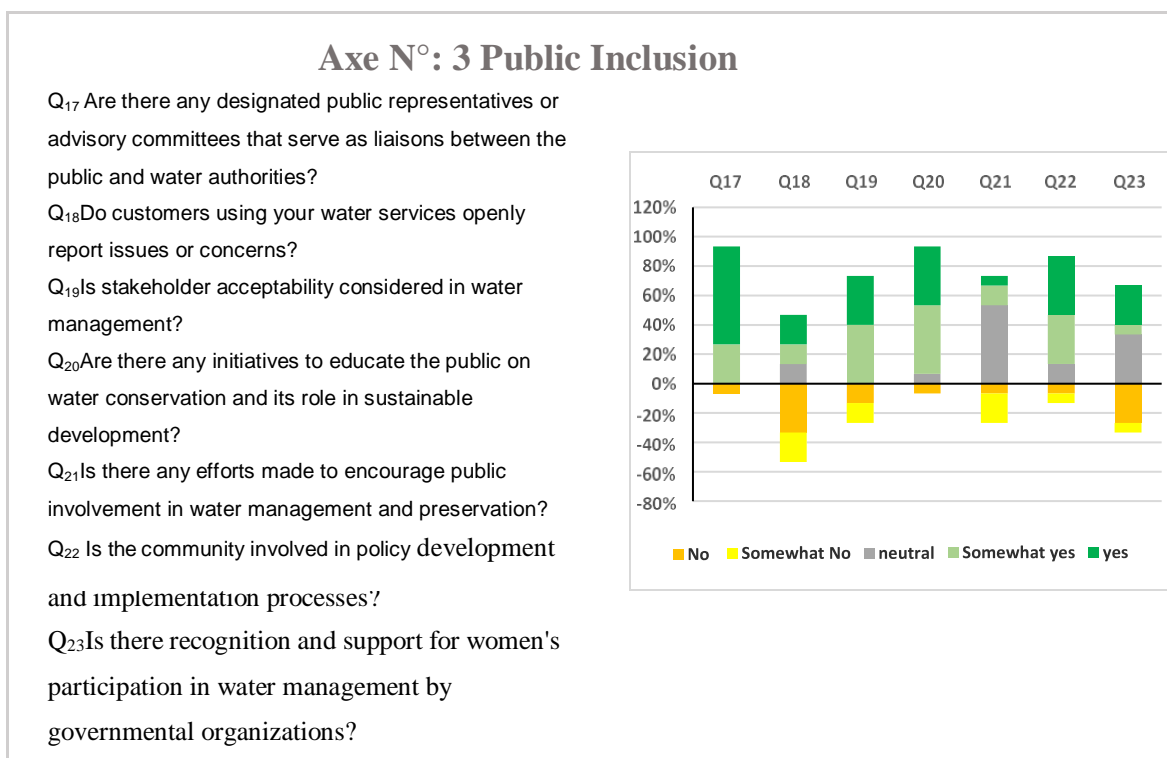


Figure. 10 Presentation of the questions related to the axe Public Inclusion.

Axis N°: 4 Water Services

In the context of water resources management, "water services" typically refers to the provision of clean water to meet human requirements, support economic activity, and advance public health. The supply of dependable and safe drinking water, sanitation services, the appropriate disposal of wastewater are typical examples of these services. (Butterworth, J, and John ,S. 2001)

The aims of this inquiry are outlined as follows:

- ✓ Analysis of strategies for equitable and effective water distribution.
- ✓ Evaluation of the control of water quality and adherence to standards.
- ✓ The assessment of water services quality and affordability.

Table 6: Representation of the details of the Water services axe.

Axis N°: 4	Number of Questions	Number of respondents
Water Services	11	15

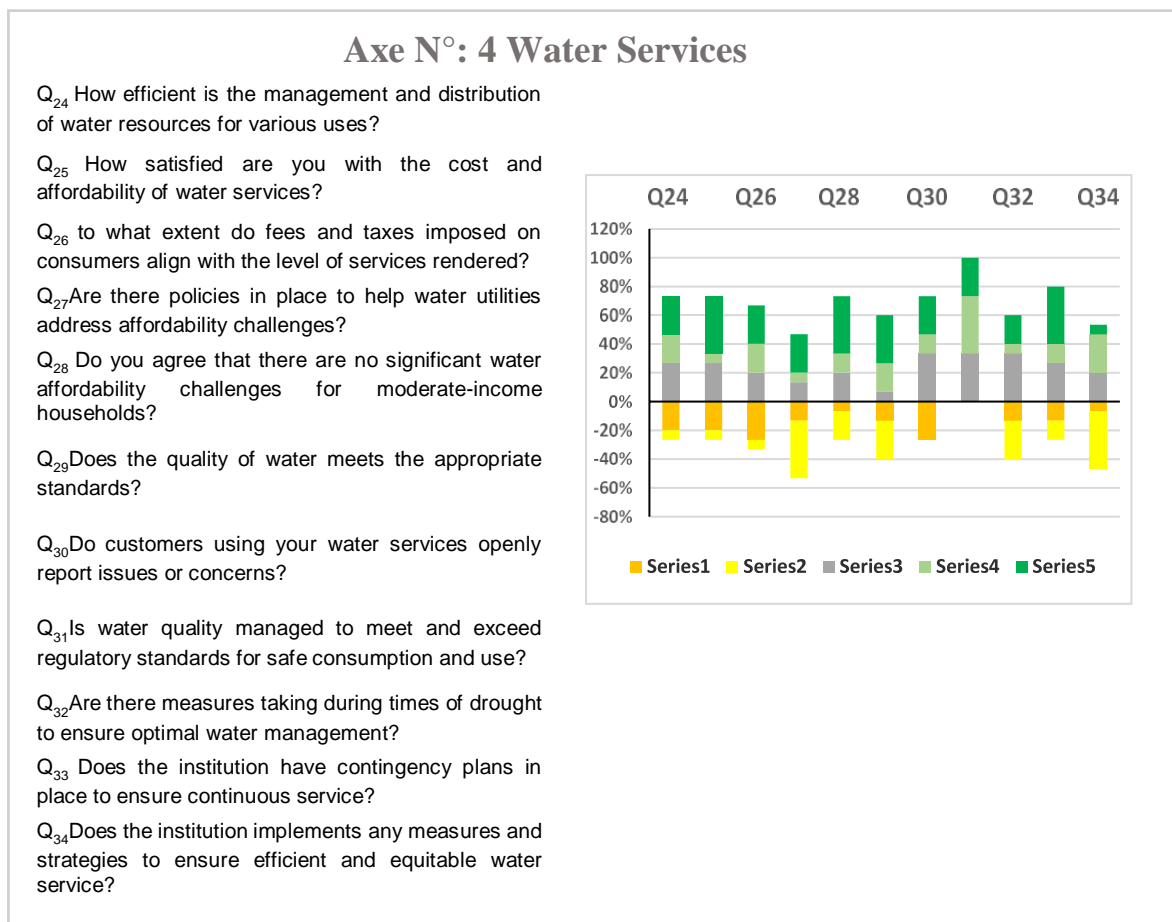


Figure. 11 Presentation of the questions related to the axe Water Services.

Axis N°: 5 Optimize Water Demand

The optimization of water demand pertains to the utilization of strategies and methodologies designed to diminish and regulate the need for water in an effective and sustainable manner. This encompasses supporting initiatives encouraging water preservation, enhancing water utilization effectiveness, and adjusting water usage to the existing water reservoirs. (Lenton, R, and Mike,M. 2012).

The aims of this inquiry are outlined as follows:

- ✓ Examine efforts made towards water conservation and reduction of water demand.
- ✓ Assess the efficacy of measures aimed at optimizing water demand.
- ✓ Evaluate the deployment of water metering and monitoring systems.

Table 7: Representation of the details of the Optimise Water Demand axe.

Axis N°: 5	Number of Questions	Number of respondents
Optimise Water Demand	9	15

The questions related to this axis are presented in the following figure:

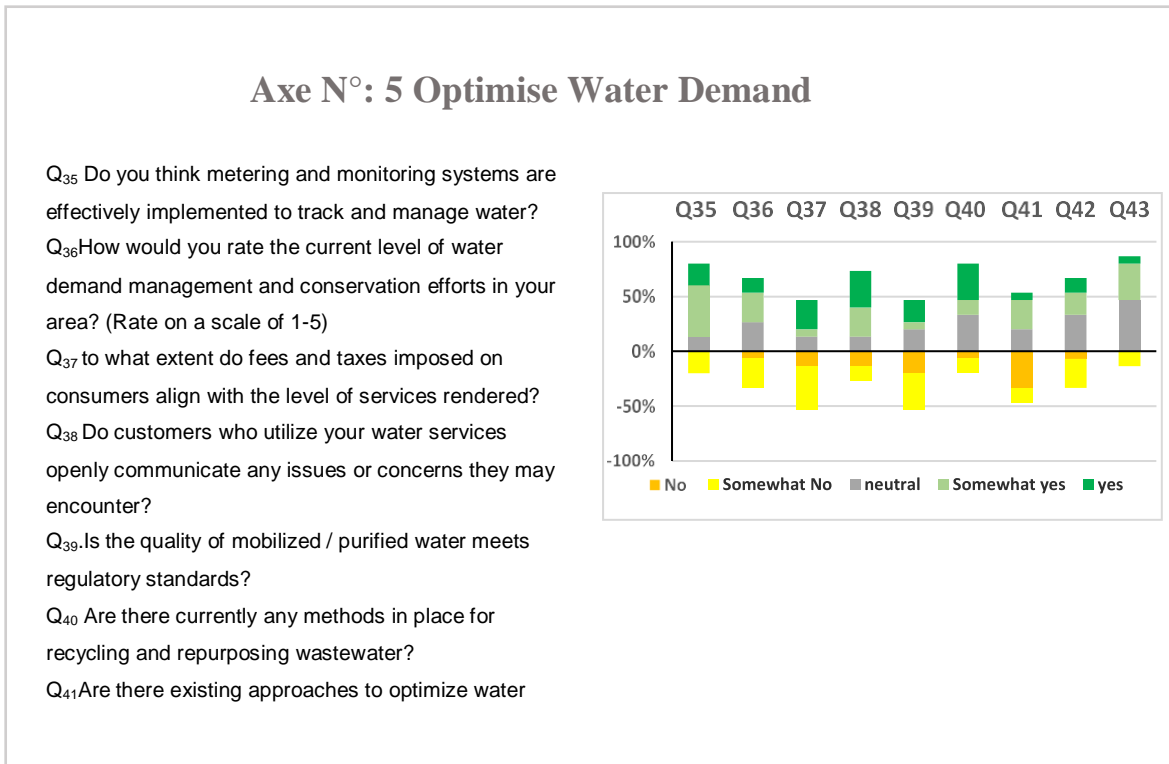


Figure. 12 Presentation of the questions related to the axis Optimization of water demand.

Axis N°: 6 Financial Autonomy

Financial autonomy refers to the ability of water resource operators to have a greater degree of financial independence and control over financial resources through mechanisms like increased fiscal and tariff revenues. This autonomy allows operators to make decisions and investments that align with the sustainable management and development of water resources (Wang, Tien-Chin, et al. 2021) .This axis provides us with the capability to:

- ✓ Evaluate how much money is available for water management.
- ✓ Assess the financial barriers impeding the effective execution of policies.
- ✓ Decide whether to investigate novel funding sources for financial independence.

Table 8: Representation of the details of the Financial autonomy axis.

Axis N°: 6	Number of Questions	Number of respondents
Financial Autonomy	6	15

The questions related to this axis are presented in the following figure:

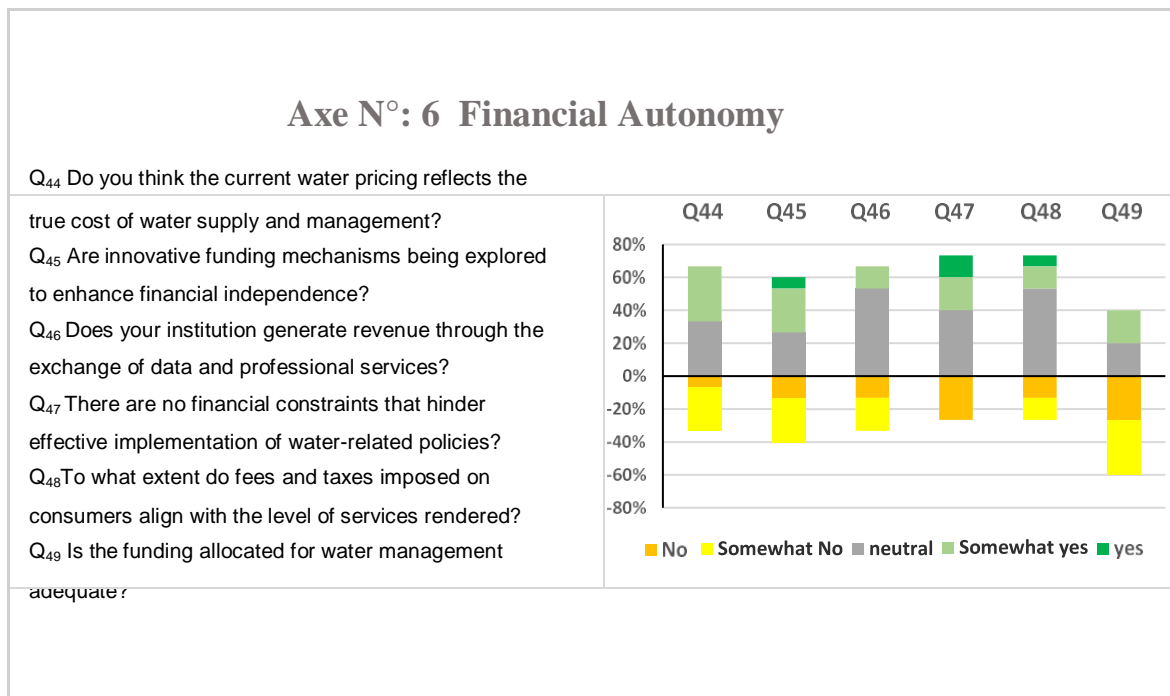


Figure. 13 Presentation of the questions related to the axe Financial Autonomy.

