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CONTRIBUTION OF WATER RESOURCE SYSTEMS ANALYSIS FOR THE DYNAMICS OF TERRITORIAL REBALANCING, CASE OF TAFNA SYSTEM, ALGERIA

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ABSTRACT

In systems engineering, the analysis of the water resources system must take into account and combine the typologies of the relationships between uses, often conflicting, as well as the joint concept of water and territory, which cannot be dissociated from the hydrographic basin entity. The systemic concept revolves around the notions of organization, interdependence, prioritization, coordination and integration. This article focuses on the water resource system of Tafna, located in northwest Algeria, which is composed of several interactive subsystems in terms of resource uses (surface water, groundwater, desalination, purification, etc.). The committed analysis, based on systemic explorations, integrated the needs, requirements and constraints of the system. The responsibilities and implications of the actors and stakeholders related to the scales of planning and strategic decisions were also defined by the production of a consultation matrix between the actors. The integration of all these physical and functional elements in permanent interaction represents a real challenge for the analysis of the complex system. Depending on these objectives, the performance of the system was analyzed with the production of indicators related to the singular or combined influence of desalination yields, wastewater reuse rates, industrial water recycling and the effect of climate change on underground and surface reserves. All these connected parameters were used to assess trends in the evolution of water resources according to needs. The influence of these trends was then compared to the national land-use plan guidelines projected for 2030 and based on a spatial distribution by planning area. Finally, the balance of the system, at the scale of the hydrographic entity, was studied through the proposal of efficiency actions encompassing uses and users. The study led to the proposal for efficiency action to anticipate water deficits in the system. It has also been clarified that sectoral organization is not compatible with the multifunctional nature of water. Reused wastewater and the recycling of industrial water contribute to the water balance of the system. According to the water balances drawn up, desalination is a very strategic vector in terms of meeting needs

Keywords: Systems, water resources, Tafna, management, efficiency.

INTRODUCTION

Water management decisions have evolved from addressing simple problems, such as accessing water near its source, to complex problems of managing and allocating water in the face of multiple and competing demands in the natural, societal and political domains (Islam and Repella, 2015).

Watersheds are a suitable socioeconomic-political unit for management planning and implementation (Wang et al., 2016).

The approach to water resource management requires, in terms of action policy and governance, new cooperation and institutional adaptations (Saguier et al, 2021). The sectoral organization of institutions as it is currently established is in contradiction with the multifunctional nature of water: it is urgent to adapt the concepts and methods of management to be more participatory (Markowska et al., 2020).

To satisfy a sustainable use of water resources, the importance of involving all the actors and stakeholders concerned within the same basin is underlined (German et al, 2007). This is to implement the concepts of “participation” and “integration” in watershed water resource management (Grill et al., 2015).

Integrated water resource management at the watershed scale involves adopting a methodological approach that encompasses all the appropriate activities to design, evolve and verify the efficiency of the water resource system, providing a technical, economical and efficient solution to the needs of customers while satisfying all stakeholders (Rouissat et al., 2021; Baron and Allegro, 2019). The development of relationships and links between technical systems (surface and underground mobilizations, water purification and treatment, protection of ecosystems, desalination and others), the definition of needs and requirements, long-term constraints disrupting sustainable development and the degree of stakeholder involvement allow solving, with relevance, all the problems linked to the integrated and participatory management of water resources (Dacko, 2009). Integrated water resource management must ensure an upgrade in economic and social well-being in an equitable manner and without compromising, in the present or future, the sustainability of vital ecosystems (Duran-Sanchez et al., 2018; Dobner and Frede, 2016).

The performance of a system is a characteristic that qualifies and/or quantifies the result of system engagement. This characteristic is built from the produced results and the manner in which these results were obtained, it can take many forms and concern different aspects representative of the system such as effectiveness or efficiency (Mwambo and

Furst, 2019). Two approaches are generally adopted for the identification and analysis of water resource system: a structural view based on a set of constituents (subsystems) in mutual interaction and interaction with the environment integrated according to the mission. A dynamic view is based on a sequence of processes (activities, functions) in interaction with the environment chained (coordinates) according to the mission or the results (Turner and Baker, 2019).

We are interested in this paper on the Tafna water resources system through the analysis of its performance with respect to the satisfaction of the various needs and the participation of all the actors.

Herein, the Algerian word “Wilaya” is used to design a province. Each Wilaya constitutes a decentralized administrative area composed of a certain number of towns.

The Tafna system is located northwest of the Algerian territory. It extends over the entire Wilaya of Tlemcen and on a part of the Moroccan kingdom. It extends into Algerian territory on an area of 7245 km^2. It is the most important water reservoir in western Algeria. The western part encompasses the watershed of the Mouillah River, the largest tributary of the Tafna River, the major part of which is in Morocco and encompasses the plains of Angad and Maghnia.

This system is open to its environment, with multiple feedbacks, integrating actors with conflicting objectives in terms of water resource allocation and often acting by sector of activity without a vision of the global system in relation to its administrative limits.

In the territory of the Wilaya of Tlemcen, this system includes six large dams, twenty small dams, three desalination plants, eight wastewater treatment plants and approximately 180 wells and boreholes. The annual average exploitable volume of underground reserves is 100 Hm^3. The total capacity of the surface water amounts to 394 Hm^3 for a regularized capacity of 203 Hm^3. At the level of the Tafna system, there are three desalination stations for an annual production of approximately 148 Hm^3.

Several transfers of water from desalination stations, catchment fields of groundwater and dams supply different municipalities in the Wilaya. The Tafna system also receives another transfer from the chott El Gharbi located in the Wilaya of Naâma. Three water transfers from the watershed are equally assigned to the neighboring Wilayas, including Oran, Ain, Temouchent and Sidi bèl Abbès. In terms of management, multiple actors and stakeholders are involved at the level of the hydrographic system. The fields of activities and decisions concern the planning of investments, the allocations and uses of water and the protection of the environment. This water resource system involves subsystems in constant interaction and conflicts, namely mobilization, treatment, wastewater treatment and transfer of water. Its performance must take into account a certain number of parameters: the satisfaction of long-term needs, the influence of constraints related to governance, climate change and the preservation of the environment as well as the roles and responsibilities of the actors and stakeholders involved in the governance of water resources. On the basis of the fundamental concepts of totality, interactivity and sustainable development, this paper aims at an analysis of the water resource balances in the water resource system, the production of a responsibility matrix of the actors and stakeholders in charge of integrated water resource management and the proposal of actions encompassing uses and users to improve the efficiency of the system.