Axis N°: 7 Reduce Risks / Impacts

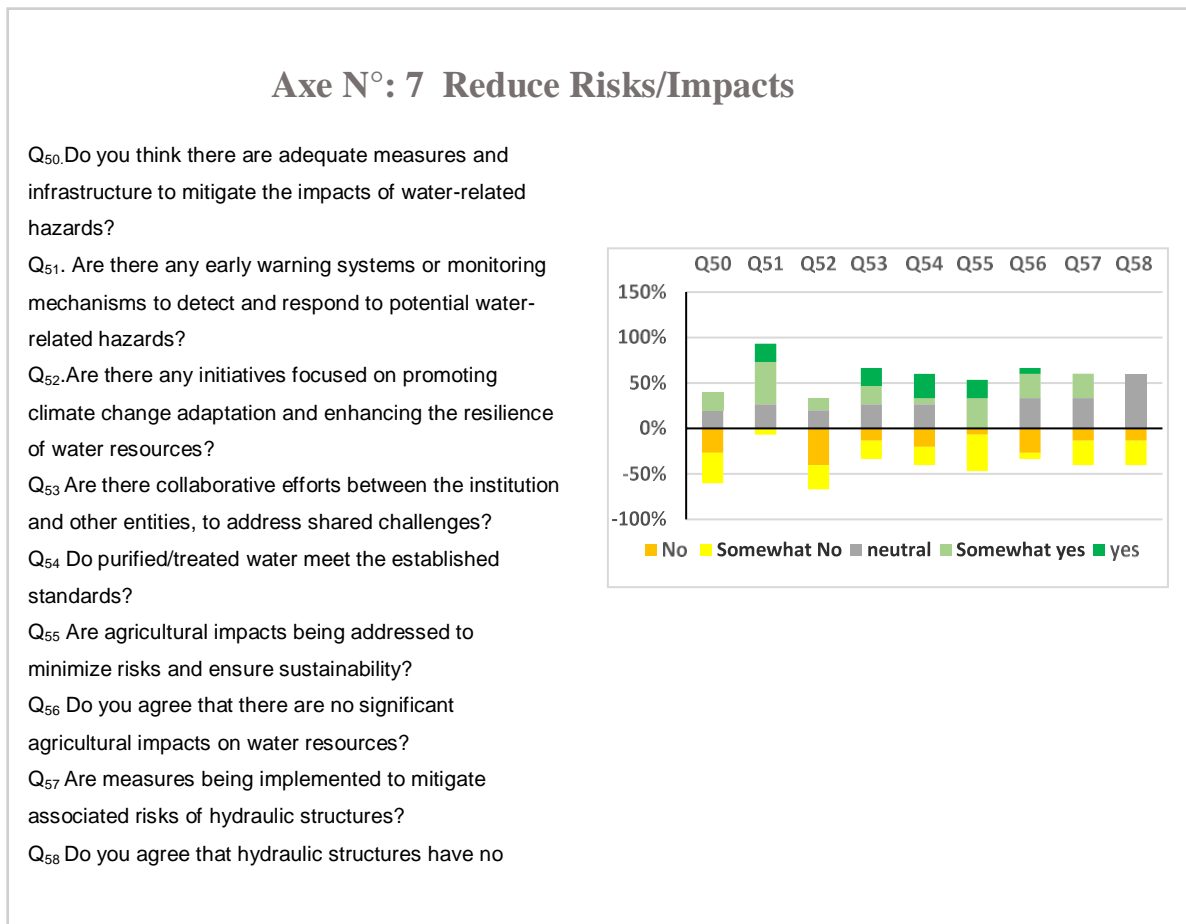
The concept of "Mitigating Risks and Minimizing Impacts" pertains to the implementation of various strategies and measures aimed at decreasing the negative effects of water-related disasters such as floods, droughts, and storms on both communities and ecosystems. These initiatives are centered on enhancing community resilience, improving water management practices, promoting collaboration among different stakeholders, and integrating adaptive and mitigative methods to address the issues arising from climate change on water resources. (Brekke, Levi D. 2009). This axis's purpose is to :

- ✓ Examine the effects of hydraulic structures and agricultural activities on water reserves.
- ✓ Analyze the efficiency of the existing strategies in reducing risks and improving sustainability.
- ✓ Assess initiatives aiming at advancing climate change adaptation and enhancing the resilience of water resources.

Table 9: Representation of the details of the Reducing Risks and Impacts axe.

Axis N°: 7	Number of Questions	Number of respondents
Reduce Risks / Impacts	9	15

The questions related to this axis are presented in the following figure:

**Figure. 14** Presentation of the questions related to the axe Reducing Risks and Impacts.

Axis N°: 8 Optimise Use of Resources

The optimization of water, energy, and material resources entails maximizing their efficiency and sustainability to promote responsible utilization and conservation. This process is designed to improve resource management by reducing resource waste and mitigate environmental impacts linked to water-related activities. (Salam, P. Abdul, et al. 2017). The questionnaire regarding this axis helps us to:

- ✓ Examine the application of sustainable energy sources in water resource management.
- ✓ Analyze the repurposing and reutilization of wastewater and sediments.
- ✓ Evaluate the involvement of stakeholders in enhancing the efficiency of water, energy, and material assets.

Table 10: Representation of the details of the Optimizing the Use of Water, Energy, and Material axe.

Axis N°: 8	Number of Questions	Number of respondents
Optimise Use of Resources	6	15

The questions related to this axis are presented in the following figure:

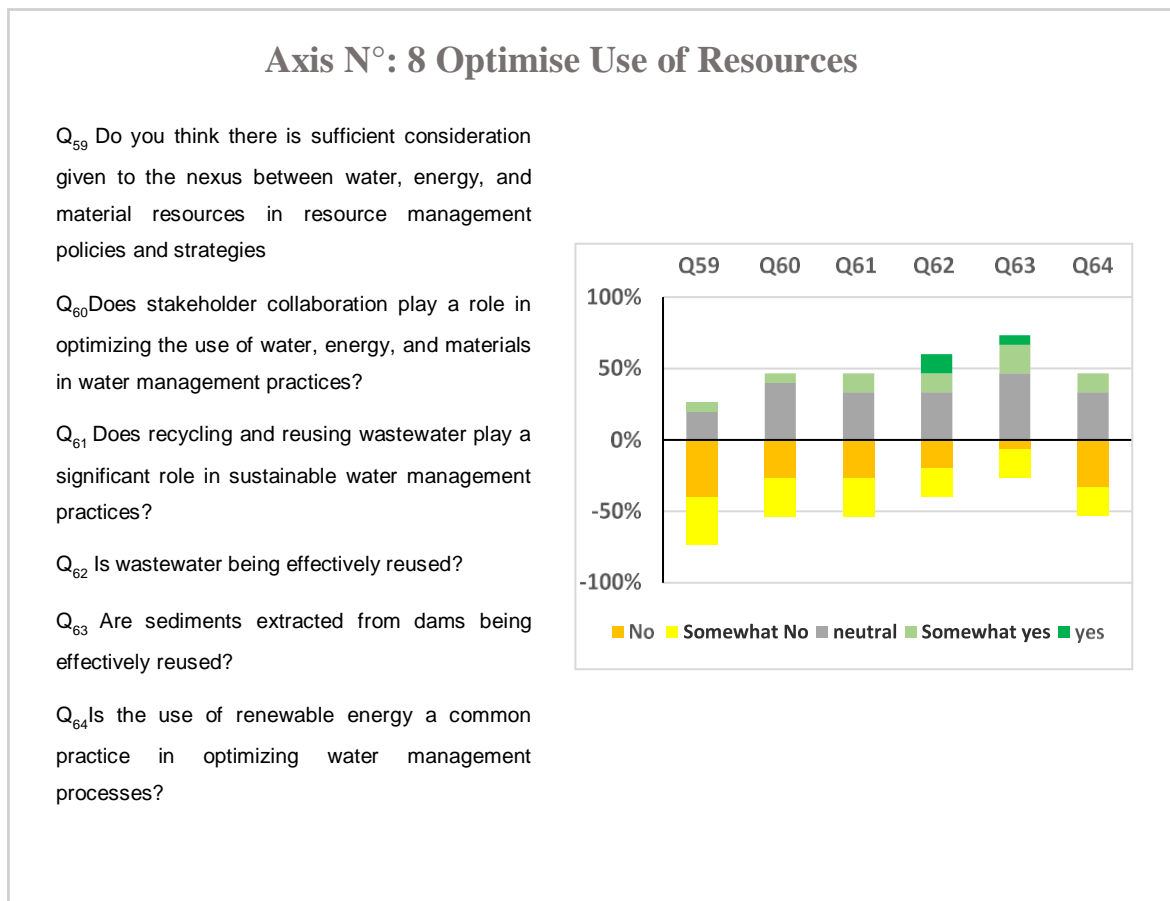


Figure. 15 Presentation of the questions related to the Optimise Use of Resources

Axis N°: 9 Data and Information

Data and information" refer to the fundamental elements required to handle ecological, political, social, and physical challenges pertaining to the availability, accessibility, supply, and consumption of water. These elements facilitate effective planning and decision-making

processes in a variety of water related disciplines, including flood risk assessment, water supply management, reservoir operation, and water sanitation (Jahanddideh-Tehrani, Mahsa, et al. 2021)

In the current survey a special focus is attributed to

- ✓ Assessing the water data's regular update and accessibility.
- ✓ Evaluating the water data's dependability and accuracy.
- ✓ Assessing the use of remote monitoring and advanced tools for decision-making.

Table 11: Representation of the details of the Optimization of water demand **axe**.

Axis N°: 9	Number of Questions	Number of respondents
Data and Information	9	15

The questions related to this axe are presented in the following figure.

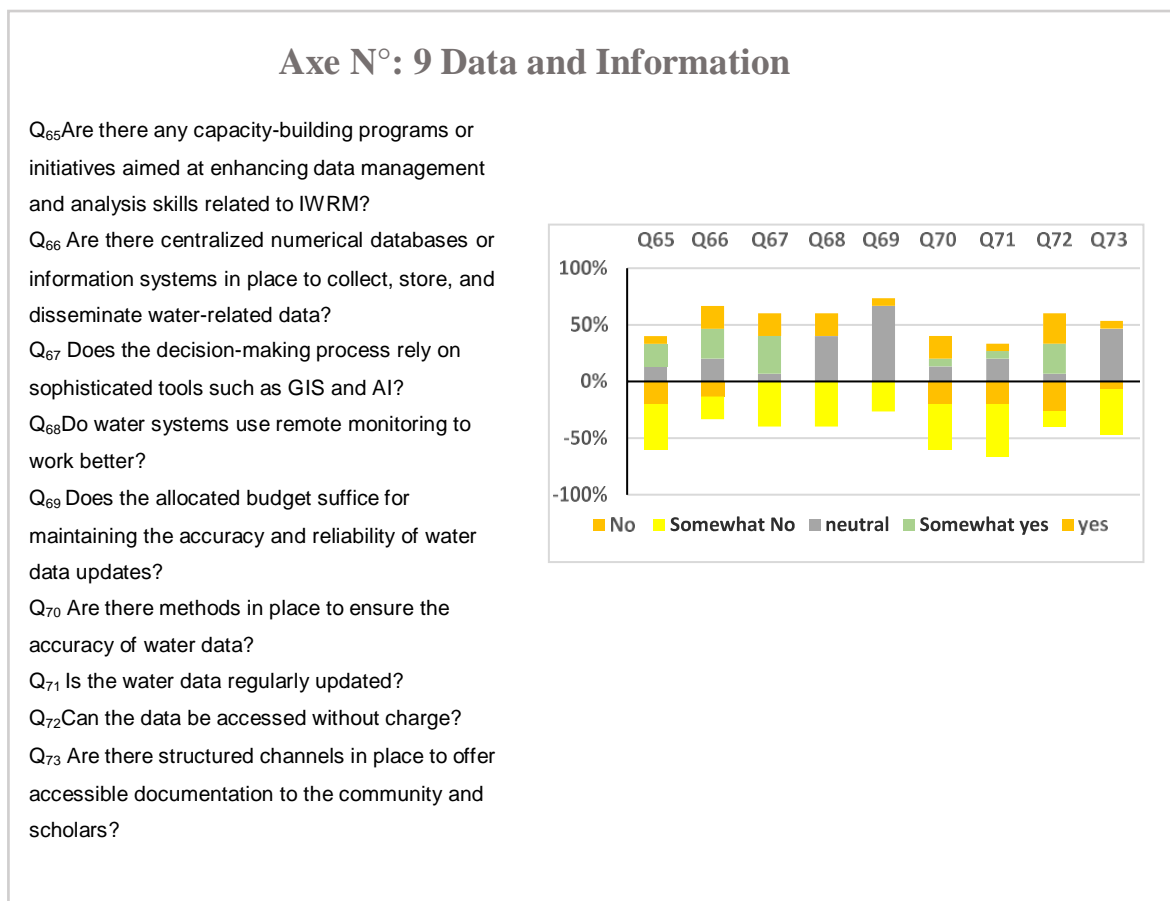


Figure. 16 Presentation of the questions related to the axe Data and Information

Axis N°: 10 Modernization

Modernization is the deliberate upgrading of technologies, infrastructures, and management techniques to improve productivity, sustainability, and water efficiency. Modernization is extremely important for optimizing water allocation, distribution, and usage for home, industrial, and agricultural uses. This process frequently entails the adoption of creative ideas, digital tools, and enhanced governance structures. (Atampugre, Gerald, et al. 2016).