The analysis process includes several steps such as the identification of the system through all these subsystems and components, the analysis of the constraints of the system, and the definition of its requirements. The definition of the actors in charge of resource management and their respective interactions and consultations are also integrated into the approach. The water and territory concept was considered by juxtaposing the administrative limits of the Wilaya of Tlemcen divided into economic planning areas and the hydrographic system with all these components. The objective was to see within what limits, a coherent overall scheme could satisfy all stakeholders in water use. The last step consisted of the evaluation of the performance of the system according to the changes in certain variables, in particular the effect of the reuse of wastewater, the recycling of industrial water and the effect of climate change.

METHODS

The fundamental assumptions underlying sequential processes, prespecified requirements, and functional-hierarchy product models are necessary to evaluate and often commit to solution components before finalizing the relationship between objectives and requirements of a complex system. This approach emphasizes the principles of understanding needs and envisioning opportunities, system scoping, system objectives and requirements determination, architecting and designing of the system or improving its performance (Boehm et al., 2012). The systemic approach claims to remedy to a large extent the shortcomings of the traditional approach. It replaces the principle of linearity with that of circularity: the decision is captured in a process that does not have its starting point in registering the problem; the idea of the final cause is reintegrated into the analysis. However, the limits of such an approach can be influenced by taking into account ambiguities, irrationalities, interactions and unforeseen retroactions appearing at the level of the system.

The approach adopted for the case of the analysis of the Tafna system is based on planning and bottom-up management. The different steps retained for the analysis can be summarized as follows:

- Identification of the system by these components (resources, infrastructures, etc.),
- Consideration of system constraints and formulations of system requirements,
- Analysis of the planning areas subsystem in terms of needs and production of multisector water balances of the system,
- Definition of institutional actors and production of the matrix of responsibilities for effective management,

- Production d'actions de performance du système en vue d'une dynamique de rééquilibrage territorial

The water resource system is interdisciplinary. We distinguish the three major components: the structure, the actors and the intrinsic characteristics of water. The management of water resources must be integrated into a development project for all water-related activities, themselves integrated into a sustainable development project. It takes into account both the natural and social characteristics specific to the environment and the economic and social development expectations of the populations established in these environments.

SYSTEM IDENTIFICATION

The development of the purpose of a system is achieved at the level of these units. System characteristics must be identified, and system requirements must be well defined. The management of water resources is organized according to the available water resources, the needs of users to be met, and the level of land use planning determining both the uses and the exploitation capacity of the available resources. Four sets of interactions must be identified: the water resources subsystem, regional planning subsystem, uses subsystem and actor's subsystem. These four subsystems fit within the watershed system. They ensure the operation, consistency and development of the water management system (Butterworth et al., 2010). Fig. 1 shows that the water management system is also influenced by other factors: topographical, geological, climatological, socioeconomic context, cultural environment, political and legislative framework. These relationships with its "environment" constitute inputs and outputs for the system. They influence the organization of the system to a greater or lesser extent, depending on its internal resistance. These inputs and outputs can be of three different types: matter, energy and information. Factors such as growth and demographic changes, economic development and climate change clearly have a very large impact on water resources. Likewise, water resources have a significant impact on production and economic growth, health and livelihoods, and national security.

The water resources system is a system located at the interface between the human system (synthesis of social and technical systems) and the natural system. This position manifests itself mainly in two forms: environmental management and land use planning. Environmental management should be considered a reasoned manipulation of the internal rebalancing of the environmental system, with the aim of maximizing its productivity while minimizing negative effects, while land-use planning plans the spatial organization of activities, infrastructures and the use of natural resources (Jin et al., 2015). Designers need to cope with socio-technical uncertainties and design systems to provide high performance during long life cycles. However, it is difficult to identify the appropriate system elements sensitive to changes especially when they are subject to a complex interdependence between the sociotechnical elements and the system elements (Hu and Cardin, 2015).

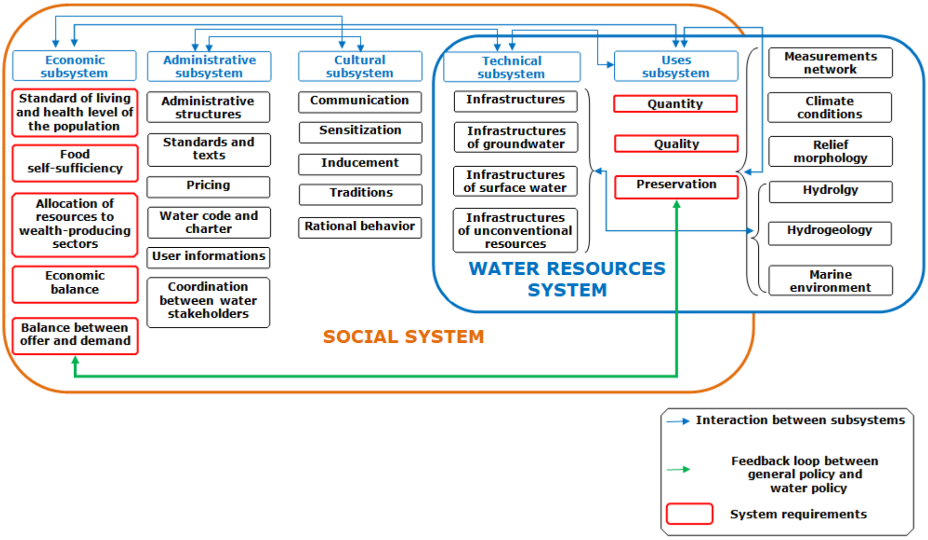

Figure 1: Cross-objectives of the general policy and that of water resources

SYSTEM CONSTRAINTS

Sustainable development means working to improve human productive power without damaging or undermining society or the environment. The search for a point of balance between economic development and the preservation of water resources subjects system managers to enormous pressures, risks and conflicts (Mugagga and Nabaasa, 2016). The success of planning in the water resources sector remains dependent on many actions, namely

- Carry out an inventory of the state of water resources and ecosystems,
- Assess the needs and priorities for intervention,
- Identify the actors concerned for all the water and development sectors, which it is necessary to involve in management,
- Define knowledge, data and information exchange systems,
- Establish mechanisms to coordinate decision-making between the different levels and actors,
- Stimulate dialog between water stakeholders
- Specify the water allocation process,
- Reduce water pollution and restore ecosystems,
- Fighting against floods and droughts (climate variability),
- Ensure the financing of water management

SYSTEM REQUIREMENTS

The characteristic nature of water management requires a synergetic line of reasoning. The effects of human activities on water resources have great consequences for water users. Natural and social relationships are mutually dependent and coexist in place and time. The behavior of resources and demands is frequently stochastic and nonstationary. A system must, by its organization, obey to respond to the needs, expectations and constraints of all stakeholders, be acceptable to and for the environment (physical, social, ecological, etc.), and represent a globally balanced and optimized solution throughout its life cycle (Rouissat et al., 2021). The definition of the requirements of the system is declined at the level of the exploration of the insufficiencies noted at the level of the governance of the water resources adapted to the changes of the environment. Table 1 shows the hierarchy of parameters to improve the system response to requirements and meet the needs of different stakeholders.