The questionnaire regarding this axis helps us to:

- ✓ Examine the implementation of remote monitoring and contemporary technologies in water systems.
- ✓ Evaluate training initiatives for technical personnel and the incorporation of international standards.
- ✓ Investigate the effects of modernization on the operational efficiency of water infrastructures.

Table 12: Representation of the details of the Modernization axe.

Axis N°: 10	Number of Questions	Number of respondents
Modernization	10	15

The questions related to this axe are presented in the following figure:

Axe N°: 10 Modernization

- Q₇₄ Does the decision-making process rely on sophisticated tools such as GIS and AI?
- Q₇₅ Do water systems use remote monitoring to work better?
- Q₇₆ Is there a strategic plan to guarantee that the allocated budget is sufficient to maintain the accuracy and reliability of water data updates?
- Q₇₇ Does the modernization in water management impact the performance and durability of water infrastructures?
- Q₇₈ Are water facilities maintained and rehabilitated on a regular and adequate basis?
- Q₇₉ Does the modernization of water management aligns with the existing water structures?
- Q₈₀ Are global standards integrated into the day-to-day tasks of employees in the water management sector?
- Q₈₁ Does the water management sector provides training programs for technical staff to enhance their skills and knowledge?
- Q₈₂ Do you have all the special tools and equipment you need?
- Q₈₃ Do water systems utilize remote monitoring to enhance their functionality?

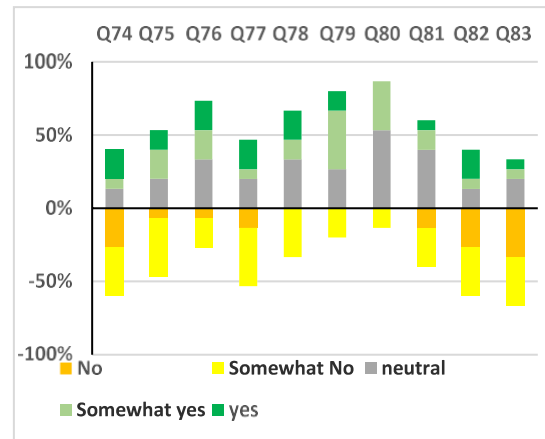


Figure.17 Presentation of the questions related to the axe Modernization.

Determination of the average Percentage of each axe

Calculation Methods:

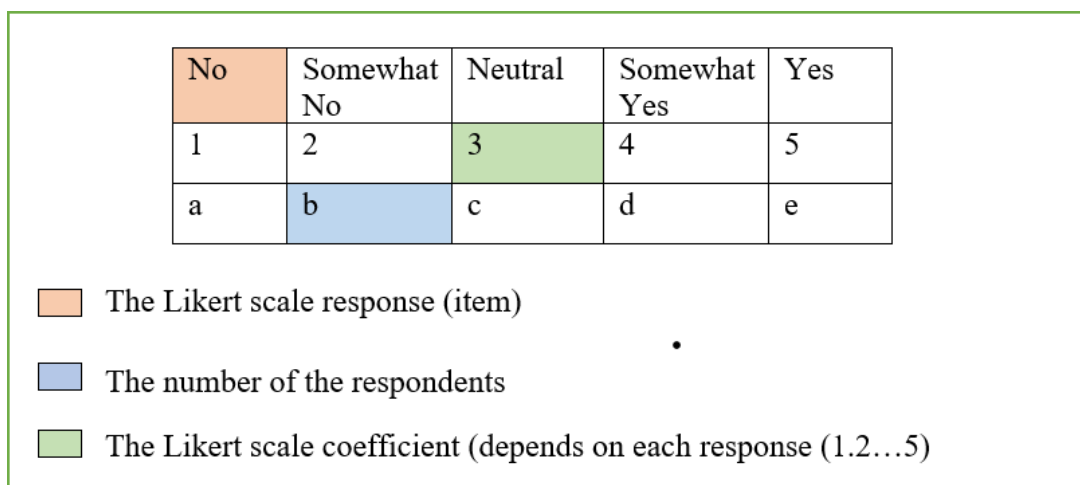


Figure.18 Calculation Method of the Likert scale.

3.6.2. Part two: Assessment of the sustainability of water management using the AHP model Analytical hierarchy process (AHP)

The Analytic Hierarchy Process (AHP), which was developed by T. Saaty (1977, 1980, 1988, 1995), is one of the most widely used MCA approaches. It allows users to assess the relative weight of multiple criteria or multiple options against given criteria in an intuitive manner. In case quantitative ratings are not available, policy makers or assessors can still recognize whether one criterion is more important than another. Therefore, pairwise comparisons are appealing to users. AHP established a consistent way of converting such pairwise comparisons (X is more important than Y) into a set of numbers representing the relative priority of each of the criteria (Kasperczyk, Nadja. 1996).

Table13: Evaluation scales of pair-wise comparison (Cabala and Pawel, 2010).

Important Value	Definition	Explanation
1	Equal direct influence	Both elements are same with the objective
3	Weak direct influence	Experience and judgments minimum evaluate process between another factor
5	Moderate direct influence	Experience and judgments medium evaluate process between another factor
7	Strong direct influence	Very useful process between another factor
9	Very strong direct influence	Extreme processes factor compared with all the factors

Structuring the Hierarchy

The implementation of AHP comprises the next steps: 1: Specifying the problem and the objectives; Step 2: Defining the criteria (and sub-criteria) that contribute to the problem; Step 3: Establishing a pairwise comparison matrix. Step 4) Estimating the relative weights for the criteria/sub-criteria through calculating the eigen values and eigen vectors of the associated matrices.

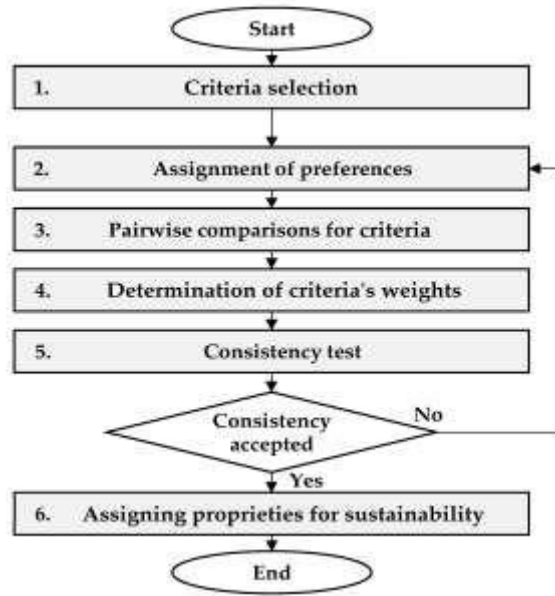


Figure. 19 The AHP process flowchart

The pairwise comparison among criteria is based on expert’s preferences. A Numerical value is used to represent the relative importance of a given criteria over another based to the Saaty scale (Figure 13). It is expressed as follows:

$$A = \begin{pmatrix} x_{11} & x_{12} & \dots & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & \dots & x_{2n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ x_{n1} & x_{n2} & \dots & \dots & x_{nm} \end{pmatrix} \quad (1)$$

$$\text{where } x_{ji} = \begin{cases} 1 & \text{if } i = j; \\ \frac{1}{x_{ij}} & \text{if } i \neq j; \end{cases} \quad (2)$$

Then, a standardized pairwise comparison matrix is constructed based on the following procedure:

$$a_{ij} = \frac{x_{ij}}{\sum_{i=1}^n x_{ij}} \quad (3)$$

$$A = \begin{pmatrix} a_{11} & a_{12} & \dots & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & \dots & a_{2n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \dots & \dots & a_{nm} \end{pmatrix} \quad (4)$$

The weight of each criterion i is determined based on the average row approach in the standardized matrix:

$$W_i = \frac{\sum_{j=1}^n a_{ij}}{n} \quad \text{and} \quad \sum_{i=1}^n W_i = 1 \quad (5)$$

where n represents the order of the matrix.

The consistency of the pairwise comparison matrix is verified using the consistency index, which is determined by:

$$CR = \frac{CI}{RI} \quad (6)$$

RI represents the stands for the random index (table 1) and CI is the consistency index, which is determined according to the following expression:

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad (7)$$

where, λ_{max} is the principle eigenvalue of the matrix, and n its order.

A CR less than 0.1 Indicates a reasonable accuracy for the pairwise comparison matrix; otherwise the matrix needs to be revised.

Table 14: The Random Consistency Index (Karami, A. 2011, Dolalah, D et al, 2010).

n	Random Index (RI)	Cut-off CI(10%)
1	0.00	0.00
2	0.00	0.00
3	0.58	0.058
4	0.90	0.090
5	1.21	0.121
6	1.24	0.124
7	1.32	0.132
8	1.41	0.141
9	1.45	0.145
10	1.49	0.149
11	1.51	0.151
12	1.48	0.148
13	1.56	0.156
14	1.57	0.157
15	1.59	0.159

3.8. SWOT analysis framework

The SWOT analysis framework is a commonly used strategic planning tool employed by institutions to assess their internal strengths and weaknesses, along with external opportunities and threats. This systematic methodology offers valuable and insightful information that support decision-making processes (Gurl, Emet. 2017).

In the context of water resources management, SWOT analysis can be a particularly useful tool. Incorporating this methodology can help organizations and policymakers develop more informed, holistic, and effective strategies, and implement sustainable water solutions that address the specific needs and challenges of their community (Ziara & Ayyub, 1999).

4 . RESULTS AND DISCUSSION

4.1. Introduction

In the upcoming chapter, the outcomes derived from the application of both the survey method and the Analytic Hierarchy Process (AHP) method will be presented, examined, explained, and discussed.

4.2. Survey results

The following figures illustrate the varying survey scores of the 10 axes:

Axis N°: 1 Policy Implementation

The overall percentage of this axe is: 61 % (Figure 20):

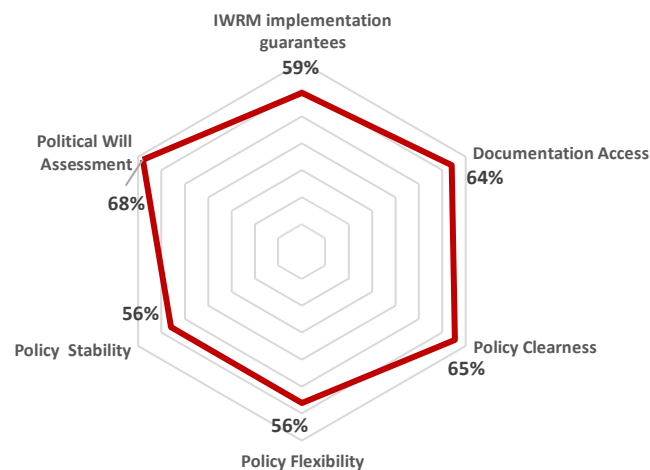


Figure. 20 The radar representation of the axe of Political Commitment.

The radar representation of the survey outcomes for the axis “Policy implementation “ (Figure 20) Accentuates the level of political will to implement local water-related laws and regulations in the study area as indicated by the score of 68%.

Axis N°: 2 Transparency

The overall percentage of this axe is: 65 % (figure 21):

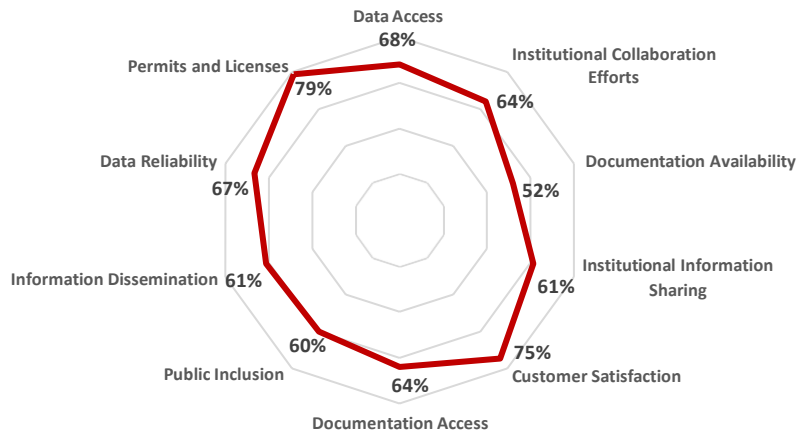


Figure. 21 The radar representation of the axe of Transparency.

The survey outcomes of the axis “Transparency” (Figure 21) reveals a low performance score regarding the availability of documentation (52%) as well as a low degree of community involvement in the water management process which is consistent with the results of the “public inclusion” axis.

Axis N°: 3 Public Inclusion

The overall percentage of this axe is: 70 % (Figure 22):

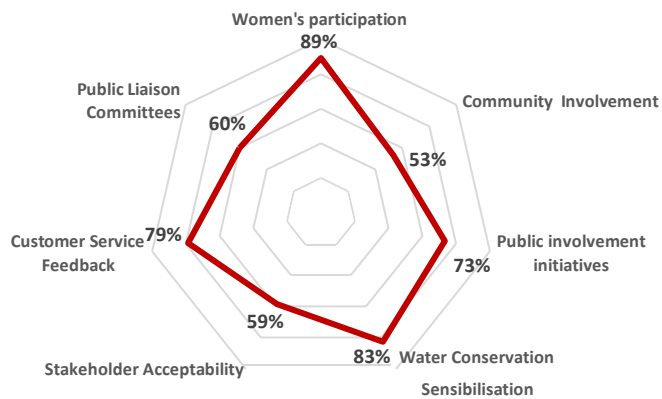


Figure. 22 The radar representation of the axe of Public Inclusion

The radar representation of the survey outcomes for the axis “public inclusion” (Figure 22) highlights the low degree of community involvement in water management process (53%) despite the several initiatives supporting public integration in water management process along with recurrent sensibilization calls for water conservation since these two aspects showed performance scores of 73% and 83% respectively.

Axis N°: 4 Water Services

The overall percentage of this axe is: 66 % (figure 23):

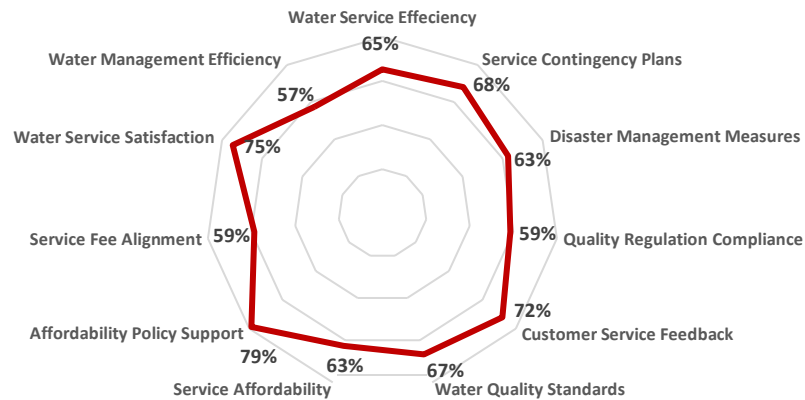


Figure. 23 The radar representation of the axe of Water Services

The results of the survey of the axis “water services” (Figure 23) reveals that the current water resource management practices are showing a low performance score regarding service fee alignment (57%) as well as water quality regulation compliance (59%).

Axis N°: 5 Optimise Water Demand

The overall percentage of this Axe is: 63 % (Figure 24):

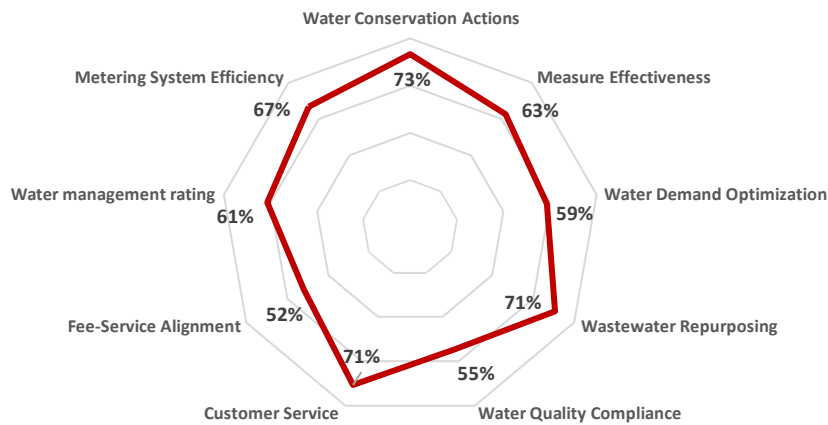


Figure. 24 The radar representation of the axe of Optimize Water Demand

The radar graph depicting the survey outcomes for the axis” Optimize Water Demand” (Figure 24), underscores an inadequate service fee alignment 52% ,this finding provides insight into the low performance of the water quality compliance which was rated at 55%. The graph also underscored that significant efforts made to enhance water demand optimization as indicated by the score of 59% related to this aspect.

Axis N°: 6 Financial Autonomy

The overall percentage of this axe is: 55 % (figure 25):

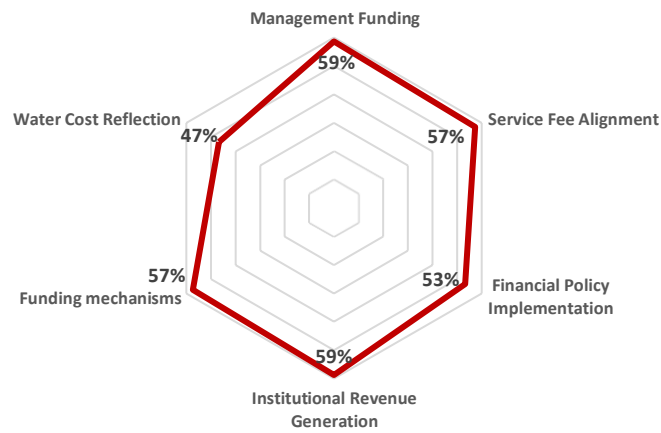


Figure. 25 The radar representation of the axe of Financial Autonomy

The radar presentation depicting survey findings related to the "Financial autonomy" axis, (Figure 25) revealed a major concern regarding water cost reflection (47%) while the adequacy of the budget allocated for water management presented a score of 59% and the ongoing exploration of innovative funding mechanisms achieved a score of 57%.

Axis N°: 7 Reduce Risks / Impacts

The overall percentage of this axe is: 58 % (figure 26):

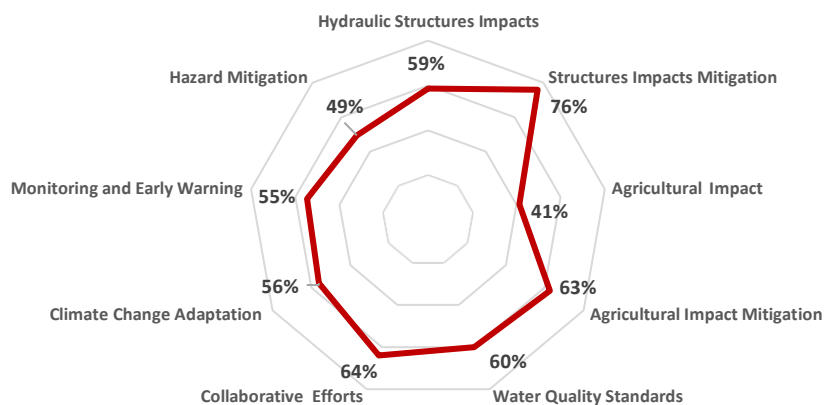


Figure. 26 The radar representation of the axe of Reduce risks / Impacts

The radar representation of the survey outcomes for the axis 'Reduce risks/impacts' (Figure 26) highlights the collaborative efforts (64%) between institutions to address shared challenges constraining the sustainable management of water resources in the Souk-Ahras

region. Similar attention is given to the mitigation of agricultural impacts (63%) and hydraulic structures impacts (76%). The graph also illustrates a certain level of commitment towards implementing initiatives or programs focused on promoting climate change adaptation and enhancing the resilience of water resources, scoring at 56%.

Axis N°: 8 Optimize use of resources

The overall percentage of this axe is: 49 % (figure 27):

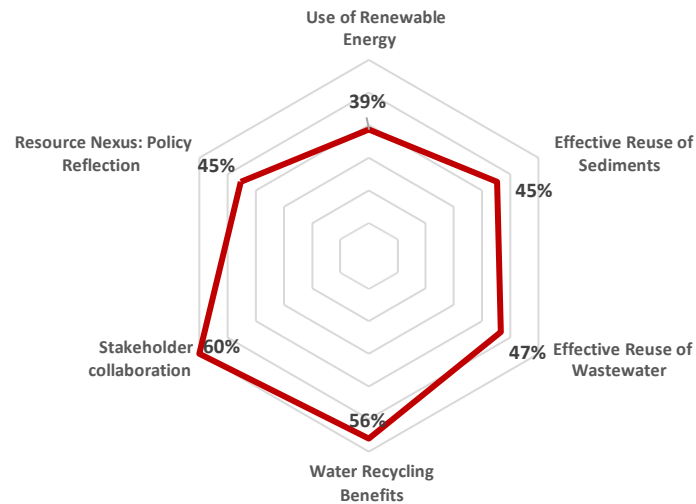


Figure. 27 The radar representation of the axe of Optimizing the Use of Resources

The radar representation of the survey results regarding the axis “Optimize the Use of Resources” (Figure 31) (41%) revealed major worries regarding the agricultural impacts which may lead to negative effects on both water quality and quantity.

Axis N°: 9 Data and Information

The overall percentage of this axe is: 57 % (figure 28):

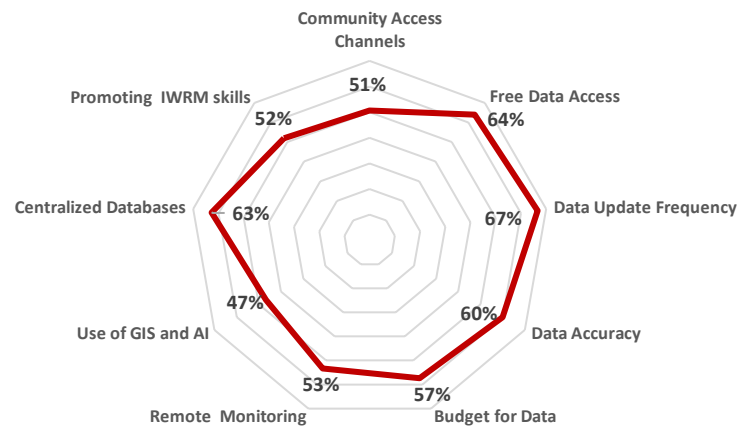


Figure. 28 The radar representation of the axe of Data and Information

In the axis “Data and Information” (Figure 28) that highlights the limited use of sophisticated tools such as GIS and AI in the current management practices. In addition, the same radar representation underscores a low performance score of 47% regarding the availability and the effectiveness of channels allowing the access for community to data and information.

Axis N°: 10 Modernization

The overall percentage of this axe is: 58 % (figure 29):

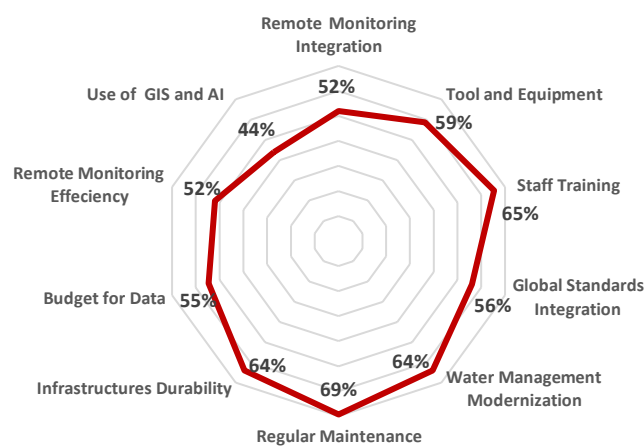


Figure. 29 The radar representation of the axe of Modernization

The radar graph illustrating the survey results for the "Modernization" axis (Figure 29), highlights a lower utilization of sophisticated tools such as GIS and AI, which achieved a score of 44%, despite the water sector providing training programs for technical staff to enhance their skills and knowledge as indicated by the relatively high score of 65% related to this aspect. Also the graph revealed poor ratings for Efficiency and Remote Monitoring

Integration (both at 52%) Moreover, the graph displays an inadequate funding allocation for Data, achieving a score of 55% which have a direct impact on the accuracy and reliability of water data.

Determination of the final overall sustainability score using the survey method

The following figure represents the different percentages of the 10 axes:

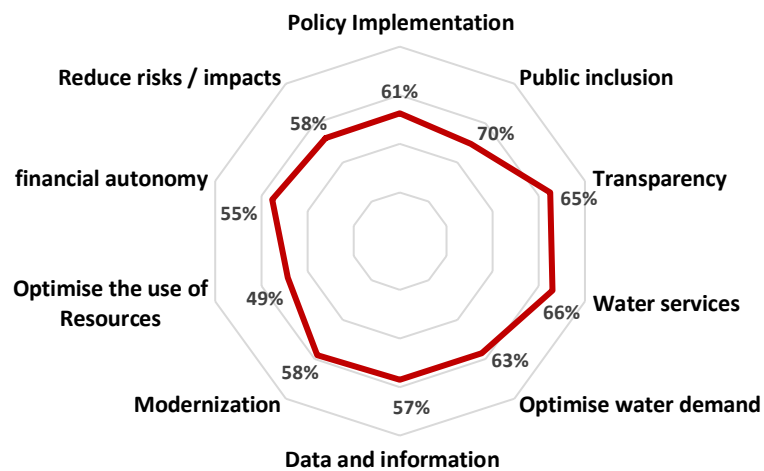
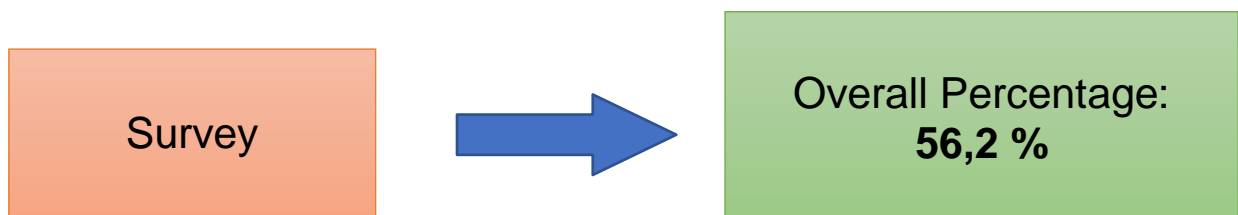


Figure. 30 Representation of the different percentages of the 10 axes

The total percentage of the various axes established through the survey methodology is determined as the mean percentage across the 10 axes, and is calculated through the following formula:

$$\frac{\sum_{1}^{10} SCORE}{10}$$



AHP results

The calculated weights, which represent the contribution of each criterion to the overall sustainability index, are illustrated in figure 36. The criteria with the most significant AHP-weight reflect the priorities of sustainable water resource management in the region of Souk-Ahras.