Table 1: Parameters for improving the requirements of the system against the support of stakeholder needs

Sectors	Improvement parameters for meeting requirements
Water mobilization	• Evaluate the additional quantities to be mobilized as well as their respective orders • Define the mode of allocation and distribution of these new resources.
Drinking water supply	• Identify strategies for integrating desalination into the overall system • Accurately assess the costs of water transport • Evaluate the quantities of water that can be saved for better governance.
Sanitation	• To what extent should sanitation infrastructures be combined with reuse facilities • What are the respective costs and risks
Irrigation/agriculture	• Look for solutions aimed at achieving food security and rural development • Identify the mobilizations and additional allocations necessary to increase irrigated areas • What would be the influence of these mobilizations on other uses of water?
Industrial water	• Integrate and consolidate the incentives to save water in industrial policy (recycling or modification of processes • Implement and strengthen regulatory measures to protect the environment
Unconventional water resources	• Accurately define the importance to be given to desalination (reserve for emergency situations, or be a source of supply like any other.
Conservation and protection of the resource	• Water quality: What scope and role does the conservation of the resource cover?

The multifunctional nature of water on the scale of hydrographic entities, the conflicting aspect between the uses of water and the satisfaction of different needs require the combination of a global approach. Fig. 2 schematically represents the approach adopted for the analysis of the system studied.

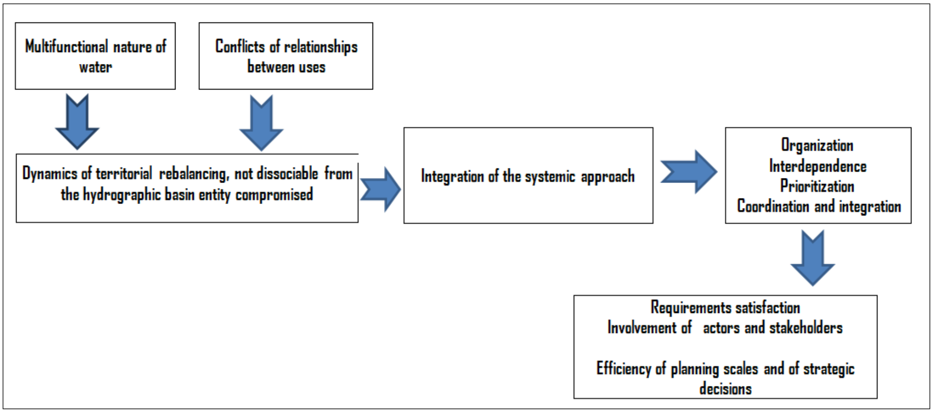

Figure 2: Graphical diagram of the analysis process

PRESENTATION OF THE STUDIED CASE

The Tafna watershed, shown in Fig. 3, is located northwest of the Algerian territory. It extends over the entire Wilaya of Tlemcen and on a part of the Moroccan kingdom. It extends into Algerian territory on an area of 7245 km^2. The eastern part is characterized by mountainous relief and is covered by vast areas of forest (37% of the area of the watershed). The western part encompasses the watershed of the Mouillah River, the largest tributary of the Tafna River, the major part of which is in Morocco and encompasses the plains of Angad and Maghnia. According to the new structure of hydrogeological units in Algeria, the Tafna basin belongs to the entire Oranie-Chott-Chergui (Bougara et al., 2020).

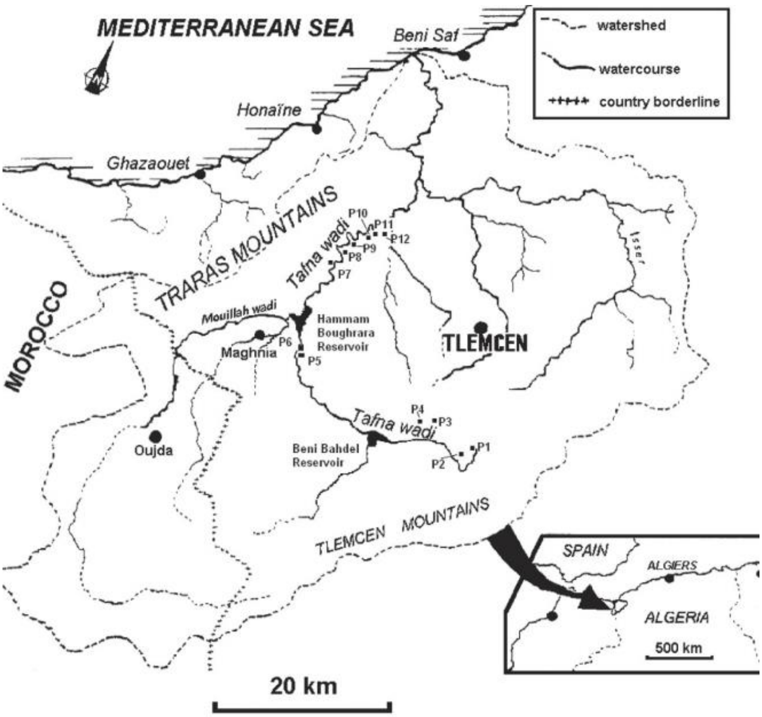

Figure 3: Situation of the Tafna watershed with hydrographic map (Belaidi et al., 2011)

WATER RESOURCES OF THE TAFNA SYSTEM

Groundwater

According to the hydrological data of the region (AGIRE, 2016), appearing in the directories of the national agency for integrated water resources management in Algeria AGIRE and the department of programming and budget monitoring of the Wilaya of Tlemcen (DPSB, 2017), the annual average exploitable volume of underground reserves is 100 Hm^3. One hundred eighty wells, boreholes and catchment fields participate in this water potential. The production capacity is 270.000 m^3/day. A water transfer from a catchment field (Chott El Gharbi), in the Wilaya of Naâma, contributes an annual volume of 18.2 Hm^3 to the water resources of the Tafna watershed.

Surface water

The Tafna system contains five large dams in service namely the Beni Bahdel dam, Meffrouche dam, Sidi Abdelli dam, Boughrara dam and Sikkak dam. They are designated BBB, BM, BSA, BHB, and BS respectively. The total capacity of the surface water amounts to 394 Hm^3 for a regularized capacity of 203 Hm^3 (Hamlat et al., 2017). Small dams are of local importance, and are generally intended for irrigation of small perimeters. With a total of twenty small dams at the level of the Tafna watershed, the mobilization capacity amounts to 12.28 Hm^3 (M.R.E., 2010; ANAT, 2010).

Unconventional resources

At the level of the Tafna system, there are three desalination stations for seawater. These are the stations of Ghazaouet (capacity: 1.8 Hm^3/year), Souk Tlata (capacity: 73 Hm^3/year) and Tafsout (capacity: 73 Hm^3/year). The Tafna system has eight wastewater treatment plants that will be operated in the future. Only three stations are functional (AGIRE, 2016). With the completion of the total wastewater treatment program, the produced volume would be 26.28 Hm^3/year.

Resource assignment to the system level

Taking into account the irregularity of resources at the system level, multiple transfers are carried out inside the Tafna system: three internal transfers from desalination plants, and seven internal transfers from dams and catchment fields. From the Tafna system, two external transfers to the neighboring Wilayas of Oran and Sidi Bèl Abbès (31.9 Hm^3/year) and one transfer from the Naâma Wilaya toward the Tafna watershed (18.2 Hm^3/year) are carried out. Fig. 4 shows all the components of the Tafna water resources system.

Figure 4: Components of the Tafna water resources system

RESULTS AND DISCUSSION

Fig. 5 summarizes the quantitative evaluation of water resources at the Tafna system level. This evaluation constitutes the balance sheet of resource flows at the Tafna system level in interaction with its internal and external environment.

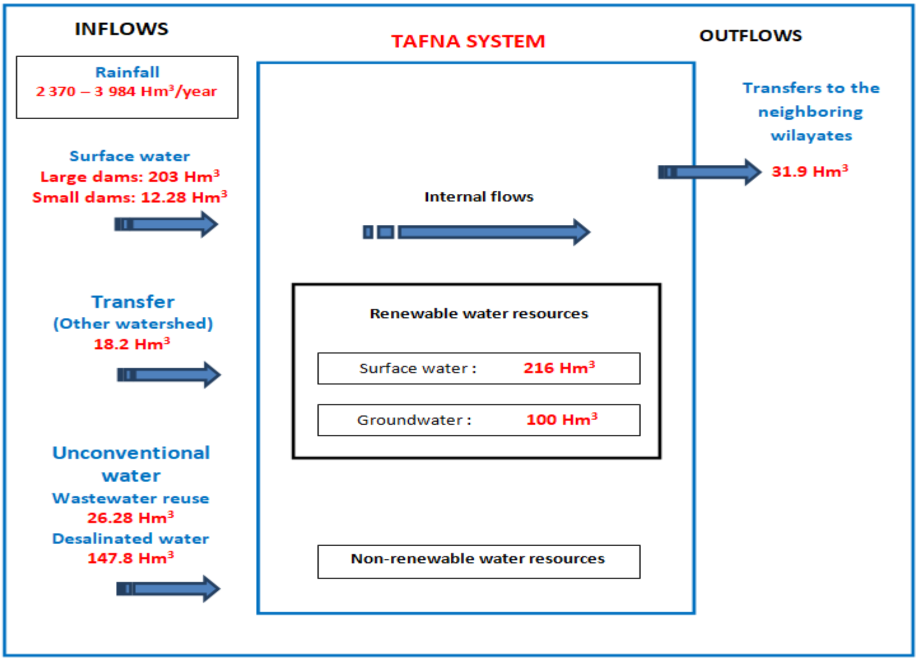

Figure 5: Quantitative evaluation of water resources at the Tafna system level

Concept of water and territory in the Tafna system

Due to the multiple links between the different uses and users of water, the management of water at the watershed level has a direct impact on communities, administrative regions and the territories of this watershed. The development plans are broken down at the scale of planning areas which are groupings of municipalities with natural and socioeconomic similarities. These considerations and orientations mean that the vision of the "watershed" entity can, in no way, be dissociated from the "territory" entity. Thus, for the Tafna water resources system, and taking into account its strong interactions in terms of mobilization, allocation and uses across the territory of the Wilaya of Tlemcen and the neighboring Wilayas, its analysis will be guided by integrating the territory parameter and in particular that relating to the limits of the Wilaya of Tlemcen.

In accordance with the Official Journal of the Democratic and People's Republic of Algeria "JORADP", the analysis of growth trends will focus on the spatial distribution by planning area. Based on the major issues, four guidelines have been identified by the Algerian state within the framework of the national land use planning plan by 2030 (JORADP, 2010).

- Create a sustainable territory,
- Create dynamics of territorial rebalancing,

- Create conditions for the attractiveness and competitiveness of territories,
- Achieve territorial equity.

At the level of the study of the development plan of the Wilaya of Tlemcen by the national agency for territorial planning "ANAT", seven planning areas were targeted by socioeconomic balance analyses; these are the areas shown schematically in Fig. 6 (ANAT, 2012). These areas constituting hydrographic units of the Tafna system can be considered subsystems in dynamic interactions in terms of mobilization and allocation on the one hand and in terms of uses (drinking water supply, water for irrigation and water for industries) on the other hand. The hydrographic limits of the watershed can, in no case, be dissociated from the limits of the administrative territory.

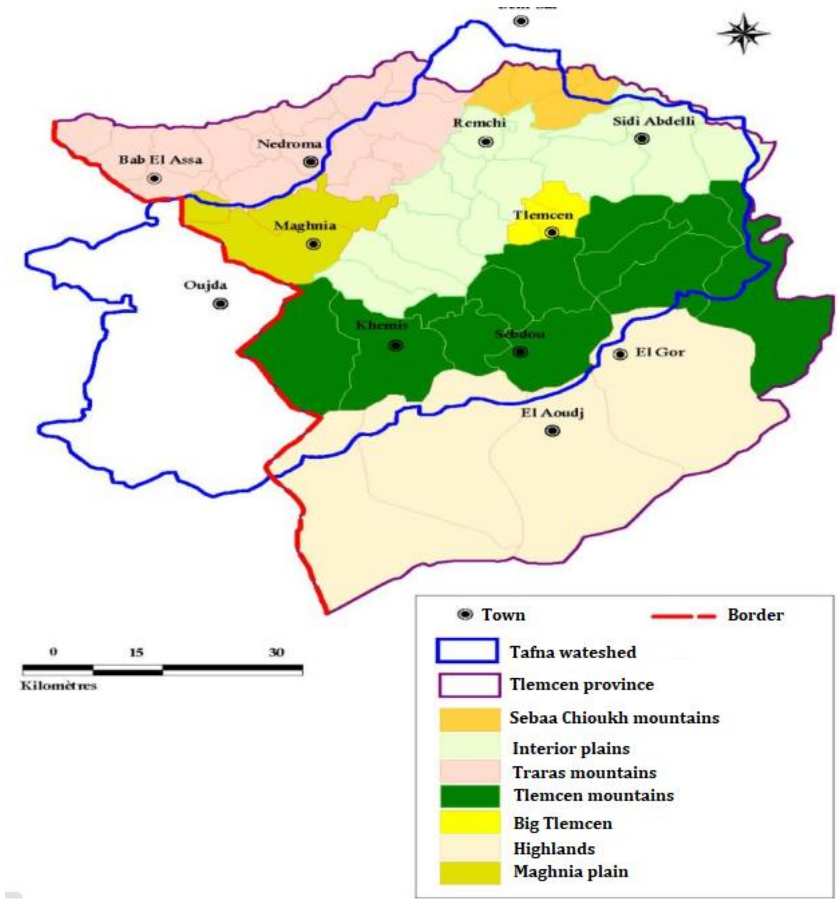

Figure 6: Interaction of administrative boundaries of the Wilaya of Tlemcen with the Tafna system (ANAT, 2012)