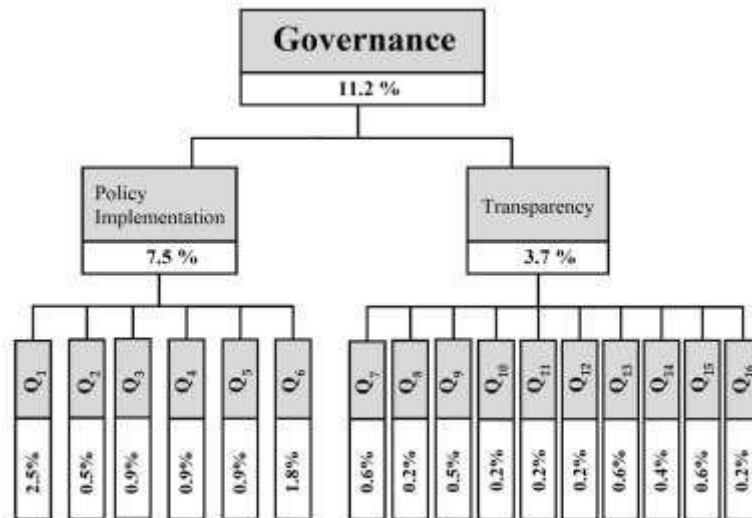


Figure. 31 Prioritizing criteria and sub-criteria related to governance dimension using AHP.

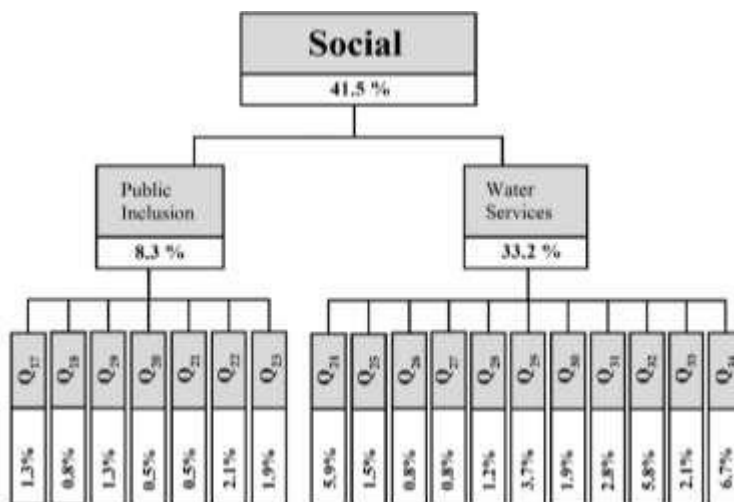


Figure. 32 Prioritizing criteria and sub-criteria related to social dimension using AHP

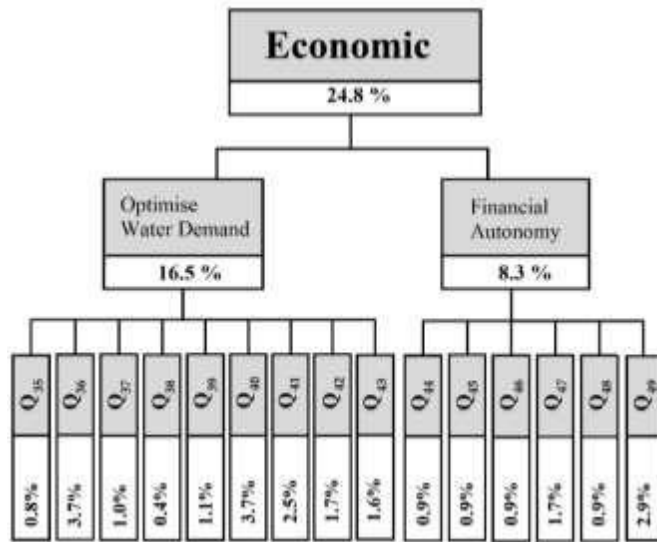


Figure. 33 Prioritizing criteria and sub-criteria related to economic dimension using AHP

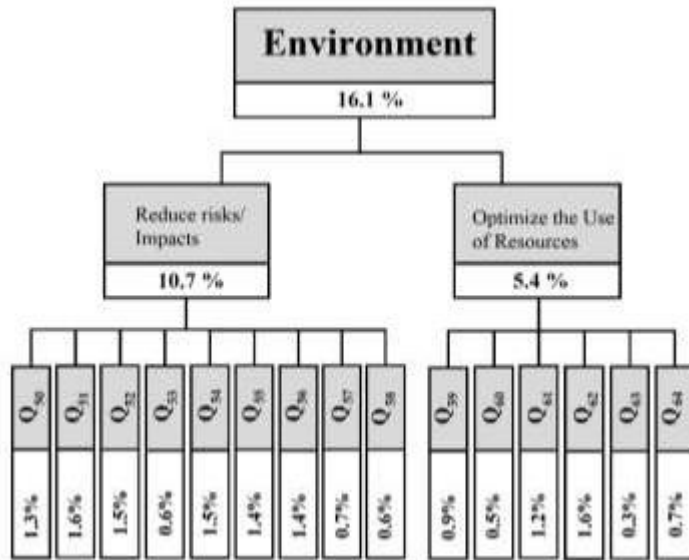


Figure. 34 Prioritizing criteria and sub-criteria related to environment dimension using AHP.

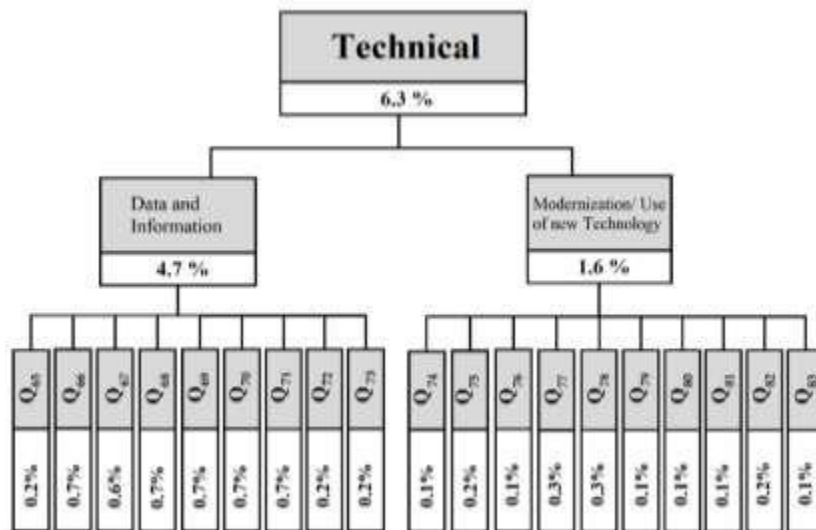


Figure. 35 Prioritizing criteria and sub-criteria related to technical dimension using AHP

According to Figure 31 which represents the priorities determined by the AHP method for the Axis number 1 “Policy Implementation”, the sub-criterion Q1 which represent level of political will to implement local water related laws and regulations showed the highest weight (2.5%). In fact, political leaders and decision-makers hold the authority to formulate laws, regulations, and policies that govern water management and ensuring their implementation (Rogers, Peter, and Alan W. Hall, 2003). Furthermore, the role of political leaders and decision-makers extends beyond policy development to comprise resource allocation, stakeholder acceptability, and collaboration among institutions (Agarwal, Arun, et al.2012).

The prioritization of the sub-criteria representing the Axis number 7 (criterion)“Reduce Risks/Impacts” (Figure 34) revealed that the highest weight (1.6%) was attributed to the sub-criterion Q51 which is related to the enhancement of remote monitoring and early warning systems in the current water management practices and more specifically to mitigate water related hazards . This aspect is fundamental for improving the quality and the update frequency of information and real time records, as well. In fact, remote monitoring systems are considered as one of the most important features for effective functioning of water systems and structures (Yang 2022).

The prioritization of the sub-criteria representing the Axis number 8 “Optimize use of resources” (Figure 34) revealed that the highest priority was assigned to the criterion (Q62) that relate to the effective reuse of wastewater (1.6%). Similarly, wastewater re-purposing ranked as the highest priority in the Axis number 5 “Optimize Water Demand” with a weight

of 3.75%. Efficient and appropriate water reuse stands as a fundamental component in ensuring the sustainability of water resource management (Angela Kais 2001). It not only contributes to environmental conservation, but it also proves to be economically beneficial by reducing the demand for new water supplies, which generally incur higher costs (Ai-Gayyousi, O.O.R 2003). This finding is of great significance as it has the potential to greatly support various water institutions in achieving financial autonomy, especially in light of the implementation of AHP on Axis number 6, "Financial autonomy." Here, the sub-criterion Q49, which represent the adequacy of the funding allocated to water resources management, achieved the highest priority (2.9%) in promoting sustainable water resource management in the region of Souk-Ahras.

The prioritization of the sub-criteria representing the Axis 9 (criterion) "Data and Information" (Figure35) revealed that the highest weight (15%) related to the enhancement of remote monitoring systems (Q68) in the current water management practices. This aspect is fundamental for improving the quality and the update frequency of information and real time records. These two aspects showed also significant involvement in this Axis. Similarly, the integration of remote monitoring depicted a significant contribution to the modelling in the axis "Modernization" achieving the third highest weight (0.19%) (Q75). In fact, remote monitoring systems are considered as one of the most important features for effective monitoring of water systems and structures (Usali, N & Mohd Hasmadi. 2010). Furthermore, another factor heightens the significance of integrating remote monitoring in the sustainable water resource management of the study area, which is the fact that the highest contributions in the axis "Modernization" were achieved by the sub-criteria that relate to regular maintenance of water facilities and infrastructure durability (Q77) (Q78), with weights of 0.27% and 0.27% respectively.

4.3 SWOT analysis results

the synthesis of survey findings and AHP analysis facilitated the identification of Strengths, Weaknesses, Opportunities, and Threats (SWOT). Weaknesses such as water quality not meeting standards, poor water services, and inadequate funding for water management were the synthesis of survey findings and AHP analysis facilitated the identification of Strengths, Weaknesses, Opportunities, and Threats (SWOT). Weaknesses such as water quality not meeting standards, poor water services, and inadequate funding for water management were highlighted, while strengths included high political will, significant women participation,

and affordable water services. Identified threats encompassed drought, climate change, and agricultural impacts on resources, while opportunities were centered around effective wastewater reuse. re highlighted, while strengths included high political will, significant women participation, and affordable water services. Identified threats encompassed drought, climate change, and agricultural impacts on resources, while opportunities were centered around effective wastewater reuse.

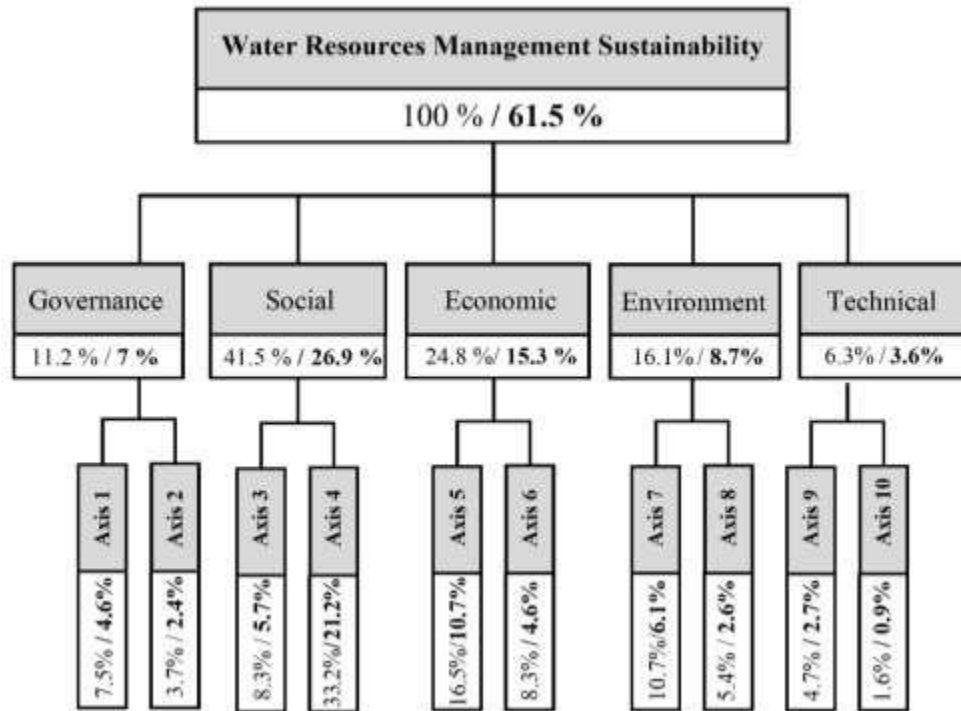


Figure. 36 Overall performance assessment of water resources management sustainability

The main findings of the SWOT analysis are illustrated in the Figure 37.