Water needs and definition of system customers

The land-use plan targets the 2030 deadline. Within the limits of the Wilaya of Tlemcen, the indicators allowing needs assessment of the different sectors are summarized as follows:

- The total population of the Wilaya of Tlemcen at the deadline of 2030 would be 1.2 million inhabitants. The endowment defined for the assessment of drinking water needs is 150 l/day. Inhabitant. The annual need is estimated at 65.89 Hm^3/year.
- The useful agricultural area is 327 000 Ha. The average annual water demand is 600 m^3/Ha. Year. Annual agricultural needs are assessed at 196 Hm^3/year.
- Annual industrial water demand was 6.5 Hm^3 in 2010, the annual needs have increased to 8.2 Hm^3 in 2015 and will reach 17.2 Hm^3 in 2030 (ANAT, 2010).

Institutional management of the system, definition and roles of stakeholders

Water resources professionals have been engaged in preparing integrated, multipurpose master development plans. This is a top-down approach. Using this approach, there is usually little or no active participation from interested stakeholders. Currently, water resources planning and management processes have increasingly involved the active participation of interested stakeholders who are potentially affected by the decision being considered. We then speak of an approach based on bottom-up planning and management (Loucks and Beek, 2017). Many current water planning and management problems are affected by high levels of complexity, uncertainty, and conflict (Von Korff et al., 2012). Watershed management requires good stakeholder knowledge: those involved in decision-making in watershed-scale water and soil management, and those who will be affected by decisions (Winz et al., 2009). Once the context has been analyzed, it is possible to seek to involve in watershed management the good combination of water actors at the appropriate levels. To identify stakeholders involved in watershed management and those affected by decision-making, it is useful to establish stakeholder roles and responsibilities. Some actions allow this coordination between actors for system-wide management: ensure that key stakeholders are represented in watershed management, find a balance between informing all actors and involving a small number, ensure that administrative processes do not jeopardize the effective participation of water stakeholders and ensure good communication between the actors of the local management plans, the heads of the public water agencies and the managers of the watershed organizations (Kallis et al., 2006).

At the level of the Tafna system, multiple agencies and administrations are involved in the management of water resources, from design and construction projects to the operation of infrastructures. Feedback on the shortcomings observed in terms of intersectoriality enabled us to draw up Table 2. According to the missions of the actors (System stakeholders) and the requirements of the system, the responsibilities and the different coordination must take place between the various actors of the system for efficient participative management of resources.

Table 2: Coordination and consultation matrix between the actors and stakeholders of the Tafna system

System requirements	Actors and stakeholders							
	ABH	**ANBT**	**ONA**	**ONID**	**ADE/AEC**	**ANRH**	**DRE**	**APC**
Quantitative system requirements								
Surface water		**R**		**I**	**I**		**R**	
Groundwater			**C**	**I**	**I**	**R**	**R**	
Water supply and distribution				**R**	**R**		**C**	**R**
Wastewater treatment			**R**	**I**				
Water desalination					**R**			
Water pricing		**R**	**R**	**R**	**R**			
Qualitative system requirements								
Surface water		**R**	**C**		**I**		**R**	**I**
Groundwater			**C**		**I**	**R**	**R**	**I**
Water supply and distribution			**R**	**R**	**R**		**C**	**C**
Wastewater treatment			**R**	**I**				
Water desalination					**R**			
Infrastructure maintenance		**R**	**R**	**R**	**R**		**R**	**R**
Monitoring indicators								
Measurement network	**C**	**I**				**R**		
Water resources database	**R**	**I**	**I**	**I**	**I**	**R**	**I**	**I**
Information système management	**R**	**C**	**C**	**C**		**C**		

R: Direct liability **C: Consulted** **I: Informed**

ABH: watershed agency ANBT: dams and transfers agency ONA: sanitation agency

ONID: irrigation and drainage office ADE: supply and distribution agency

AEC: energy company ANRH: hydraulic research agency

DRE: water resources direction APC: municipal assembly

Water balance sheet of the system

Conventional and unconventional water

The volume of wastewater discharged was 52.72 Hm^3/year. The efficiency of the treatment plants was set at 50%. The recycling of industrial water is estimated at 20% of total industry needs. For the deadline of 2030, table 3 gives an overview of the water balance at the system level by taking stock of conventional and unconventional resources in relation to the needs of different customers or sectors. For this situation, an excess of 200 Hm^3/year is checked in.

Effects of climate change on the water balance sheet of the system

The mobilization forecasts were set according to the guidelines of the Ministry of Water Resources: an average hypothesis, corresponding to the normal rainfall trend and a "dry" hypothesis corresponding to a trend of a 50% decrease in surface resources and 30% in underground resources with approximately 50% exploitation for the regeneration of underground reserves. The prospective approach must take into account all trends that can best reflect the levels of conventional resources. For the scenario mentioned in Table 3, the excess water passes to only 16.63 Hm^3/year.

Effects of climate change combined with reduction of desalination capacities on the water balance sheet of the system

Further analysis of the economic feasibility of different desalination technologies and optimal energy solutions helps to move toward more effective and efficient desalination solutions (Silva Pinto and Cunha Marques, 2017). However, the consideration of desalination as the main resource requires taking charge of all the possible hazards linked to possible malfunctions. Performance evaluation becomes essential to deal with these constraints to estimate the influence of the operational environment on the performance of systems relating to the use of desalinated water (Silva Pinto et al., 2017).

Another scenario was analyzed by integrating the constraints and operating costs related to the production of desalination water. Desalination stations have recorded multiple shutdowns during their operation caused by technical constraints. Table 3 illustrates the water balance sheet of the system with the annual production capacities of the desalination stations reduced to 50%. The balance sheet will record a deficit of 57.27 Hm^3/year.

Table 3: Water balance sheet of the system in different situations

	System balance sheet with integration of the reuse wastewater and industrial water recycling (Hm^3/year)	Impact of climate change on the system water balance sheet (Hm^3/year)	Impact of climate change and desalination capacity (Hm^3/year)
Surface water	215.28	107.64	107.64
Groundwater	100	35	35
Desalination water	147.8	147.8	73.9
Transfers from watershed	31.9	15.95	15.95
Transfer toward the watershed	18.2	6.37	6.37
Wastewater reuse	26.28	13.14	13.14
Industrial water recycling	3.44	1.72	1.72
Drinking water needs	65.89	65.89	65.89
Agricultural needs	196	196	196
Industrial needs	17.2	17.2	17.2
Balance sheet (2030)	200.01	16.63	-57.27

Integration of the water and territory concept

Water planning in a territory defined by an appropriate policy must meet two simultaneous objectives. It must proceed to the real confrontation between the natural environment and the actions of water management of all kinds when these begin to interfere, to enter into a competition or even conflict, and especially when these situations are foreseeable. It can then be induced by general economic planning and by land-use planning options.

At the level of the study on the Tlemcen Wilaya management plans, seven planning areas, shown in Fig. 7, were targeted by socioeconomic similarity analyses. To assess the territorial balance of the system, Fig. 6 summarizes the annual needs (drinking water supply, irrigation and industry) for the different planning areas by 2030.

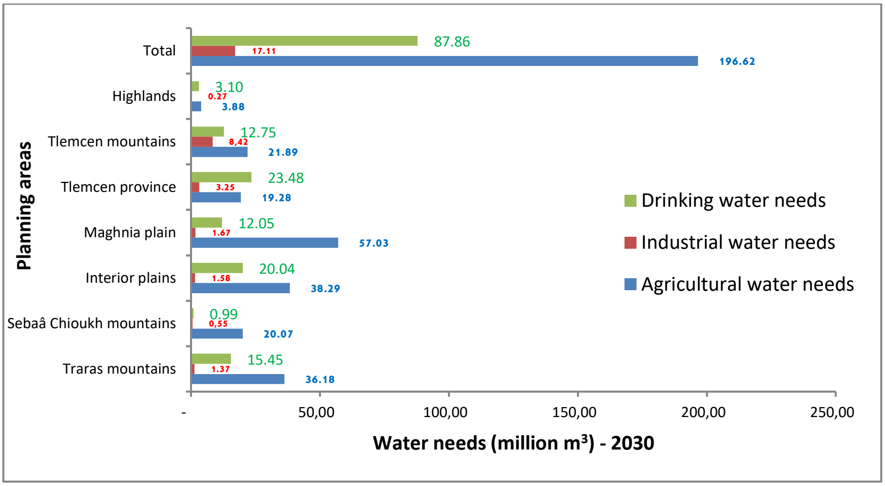

Figure 7: Annual needs of different planning areas, deadline 2030 (ANAT, 2012)

Figs. 8 and 9 summarize the evolution of the population at the level of the various planning areas and the rates of drinking water needs, respectively, compared to the overall need by 2030.

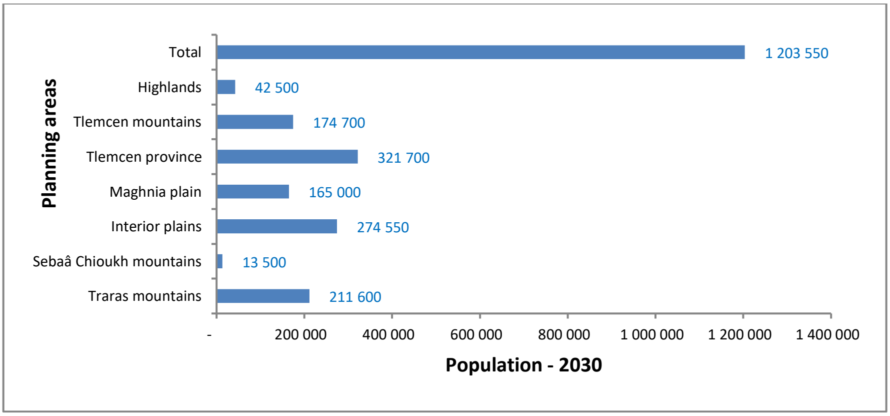

Figure 8: Population in the planning areas by 2030

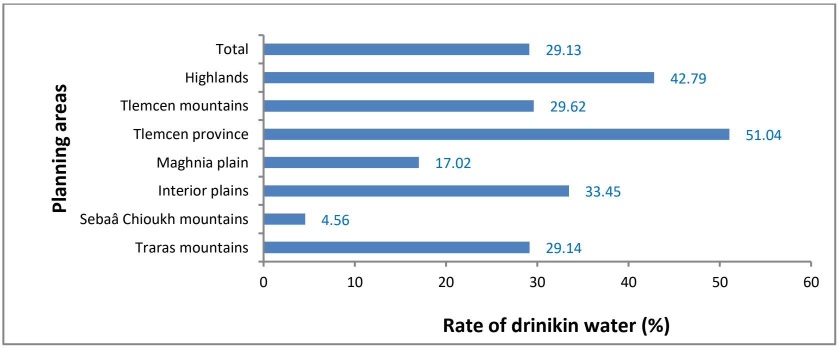

Figure 9: Percentage of drinking water needs in relation to overall needs

The functional identification through the juxtaposition of the hydrographic entity with the administrative boundaries as well as the consideration of the watershed as the basic unit for planning made it possible to take into account the relationships and conflicts between water uses.

The water balances carried out at the scale of the hydrographic unit made it possible to overcome the constraint relating to the planning plans established by the sector of activity without a global vision linked to the objectives of the global system.

This action also makes it possible to think in a more rational way about territorial rebalancing according to the needs of the planning areas.

The production of the matrix of responsibility and participatory consultation offers a common management framework on the scale of the global system and not according to the sectors of activity as is currently the case.

The overall analysis of the system shows that the contribution of the reuse of wastewater and the recycling of industrial water is relatively significant. Actions must be taken to encourage industrial units to recycle water and solve all the constraints linked to the low yield of wastewater treatment plants.

The impact of constraints related to the management of desalination stations is significant. Indeed, the water balance becomes deficient if the production of desalinated water is reduced by half.

Research and identification of strategies to integrate desalination into the global system are necessary.

The analysis of the different needs shows that some planning areas require additional capacities and allocations for the agricultural sector, in particular, the Traras Mountains, Maghnia plains, interior plains, and Tlemcen Mountains where the needs are 53, 70.75, 59.91 and 43.06 Hm^3/year, respectively. These water needs represent 75% of the total needs.

A new water resource allocation plan becomes mandatory. Desalination water will be used to supply drinking water. For the agricultural sector where the need is important the reallocation of dams for agriculture is necessary. The new allocation plan must be implemented in relation to new interconnections between the planning areas.