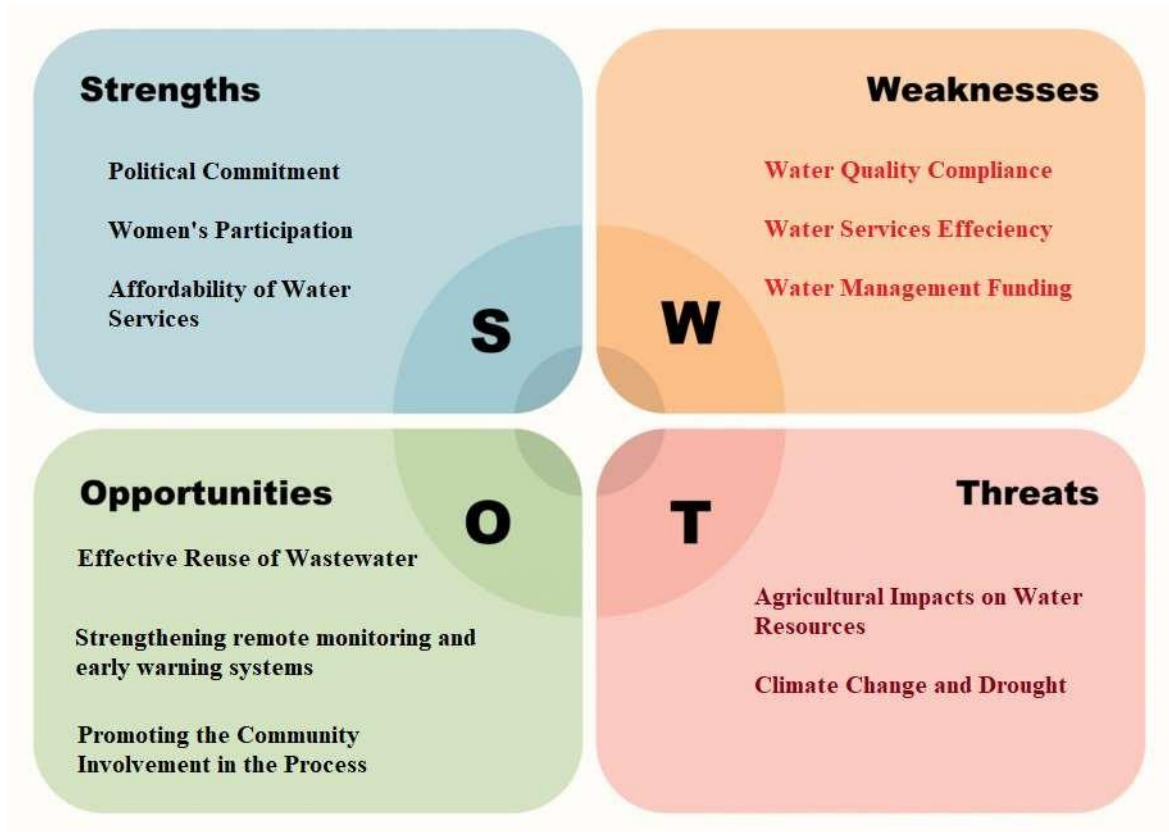
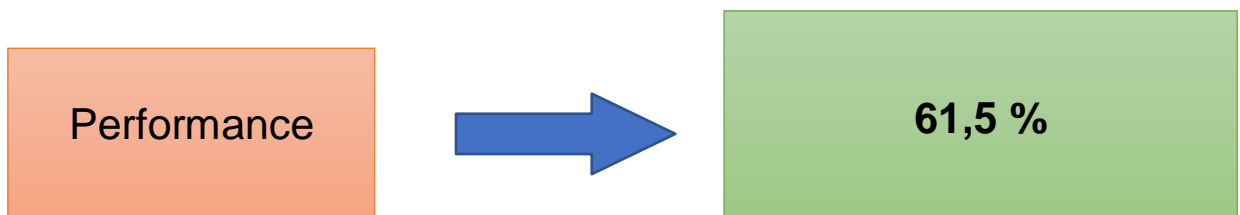


Figure. 37 SWOT analysis outcomes

Finally, the performance of the current water resources management practices is determined as the sum of actual weights (**Bold** values in Figure 36) of the considered sustainability dimensions, which are defined as the products of survey scores and AHP weights (Normal font values in Figure 36).



5. CONCLUSIONS AND RECOMMENDATIONS

General Conclusion:

For future research on assessing the sustainability of water resources management ,the proposed methodology can be improved by the following points:

- Incorporate some quantitative indicators such as water quality physicochemical parameters.
- Extend the depth of our analysis by considering the possibility of adding another level at the bottom of the hierarchical structure in order to better identify the water related issues of Souk Ahras region.
- Expand our survey to include other stakeholders, such as academics, community representatives, and private sector companies.
- Given the complexity of water resource management sustainability, we propose the use of the Analytic Network Process (ANP). This method, specifically, considers interdependencies among criteria at lower levels of decision-making.

References

- Abdellah, Bouchedja. "La politique nationale de l'eau en Algérie." Ministère des Ressources en Eau, Agence de Bassin Hydrographique Constantinois-Seybousse-Mellegue Euro-RIOB 2012: 10ème Conférence Internationale, Istanbul–Turquie–17 au, 2012. *Academy of Sciences*, vol. 115, no. 36, 2018, pp. 8863-8871.
- Afsordegan, Arayeh. "A contribution to multi-criteria decision making in sustainable energy management based on fuzzy and qualitative reasoning." (2015).
- Agarwal, Arun, et al. "Climate policy processes, local institutions, and adaptation actions: mechanisms of translation and influence." *Wiley Interdisciplinary Reviews: Climate Change* 3.6 (2012): 565-579.
- Ahmed, Bousmaha, and Boulkaibet Aissa. "Water Resources Management Policy in Algeria: Strategies and Means." *International Journal of Scientific Research and Management (IJSRM)*, University-of-Oum-El-Bouaghi, Algeria, p19. Disponible-sur: <file:///C:/Users/utilisateur/Downloads/2798-ArticleText-7514-1-10-20200702BousmahaAhmed.pdf> (2020).
- Akram, Muhammad, Kiran Zahid, and Muhammet Deveci. "Multi-criteria group decision-making for optimal management of water supply with fuzzy ELECTRE-based outranking method." *Applied Soft Computing* 143 (2023): 110403.
- Alam, M. N., Jebran, J. K., and Hossain, M. A. "Analytical Hierarchy Process (AHP) Approach on consumers preferences for selecting telecom operators in Bangladesh." *Information and Knowledge Management*, vol. 2, no. 4, 2012, pp. 7-19.
- Al-Jayyousi, Odeh R. "Greywater reuse: towards sustainable water management." *Desalination* 156.1-3 (2003): 181-192.
- Alley, W. M., T. E. Reilly, and O. L. Franke. *Sustainability of Ground-water Resources: US Geological Survey Circular 1186*. US Geological Survey, 1999. Also available at <http://pubs.usgs.gov/circ/circ1186/>.
- Alsaeed, Badir S., Dexter VL Hunt, and Soroosh Sharifi. "Sustainable Water Resources Management Assessment Frameworks (SWRM-AF) for Arid and Semi-Arid Regions: A Systematic Review." *Sustainability* 14.22 (2022): 15293.

References

- Alvandi, Ehsan, et al. "Using Improved TOPSIS and Best Worst Method in prioritizing management scenarios for the watershed management in arid and semi-arid environments." *Soft Computing* 25.16 (2021): 11363-11375.
- Ansah, R. H., Sorooshian, S., and Mustafa, S, 2015, Analytic Hierarchy Process Decision Making Algorithm. *Global Journal of Pure and Applied Mathematics*. Vol. 11, No. 4, pp. 2393-2400.
- Anvari, A., Zulkifli N., Sorooshian S., and Boyerhassani O., 2014. An integrated design methodology based on the use of group AHP-DEA approach for measuring lean tools efficiency with undesirable output. *The International Journal of Advanced Manufacturing Technology*, Vol. 70, No.9- 12, pp.2169-2186.
- B. Bouchekima, D. Bechki, H. Bouguettaia, S. Boughali, M.T. Meftah, The underground brackish waters in south Algeria: potential and viable resources, in: 13th IWRA World Water Congress, Montpellier, France, 1–4 September, 2008
- Battisti, Fabrizio. "ELECTRE III for Strategic Environmental Assessment: A “Phantom” Approach." *Sustainability* 14.10 (2022): 6221.
- Belton, Valerie, and Tony Gear. "On a short-coming of Saaty's method of analytic hierarchies." *Omega* 11.3 (1983): 228-230.
- Bensoltane, M. A. *Dégradation de la qualité d'eau potable dans les réseaux de distribution/Cas de la ville de Souk-Ahras*. Diss. Thèse Magister. Département de génie civil, Université de Souk Ahras, Souk Ahras, 2010.)
- Bensoltane, Mohamed Amine, et al. "Controlling water supply quality: case study of Souk Ahras City in Algeria." *Euro-Mediterranean Journal for Environmental Integration* 6 (2021): 1-9.
- Bhambhani, Anurag, Jan Peter van der Hoek, and Zoran Kapelan. "Life cycle sustainability assessment framework for water sector resource recovery solutions: strengths and weaknesses." *Resources, Conservation and Recycling* 180 (2022): 106151.

References

- Bilalova, Shahana, et al. "Pathways to Water Sustainability? A Global Study Assessing the Benefits of Integrated Water Resources Management." *Journal of Environmental Management* 343 (2023): 118179.
- Biswas, Asit K. "Integrated water resources management: a reassessment: a water forum contribution." *Water international* 29.2 (2004): 248-256.
- Boardman, A. E., Greenberg, D. H., Vining, A. R., & Weimer, D. L. (2020). *Cost-benefit analysis: Concepts and practice* (5th ed.). Cambridge University Press.)
- Boukhari, Sofiane, et al. "Application of the analytic hierarchy process to sustainability of water supply and sanitation services: the case of Algeria." *Water Science and Technology: Water Supply* 18.4 (2018): 1282-1293.
- Bouregaa, Tarek. "Climate change projections for Algeria: the 2030 water sector development strategy." *foresight* 25.4 (2023): 516-534.
- Brans, Jean-Pierre, and Ph Vincke. "Note—A Preference Ranking Organisation Method: (The PROMETHEE Method for Multiple Criteria Decision-Making)." *Management science* 31.6 (1985): 647-656.
- Cabala and Pawel, 2010. Using the Analytic Hierarchy Process in Evaluating Decision Alternatives. *Operations Research and Decision*, No.1, pp.5-23.
- Calizaya, A., & Zambrana, E. (2010). Water resources management in Bolivia: An application of the analytic hierarchy process. *Water Resources Management*, 24(11), 2467-2483.
- Cash, D. W., Clark, W. C., Alcock, F., Dickson, N. M., Eckley, N., Guston, D. H., Jäger, J., & Mitchell, R. B. (2003). Knowledge systems for sustainable development. *Proceedings of the National Academy of Sciences*, 100(14), 8086-8091.
- Cochrane, T., & Zapico, X. (2009). On the robustness of PROMETHEE methods against changes in preference functions. *European Journal of Operational Research*, 196(1), 1-13.
- Deng, Xinyang, et al. "Supplier selection using AHP methodology extended by D numbers." *Expert Systems with Applications* 41.1 (2014): 156-167.

References

- Ding, Yi, et al. "Study on Spatial and Temporal Differences of Water Resource Sustainable Development and Its Influencing Factors in the Yellow River Basin, China." *Sustainability*, vol. 15, no. 19, 2023, pp. 14316.
- Dolalah, D., AL-Oqla, F., and Hayajneh, M. 2010. Application of the Analytic Hierarchy Process (AHP) in Multi- criteria Analysis of the selection of cranes. *Jordan Journal of Mechanical and Industrial Engineering*. Vol. 4, No. 5, 567-578.
- Drouiche, Nadjib, et al. "Towards sustainable water management in Algeria." *Desalination and Water Treatment* 50.1-3 (2012): 272-284.
- FAO Aquastat. "Water Resources of Algeria." Food and Agriculture Organization of the United Nations, 2022, www.fao.org/aquastat/en/countries-and-basins/country-profiles/country/DZA.
- Figueira, José, Salvatore Greco, and Matthias Ehrgott. *Multiple Criteria Decision Analysis: State of the Art Surveys*. Springer Science + Business Media, Inc., 2005.
- Ghandi, Mahsa, and Abbas Roozbahani. "Risk management of drinking water supply in critical conditions using fuzzy PROMETHEE V technique." *Water Resources Management* 34 (2020): 595-615.
- Gleick, Peter H. "Transitions to Freshwater Sustainability." *Proceedings of the National Academy of Sciences* 117.12 (2020): 6373-6380.
- Good: How to Put the Principle into Practice, Stockholm: Global Water Partnership, 2019.
- Grimaldi, R., Tricase, C., & Costantino, N. (2020). A decision support system for water delivery in emergencies. *Journal of Environmental Management*, 261, 110246.
- Gueraidia, Nour El Houda, Chemseddine Fehdi, and Saida Gueraidia. "SAR interferometry for landslide investigation and surface deformation monitoring: a case study of Souk Ahras area, north-east of Algeria." *Geomatics, Landmanagement and Landscape* (2023).
- Gurl, Emet. "SWOT analysis: A theoretical review." (2017).