Efficiency actions

Loss reduction in drinking water networks

The efficiency of drinking water networks is the ratio of the volume of water produced to the volume of water consumed. This efficiency is closely linked to the rate of leaks in water transfers and distribution network. Fig. 10 illustrates the influence of networks leakage rates on drinking water needs by 2030. For a leakage rate of 30%, the gap between the needs (65.89 Hm^3/year), and the volume actually affected is approximately 20%**.**

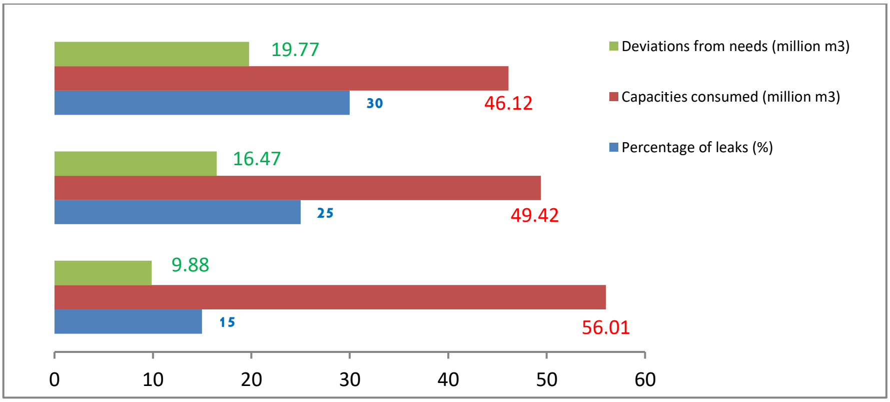

Figure 10: Influence of leakage rates in networks on the satisfaction of drinking water needs

Nonconsumptive cropping techniques and reuse of purified wastewater

The efficiency of wastewater treatment plants is very low. The annual volume of domestic water discharged amounts to 52.72 Hm^3/year.

Actions to modify cultural techniques to reduce the consumption of irrigation water, especially at the level of small and medium perimeters are mandatory. The integration of wastewater reuse in meeting needs is crucial. Fig. 11 shows that the purification capacity of the stations realized and those planned are 13.4% of the agricultural needs. An increase in the rate of purification to 70% of the domestic discharged water raises the rate of satisfaction of needs to 19%.

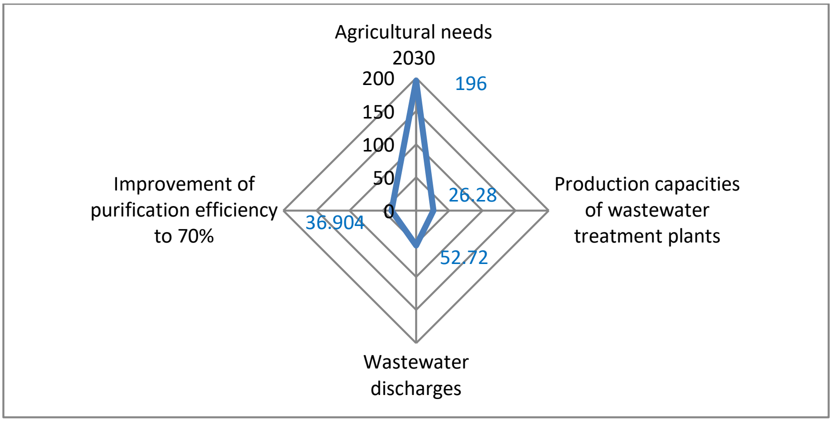

Figure 11: Influence of the reuse rate of wastewater on the satisfaction of agricultural needs

Recycling of industrial water

The annual demand for industrial water is estimated to amount to 17.2 Hm^3/year. Industrial units must rehabilitate their sewage treatment plants. A recycling rate of industrial water of 30% reduces annual needs from 17.2 Hm^3/year to 12.04 Hm^3/year.

Actions on drinking water demand

In the case of demand management with an individual endowment reduced from 150 l/day Inhabitant to approximately 100 l /day. Inhabitants, the demand for drinking water at the end of 2030 would be on the order of 43 Hm^3/year. This volume would represent 15% of the overall needs for planning areas.

Synthesis of efficiency actions

By focusing on the water-territory concept, and by implementing efficient actions, Fig. 12 illustrates some combined actions oriented mainly toward the following:

- Actions based on the control of demand for drinking water,
- Actions linked to the rate of satisfaction of agricultural needs,
- Actions encouraging the recycling of industrial water,
- Actions articulated on the necessity of the purification of wastewater for agricultural needs.
- Finally, the investment budgets must include funding dedicated exclusively to the maintenance of installations and the improvement of the performance of systems.

These actions should be based on common indicators for the different actors and stakeholders at the level of a watershed with more participatory management.

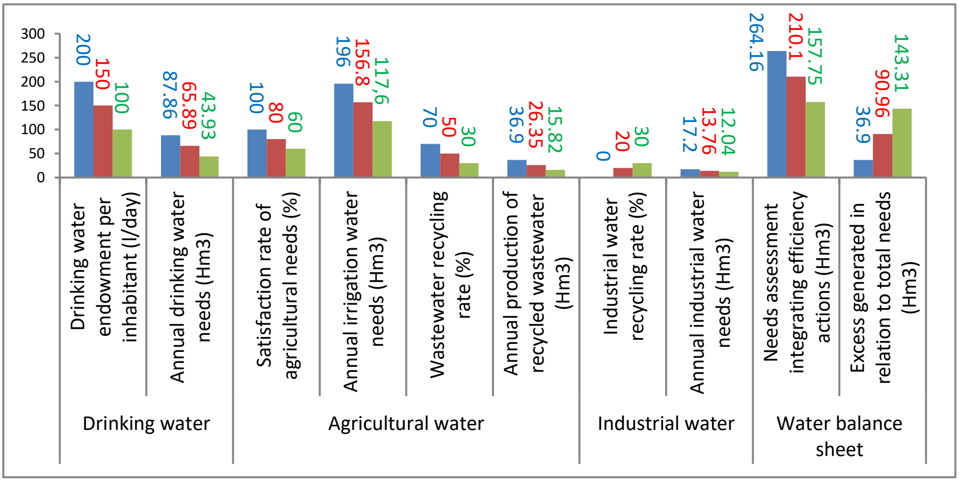

Figure 12: Global water balance with integration of efficiency actions

CONCLUSION

The analysis of complex systems, such as the water resources system, must imperatively integrate the interaction between the various components of the system. For the watershed studied, the adoption of a systemic approach has made a great contribution to the integration of all aspects relating to the coherence between the integrated management of watersheds and the sustainable development programs that are carried out at this level. The systemic approach totalizes in terms of architecture and functionality. It is, therefore, able to identify all the components of complex systems, in this case, water resource systems. The water resources system affects the physical environment, the social and economic systems, the technical system, and the politico-administrative and cultural system. Systemic analysis of this type of system, therefore, facilitates communication on these systems between researchers from various disciplines.