References

- Hajkovicz, Stefan, and Kerry Collins. "A review of multiple criteria analysis for water resource planning and management." *Water resources management* 21 (2007): 1553-1566.
- Hwang, C. L., & Yoon, K. *Multiple Attribute Decision Making: Methods and Applications*. Springer, 1981.
- International Organization for Standardization. (2020). ISO 14040: Environmental management – Life cycle assessment – Principles and framework. International Organization for Standardization
- IPCC. "Climate Change 2022: Impacts, Adaptation and Vulnerability." Intergovernmental Panel on Climate Change, 2022, www.ipcc.ch/report/ar6/wg2/.
- ISO 14040: Environmental management – Life cycle assessment – Principles and framework. International Organization for Standardization).
- Johnson, R. Burke, and Anthony J. Onwuegbuzie. "Mixed methods research: A research paradigm whose time has come." *Educational researcher* 33.7 (2004): 14-26.
- Jahanddideh-Tehrani, Mahsa, Omid Bozorg-Haddad, and Ioannis N. Daliakopoulos. "The role of water information and data bases in water resources management." *Essential tools for water resources analysis, planning, and management*. Singapore: Springer Singapore, 2021. 59-83.
- Kahraman, Cengiz, et al. "Integration of fuzzy AHP with other fuzzy multicriteria methods: a state of the art survey." *Journal of Multiple-Valued Logic & Soft Computing* 35 (2020).
- Kahraman, Cengiz, Ufuk Cebeci, and Ziya Ulukan. "Multi-criteria supplier selection using fuzzy AHP." *Logistics information management* 16.6 (2003): 382-394.
- Karami, Amin. "Utilization and comparison of multi attribute decision making techniques to rank Bayesian network options." (2011).
- Kaya, T., & Kahraman, C. "A critical review of the limitations and challenges of the PROMETHEE method." *Journal of Multi-Criteria Decision Analysis*, vol. 27, no. 5-6, 2021, pp. 313-328.
- Kaya, T., & Kahraman, C. (2020). A critical review of the limitations and challenges of the VIKOR method. *Journal of Multi-Criteria Decision Analysis*, 27(5-6), 313-328.

References

- Kebiri, L., et al. "Groundwater Potential and Water Quality Assessment for Drinking Purposes in Taoura Region, NE Algeria." *Arabian Journal of Geosciences*, vol. 14, no. 265, 2021, doi.org/10.1007/s12517-021-06549-x.
- Loucks, Daniel P. "Water Resources Planning." Analysis, Prentice-Hall, New Jersey (1981).
- Lv, Bo, et al. "Evaluation of the water resource carrying capacity in Heilongjiang, eastern China, based on the improved TOPSIS model." *Ecological Indicators* 150 (2023): 110208.
- Macchiaroli, Maria, Luigi Dolores, and Gianluigi De Mare. "Multicriteria Decision Making and Water Infrastructure: An Application of the Analytic Hierarchy Process for a Sustainable Ranking of Investments." *Applied Sciences* 13.14 (2023): 8284.
- Mardani, Abbas, et al. "Multiple criteria decision-making techniques and their applications—a review of the literature from 2000 to 2014." *Economic research-Ekonomska istraživanja* 28.1 (2015): 516-571.
- Mathura, Risimati Patrick, and Miklas Scholza. "Application of PROMETHEE II Model Technique to Evaluate Water Loss Management Strategies in Water Supply Systems." *African Journal of Water Conservation and Sustainability* ISSN 11.6 (2023): 001-020.
- Mathye, R P, and Miklas Scholza. "Application of PROMETHEE II Model Technique to Evaluate Water Loss Management Strategies in Water Supply Systems." *African Journal of Water Conservation and Sustainability* ISSN 11.6 (2023): 001-020.
- Mellahi, Dhaouadi, Ridha Zerdoumi, and Assia Chaib. "Control strategies to improve the low water quality of Souk-Ahras city." *Heliyon* 7.7 (2021).
- Messahel, Mekki. "Watershed And Water Management System In Algeria." *Sustainable Use and Development of Watersheds*. Springer Netherlands, 2008.
- Ministère des Ressources en Eau. (2020). Bilan des ressources en eau dans la wilaya de Souk Ahras. <http://www.ressources-eau.dz/bilans/souk-ahras.pdf>
- Mooselu, Mehrdad Ghorbani, et al. "A multi-objective optimal allocation of treated wastewater in urban areas using leader-follower game." *Journal of Cleaner Production* 267 (2020): 122189.

References

- MRE, 2011. <http://www.mre.gov.dz/> (accessed 06.06.12). 1998.394-411.
- Mutikanga, Harrison E., Saroj K. Sharma, and Kalanithy Vairavamoorthy. "Multi-criteria decision analysis: a strategic planning tool for water loss management." *Water resources management* 25 (2011): 3947-3969.
- Neama, Mennat Allah, et al. "Overview of Water Resources, Quality, and Management in Algeria." *Water Resources in Algeria-Part I: Assessment of Surface and Groundwater Resources* (2020): 13-25
- Ouled Zaoui, S., S. Snani, and Y. Djebbar. "Management of water resources at Souk-Ahras region (Algeria)." *14th International Water Technology Conference*. 2010.
- Pahl-Wostl, Claudia. "Towards Sustainability in the Water Sector–The Importance of
- Rane, N., Anand Achari, and S. Choudhary. "Multi-Criteria Decision-Making (MCDM) as a powerful tool for sustainable development: Effective applications of AHP, FAHP, TOPSIS, ELECTRE, and VIKOR in sustainability." *International Research Journal of Modernization in Engineering Technology and Science* 5.4 (2023): 2654-2670.
- Rangel, L. S. A. D.; Gomes, L. F. V. A. M.; Moreira, R. R. A. (2009). "Decision theory with multiple criteria: An application of ELECTRE IV and TODIM to SEBRAE/RJ". *Pesquisa Operacional*. 29 (3): 577.
- Rogers, Peter, Ramesh Bhatia, and Annette Huber. *Water as a Social and Economic*
- Roobahani, Abbas, Banafsheh Zahraie, and Massoud Tabesh. "PROMETHEE with precedence order in the criteria (PPOC) as a new group decision making aid: an application in urban water supply management." *Water resources management* 26 (2012): 3581-3599.
- Saaty, Thomas L. "Decision making with the analytic hierarchy process." *International journal of services sciences* 1.1 (2008): 83-98.
- Saaty, Thomas L. "How to make a decision: the analytic hierarchy process." *European journal of operational research* 48.1 (1990): 9-26.
- Saaty, Thomas L., et al. "The seven pillars of the analytic hierarchy process." *Models, methods, concepts & applications of the analytic hierarchy process* (2012): 23-40.

References

- Sabbaghi, Asghar, and Ganesh Vaidyanathan. "SWOT analysis and theory of constraint in information technology projects." *Information systems education journal* 2.23 (2004): 1-19.
- Science and Technology: Water Supply, vol. 18, no. 4, 2018, pp. 1282-1293.
- Strengths and Weaknesses." *Resources, Conservation and Recycling* 180 (2022): 106151.
- Sustainability Assessment Framework for Water Sector Resource Recovery Solutions: TAC, GWP. "Integrated Water Resources Management., TAC Background Paper No.4." Global Water Partnership Technical Advisory Committee, Stockholm, 2000.
- Taherdoost, Hamed, and Mitra Madanchian. "Multi-criteria decision making (MCDM) methods and concepts." *Encyclopedia* 3.1 (2023): 77-87.
- Talbi, Djamila, and Aya Al Any. *Creating a Sustainable Future in Algeria Water Resource Management*. No. 9435. EasyChair, 2022.
- The United Nations World Water Development Report 2022: Groundwater: Making the Invisible Visible, Paris, UNESCO, 2022.
- Tzeng, G. H., & Huang, J. J. (2011). *Multiple attribute decision making: methods and applications*. CRC Press..
- United Nations Educational, Scientific and Cultural Organization (UNESCO).
- United Nations. "Resolution 64/292." United Nations General Assembly, July 2010.
- Usali, Norsaliza, and Mohd Hasmadi Ismail. "Use of remote sensing and GIS in monitoring water quality." *Journal of sustainable development* 3.3 (2010): 228.
- Vaidya, Omkarprasad S., and Sushil Kumar. "Analytic hierarchy process: An overview of applications." *European Journal of operational research* 169.1 (2006): 1-29
- Vörösmarty, Charles J., et al. "Global Threats to Human Water Security and River Water Resource Planning and Management." *Water Resources Management* 21 (2007): 1553-1566.
- World Bank. "Algeria's New Renewable Energy Plan to Boost Private Sector Participation." World Bank, 6 Feb. 2018,

References

www.worldbank.org/en/news/feature/2018/02/06/algeria-new-renewable-energy-plan-boost-private-sector-participation

Xidonas, Panos, et al. *Multicriteria portfolio management*. Springer New York, 2012.

Yang, Liping, et al. "Towards synoptic water monitoring systems: a review of AI methods for automating water body detection and water quality monitoring using remote sensing." *Sensors* 22.6 (2022): 2416.

Yilmaz, Baris, and N. Harmancioglu. "Multi-criteria decision making for water resource management: a case study of the Gediz River Basin, Turkey." *Water SA* 36.5 (2010).

Zahid, Kiran, Muhammad Akram, and Cengiz Kahraman. "A new ELECTRE-based method for group decision-making with complex spherical fuzzy information." *Knowledge-Based Systems* 243 (2022): 108525.

Zamani, R. and Yousefi, P. "Optimal decision making approach for selecting effort estimation model." *International Journal of Machine Learning and Computing* 3.4 (2013): 1-4.

Zaoui, S. Ouled, S. Snani, and Y. Djebbar. "Management of Water Resources at Souk-Ahras Region (Algeria)." *Proceedings of the 14th International Water Technology Conference, IWTC*. Vol. 14.

References

Zekri, Slim, ed. *Water Policies in MENA Countries*, vol. 23, Springer Nature, 2020.

Ziara, Mohamed M., and Bilal M. Ayyub. "Decision Analysis for Housing-Project Development." *Journal of urban planning and development* 125.2 (1999): 68-85.

<http://abh-cz.com.dz/pdare.html>

http://agire.dz/fr_fr/

<https://water.fanack.com/algeria/water-resources/>

<https://www.univ-tlemcen.dz/fr>

Appendix

Appendix

Questionnaire for the evaluation of water resources management sustainability in Souk-Ahras region.

Axis N°: 1 Policy implementation	No	Somewhat No	neutral	Somewhat yes	yes
Q1. How do you assess the level of political will to implement local water-related laws and regulations in your country?					
Q2. Are the current policies stable enough to achieve long-term goals?					
Q3. Are the existing policies Flexible and adaptable to extreme situations such as drought and flood events					
Q4. Are the existing policies clear and understandable for the various stakeholders involved.					
Q5. Is the access to documentation (laws , management plans, technical reports) for the community and scholars requiring information ensured?					
Q6. Are the measures taken by policy makers to guarantee the implementation of IWRM strategies sufficient?					
Total					

Appendix

Axe N°: 2 Transparency	No	Somewhat No	neutra l	Some what yes	yes
Q7. How would you assess the level of transparency in the process of granting water permits or licenses to different users (e.g., industries, agriculture, domestic use)?					
Q8; How would you rate the quality and reliability of the data and information provided by water authorities?					
Q9.Do government agencies and water authorities regularly publish and disseminate information about water resources, water use, and management decisions?					
Q10.Are measures being taken to promote public inclusiveness regarding water management and preservation?					
Q11.Is effective and inclusive access to documentation, including laws, management plans, and technical reports, ensured for the community and scholars?					
Q12 .Do you receive frequently complaints from consumers who utilize your water services ?					
Q13 .Is there collaboration among institutions to enhance information access and resources?					
Q14 .Are there enough existing information and documentation for the implementation of water management plans ?					
Q15 .Is there collaborative efforts between the institution and other entities such as agencies, offices to address common challenges ?					

Appendix

Q ₁₆ .Is water data available for free?					
Total					

Appendix

Axe N°: 3 Public Inclusion	No	Somewhat No	neutral	Somewhat yes	yes
Q ₁₇ Are there any designated public representatives or advisory committees that serve as liaisons between the public and water authorities?					
Q ₁₈ .Do customers using your water services openly report issues or concerns?					
Q ₁₉ Is stakeholder acceptability considered in water management?					
Q ₂₀ .Are there any initiatives to educate the public on water conservation and its role in sustainable development?					
Q ₂₁ .Is there any efforts made to encourage public involvement in water management and preservation?					
Q ₂₂ .Is the community involved in policy development and implementation processes?					
Q ₂₃ .Is there recognition and support for women's participation in water management by governmental organizations?					
Total					

Appendix

Axe N°: 4 Water Services	No	Somewhat No	neutral	Somewhat yes	yes
Q ₂₄ . How efficient is the management and distribution of water resources for various uses?					
Q ₂₅ .How satisfied are you with the cost and affordability of water services?					
Q ₂₆ .To what extent do fees and taxes imposed on consumers align with the level of services rendered?					
Q ₂₇ .Are there policies in place to help water utilities address affordability challenges?					
Q ₂₈ .Do you agree that there are no significant water affordability challenges for moderate-income households?					
Q ₂₉ .Does the quality of water meet the appropriate standards?					
Q ₃₀ .Do customers using your water services openly report issues or concerns?					
Q ₃₁ .Is water quality managed to meet and exceed regulatory standards for safe consumption and use?					
Q ₃₂ .Are there measures taking during times of drought to ensure optimal water management?					
Q ₃₃ .Does the institution have contingency plans in place to ensure continuous service?					
Q ₃₄ .Does the institution implement any measures and strategies to ensure efficient and equitable water service?					
Total					

Appendix

Axis N°: 5 Optimise Water Demand	No	Somewhat No	neutral	Somewhat yes	yes
Q ₃₅ .Do you think metering and monitoring systems are effectively implemented to track and manage water?					
Q ₃₆ .How would you rate the current level of water demand management and conservation efforts in your area? (Rate on a scale of 1-5)					
Q ₃₇ .To what extent do fees and taxes imposed on consumers align with the level of services rendered?					
Q ₃₈ .Do customers who utilize your water services openly communicate any issues or concerns they may encounter?					
Q ₃₉ .Is the quality of mobilized / purified water meets regulatory standards ?					
Q ₄₀ .Are there currently any methods in place for recycling and repurposing wastewater?					
Q ₄₁ .Are there existing approaches to optimize water demand?					
Q ₄₂ .Are these measures effective?					
Q ₄₃ .Is there a specific set of actions taken to promote water conservation and reduce water waste?					
Q ₄₄ . Do you think metering and monitoring systems are effectively implemented to track and manage water?					
Total					

Appendix

Axis N°: 6 Financial Autonomy	No	Somewhat No	neutral	Somewhat yes	yes
Q ₄₄ .Do you think the current water pricing reflects the true cost of water supply and management?					
Q ₄₅ .Are innovative funding mechanisms being explored to enhance financial independence ?					
Q ₄₆ .Does your institution generate revenue through the exchange of data and professional services?					
Q ₄₇ .There are no financial constraints that hinder effective implementation of water-related policies?					
Q ₄₈ .To what extent do fees and taxes imposed on consumers align with the level of services rendered?					
Q ₄₉ .Is the funding allocated for water management adequate?					
Total					

Appendix

Axis N°: 7 Reduce Risks / Impacts	No	Somewhat No	neutral	Somewhat yes	yes
Q ₅₀ .Do you think there are adequate measures and infrastructure in place to mitigate the impacts of water-related hazards?					
Q ₅₁ . Are there any early warning systems or monitoring mechanisms in place to detect and respond to potential water-related hazards?					
Q ₅₂ .Are there any initiatives or programs focused on promoting climate change adaptation and enhancing the resilience of water resources?					
Q ₅₃ .Are there collaborative efforts between the institution and other entities, such as agencies and offices, to address shared challenges?					
Q ₅₄ .Do purified/treated water meet the established standards?					
Q ₅₅ .Are agricultural impacts being addressed to minimize risks and ensure sustainability ?					
Q ₅₆ .Do you agree that there are no significant agricultural impacts on water resources?					
Q ₅₇ .Are measures being implemented to mitigate associated risks of hydraulic structures ?					
Q ₅₈ .Do you agree that hydraulic structures have no significant impacts of on the environment ?					
Total					

Appendix

Axis N°: 8 Optimise use of resources	No	Somewhat No	neutral	Somewhat yes	yes
Q ₅₉ .Do you think there is sufficient consideration given to the nexus between water, energy, and material resources in resource management policies and strategies					
Q ₆₀ .Does stakeholder collaboration play a role in optimizing the use of water, energy, and materials in water management practices?					
Q ₆₁ .Does recycling and reusing wastewater play a significant role in sustainable water management practices?					
Q ₆₂ .Is wastewater being effectively reused?					
Q ₆₃ .Are sediments extracted from dams being effectively reused ?					
Q ₆₄ .Is the use of renewable energy a common practice in optimizing water management processes?					
Total					

Appendix

Axis N°: 9 Data and Information	No	Somewhat No	neutral	Somewhat yes	yes
Q ₆₅ .Are there any capacity-building programs or initiatives aimed at enhancing data management and analysis skills related to IWRM?					
Q ₆₆ .Are there centralized numerical databases or information systems in place to collect, store, and disseminate water-related data?					
Q ₆₇ .Does the decision making process rely on sophisticated tools such as GIS and AI?					
Q ₆₈ .Do water systems use remote monitoring to work better?					
Q ₆₉ .Does the allocated budget suffice for maintaining the accuracy and reliability of water data updates?					
Q ₇₀ .Are there methods in place to ensure the accuracy of water data?					
Q ₇₁ .Is the water data regularly updated?					
Q ₇₂ .Can the data be accessed without charge?					
Q ₇₃ .Are there structured channels in place to offer accessible documentation to the community and scholars?					
Total					

Appendix

Axis N°: 10 Modernization	No	Somewhat No	neutral	Somewhat yes	yes
Q ₇₄ .Does the decision making process rely on sophisticated tools such as GIS and AI?					
Q ₇₅ .Do water systems use remote monitoring to work better?					
Q ₇₆ .Is there a strategic plan to guarantee that the allocated budget is sufficient to maintain the accuracy and reliability of water data updates?					
Q ₇₇ .Does the modernization in water management impact the performance and durability of water infrastructures?					
Q ₇₈ .Are water facilities maintained and rehabilitated on a regular and adequate basis?					
Q ₇₉ .Does the modernization of water management align with the existing water structures ?					
Q ₈₀ .Are global standards integrated into the day-to-day tasks of employees in the water management sector?					
Q ₈₁ .Does the water management sector provide training programs for technical staff to enhance their skills and knowledge?					
Q ₈₂ .Do you have all the special tools and equipment you need?					
Q ₈₃ .Do water systems utilize remote monitoring to enhance their functionality?					
Total					

Appendix

Decision Matrix for each Axis

Axe N°: 1 Policy Implementation	Q ₁	Q ₂	Q ₃	Q ₄	Q ₅	Q ₆
Q ₁	1	3	2	2	2	1
Q ₂	0.33	1	0.5	0.5	0.5	0.16
Q ₃	0.5	2	1	1	1	0.33
Q ₄	0.5	2	1	1	1	0.33
Q ₅	0.5	2	1	1	1	0.33
Q ₆	1	6	3	3	3	1

Axe N°: 2 Transparen cy	Q ₇	Q ₈	Q ₉	Q ₁₀	Q ₁₁	Q ₁₂	Q ₁₃	Q ₁₄	Q ₁₅	Q ₁₆
Q ₇	1	2	1	4	3	4	1	2	2	3
Q ₈	0.5	1	0.33	1	0.5	1	0.5	1	0.33	1
Q ₉	1	3	1	2	3	3	1	1	1	2
Q ₁₀	0.25	1	0.5	1	1	1	0.2	1	0.33	1
Q ₁₁	0.33	2	0.33	1	1	2	0.2	0.5	0.33	2
Q ₁₂	0.25	1	0.33	1	0.5	1	0.25	0.5	0.25	0.5
Q ₁₃	1	2	1	5	5	4	1	1	1	2
Q ₁₄	0.5	1	1	1	2	2	1	1	0.5	3
Q ₁₅	0.5	3	1	3	3	4	1	2	1	6
Q ₁₆	0.33	1	0.5	1	0.5	2	0.5	0.33	0.166 667	1

Appendix

Axe N°: 3 Public Inclusion	Q₁₇	Q₁₈	Q₁₉	Q₂₀	Q₂₁	Q₂₂	Q₂₃
Q₁₇	1	1	3	3	2	1	4
Q₁₈	1	1	4	5	2	2	1
Q₁₉	0.33	0.25	1	1	0.33	1	0.25
Q₂₀	0.33	0.2	1	1	0.5	1	0.33
Q₂₁	0.5	0.5	3	2	1	3	1
Q₂₂	1	0.5	1	1	0.33	1	0.5
Q₂₃	0.25	1	4	3	1	2	1

Axe N°: 4 Water services	Q₂₄	Q₂₅	Q₂₆	Q₂₇	Q₂₈	Q₂₉	Q₃₀	Q₃₁	Q₃₂	Q₃₃	Q₃₄
Q₂₄	1	2	2	3	3	3	5	6	5	3	1
Q₂₅	0.5	1	0.33	0.25	0.33	0.33	4	5	4	2	0.16
Q₂₆	0.5	3	1	3	8	2	6	7	5	3	0.5
Q₂₇	0.33	4	0.33	1	1	1	2	2	3	2	0.5
Q₂₈	0.33	3	0.125	1	1	0.33	1	2	4	1	0.14
Q₂₉	0.33	3	0.5	1	3	1	4	4	5	4	0.5
Q₃₀	0.2	0.25	0.16	0.5	1	0.25	1	3	1	1	0.2
Q₃₁	0.16	0.2	0.14	0.5	0.5	0.25	0.33	1	0.5	1	0.14
Q₃₂	0.2	0.25	0.2	0.33	0.25	0.2	1	2	1	0.33	0.16
Q₃₃	0.33	0.5	0.33	0.5	1	0.25	1	1	3	1	0.5
Q₃₄	1	6	2	2	7	2	5	7	6	2	1

Appendix

Axe N°: 5 Optimise water demand	Q₃₅	Q₃₆	Q₃₇	Q₃₈	Q₃₉	Q₄₀	Q₄₁	Q₄₂	Q₄₃
Q₃₅	1	0.2	2	3	0.25	0.16	0.33	0.5	0.33
Q₃₆	5	1	4	7	3	1	2	3	2
Q₃₇	0.5	0.25	1	4	1	0.2	0.33	0.5	1
Q₃₈	0.33	0.14	0.25	1	0.5	0.16	0.2	0.25	0.25
Q₃₉	4	0.33	1	2	1	0.25	0.33	0.33	0.5
Q₄₀	6	1	5	6	4	1	2	2	2
Q₄₁	3	0.5	3	5	3	0.5	1	2	2
Q₄₂	2	0.33	2	4	3	0.5	0.5	1	1
Q₄₃	3	0.5	1	4	2	0.5	0.5	1	1

Axe N°: 6 Financial autonomy	Q₄₄	Q₄₅	Q₄₆	Q₄₇	Q₄₈	Q₄₉
Q₄₄	1	1.00	1.00	0.50	1.00	0.33
Q₄₅	1.00	1	1	0.50	1	0.33
Q₄₆	1.00	1.00	1	0.50	1	0.33
Q₄₇	2.00	2.00	2.00	1	2.00	0.50
Q₄₈	1.00	1.00	1.00	0.50	1	0.33
Q₄₉	3.00	3.00	3.00	2.00	3.00	1

Axe N°: 7 Reduce Risks / Impacts	Q₅₀	Q₅₁	Q₅₂	Q₅₃	Q₅₄	Q₅₅	Q₅₆	Q₅₇	Q₅₈
Q₅₀	1	1	1	2	3	1	1	1	3
Q₅₁	1	1	1	2	1	1	1	1	2
Q₅₂	1	1	1	3	2	2	1	1	2
Q₅₃	0.5	0.5	0.33	1	1	0.5	0.33	0.33	1
Q₅₄	0.33	1	0.5	1	1	0.5	0.5	0.5	1
Q₅₅	1	1	0.5	2	2	1	1	1	3
Q₅₆	1	1	1	3	2	1	1	1	2
Q₅₇	1	1	1	3	2	1	1	1	3
Q₅₈	0.33	0.5	0.5	1	1	0.33	0.5	0.33	1

Appendix

Axis N°: 8 Optimise Use of Resources	Q ₅₉	Q ₆₀	Q ₆₁	Q ₆₂	Q ₆₃	Q ₆₄
Q ₅₉	1	2	0.5	0.33	4	2
Q ₆₀	0.5	1	1	0.33	1	0.5
Q ₆₁	2	1	1	1	3	2
Q ₆₂	3	3	1	1	5	2
Q ₆₃	0.25	1	0.33	0.2	1	0.33
Q ₆₄	0.5	2	0.5	0.5	3	1

Axis N°: 9 Data and Information	Q ₆₅	Q ₆₆	Q ₆₇	Q ₆₈	Q ₆₉	Q ₇₀	Q ₇₁	Q ₇₂	Q ₇₃
Q ₆₅	1	0.2	1	0.16	0.2	0.2	0.2	0.5	0.5
Q ₆₆	5	1	1	1	1	1	1	3	3
Q ₆₇	1	1	1	1	1	1	1	3	3
Q ₆₈	6	1	1	1	1	1	1	3	3
Q ₆₉	5	1	1	1	1	1	1	3	3
Q ₇₀	5	1	1	1	1	1	1	3	3
Q ₇₁	5	1	1	1	1	1	1	3	3
Q ₇₂	2	0.33	0.33	0.33	0.33	0.33	0.33	1	1
Q ₇₃	2	0.33	0.33	0.33	0.33	0.33	0.33	1	1

Axis N°: 10 Modernization	Q ₇₄	Q ₇₅	Q ₇₆	Q ₇₇	Q ₇₈	Q ₇₉	Q ₈₀	Q ₈₁	Q ₈₂	Q ₈₃
Q ₇₄	1	2	1	4	3	4	1	2	2	3
Q ₇₅	0.5	1	0.33	1	0.5	1	0.5	1	0.33	1
Q ₇₆	1	3	1	2	3	3	1	1	1	2
Q ₇₇	0.25	1	0.5	1	1	1	0.2	1	0.33	1
Q ₇₈	0.33	2	0.33	1	1	2	0.2	0.5	0.33	2
Q ₇₉	0.25	1	0.33	1	0.5	1	0.25	0.5	0.25	0.5
Q ₈₀	1	2	1	5	5	4	1	1	1	2
Q ₈₁	0.5	1	1	1	2	2	1	1	0.5	3
Q ₈₂	0.5	3	1	3	3	4	1	2	1	6
Q ₈₃	0.33	1	0.5	1	0.5	2	0.5	0.33	0.16	1