For the Tafna system, and given the evolving nature of water resources, this study has resulted in the production of relevant indicators contributing to the governance of water resources at the watershed scale as well as to the analysis of scenarios relating to the evolution of the behavior of the components of the system. The main conclusions can be summarized in the following:

- ✓ The adoption of a systemic approach has been a considerable contribution to the definition of the various elements and components of the system. The combination of the identification of the system, and the characterization of its constraints and requirements allowed a global analysis for the satisfaction of the different needs

- ✓ The anticipation of constraints and risks concerning both the strategies and the performance of the Tafna water resources system cannot be done without the simultaneous consideration of a good scientific knowledge of the behavior of the system, the integration of the concept of water and territory
- ✓ The approach based on planning and bottom-up management involves the active participation of stakeholders potentially affected by the planned decision. The responsibility and consultation matrix ensures the interdependence of actions and decisions on the scale of the global system
- ✓ The sectoral organization of institutions as currently established is not in line with the multifunctional nature of water. Indeed, the agencies present at the level of the administrative territory act according to the sector of activity (mobilization of the resource, transfers, purification, desalination, etc.) and are not affected by the global missions of the system at the scale of the Tafna watershed. The creation of a watershed coordination organ or an observatory is more than necessary.
- ✓ According to the water balances drawn up, desalination is a very strategic vector in terms of meeting needs. The constraints related to the management of desalination plants are correlated with the importance of desalination. It now constitutes a reserve and an important source of supply, unlike in the past, when it was considered a strengthening resource.
- ✓ Incentives for water savings should be integrated into industrial water policy. The volumes of reused wastewater for agriculture must also be integrated into the management actions of the watershed.
- ✓ Past policies have always been oriented toward offerings. Demand management can be an interesting alternative, especially in the event of a water deficit in the system.
- ✓ The management of data, information, and scientific knowledge of the parameters of the watershed must be disseminated to the different actors of the system.
- ✓ An allocation master plan is necessary and can be based on the conclusions of this study to further minimize conflict situations relating to the use of the water resources and guarantee the sustainable development of the region.

REFERENCES

ANAT (Agence Nationale d’Aménagement du Territoire) (2010). Actualisation du plan d’aménagement de la Wilaya de Tlemcen, bilan de la situation et problématique de l’aménagement, Tlemcen, Algeria, pp. 12-36.

ANAT (Agence Nationale d'Aménagement du Territoire) (2012). Plan d'aménagement du territoire de la Wilaya de Tlemcen : plan d'aménagement intégré par aire de planification, Tlemcen, Algeria, pp. 32-48.

AGIRE (Agence Nationale de Gestion Intégrée des ressources en Eau) (2016). La région hydrographique Oranie - Chott Chergui, ressources en eau. http://abhoranie.dz/ Bassins.html, Accessed 22 February 2021.

BARON C., ALLEGRO B.D. (2019). About adopting a systemic approach to design connected embedded systems, A MOOC promoting systems thinking and systems engineering, Journal systems engineering, Wiley periodicals, Vol. 23, Issue 3, pp. 261-280. https://doi:10.1002/sys.21513

BELAIDI N., TALED A., MAHI A., MESSANA G. (2010). Composition and distribution of stygobionts in the Tafna alluvial aquifer (northwestern Algeria), Subterranean Biology, Vol. 8, pp. 21-32. https://doi: 10.3897/subtbiol.8.1227

BOEHM B., KOOLMANOJWONG S., LANE J.A., TURNER R. (2012). Principles for Successful Systems Engineering, Procedia Computer Science, Vol. 8, pp. 297-302. https://doi.org/10.1016/j.procs.2012.01.063

BOUGARA H., BABA HAMED K., BORGEMEISTER C., TISCHBEIN B., KUMAR N. (2020). Analyzing Trend and Variability of Rainfall in The Tafna Basin (Northwestern Algeria), Atmosphere, Vol. 11, Issue 4, pp. 2-24. https://doi:10.3390/atmos11040347

BUTTERWORTH J., WARNER J., MORIARTY P., SMITS S., BATCHELOR C. (2010). Finding practical approaches to Integrated Water Resources Management, Water Alternatives, Vol. 3, Issue 1, pp. 68-81. https://www.water-alternatives.org/index.php/allabs/77-a3-1-4/file

DACKO M., DACKO A. (2009). Management of the natural environment, a systemic approac, Polish Journal of Environmental Studies, Vol. 18, Issue 2, pp. 145-150. http://www.pjoes.com/Issue-2-2009,3825

DPSB (Direction de la Programmation et du Suivi Budgétaire) (2017). Annuaire statistique de la Wilaya de Tlemcen, Tlemcen, pp. 25-41.

DOBNER P., FREDE HG. (2016). Water Governance: A Systemic Approach. In: Hüttl R., Bens O., Bismuth C., Hoechstetter S (Eds), Society - Water - Technology, Water Resources Development and Management, Springer, pp. 79-87. https://doi.org/10.1007/978-3-319-18971-0_6

DURAN-SANCHEZ A., ALVAREZ-GARCIA J., DEL RIO-RAMA M.D.I.C. (2018). Sustainable water resources management: a bibliometric overview, Water, Vol. 10, Issue 9, pp. 1-19. https://doi:10.3390/w10091191

GERMAN L., GETACHEW H.M., MAZENGIA A.W., AMEDE T., STROUD A. (2007). Participatory integrated watershed management: Evolution of concepts and methods in an ecoregional program of the eastern African highlands, Journal agricultural systems, Vol. 94, Issue 2, pp. 189-204. https://doi.org/10.1016/j.agsy.2006.08.008

GRILL G., LEHNER B., LUMSDON A., MACDONALD G., ZARFL C., REIDY LIERMANN C. (2015). An index-based framework for assessing patterns and trends in river fragmentation and flow regulation by global dams at multiple scales, Environmental Research Letters, Vol. 10, pp. 1-15.

doi:10.1088/1748-9326/10/1/015001

HAMLAT A., GUIDOUM A., KOULALA I. (2017). Status and trends of water quality in the Tafna catchment: a comparative study using water quality indices, Journal of Water Reuse and Desalination, Vol. 7, Issue 2, pp. 228–245. https://doi.org/10.2166/wrd.2016.155

HU J., CARDIN M.A. (2015). Generating flexibility in the design of engineering systems to enable better sustainability and lifecycle performance, Journal Research in Engineering Design, Vol. 26, pp. 121-143. https://doi.org/10.1007/s00163-015-0189-9

ISLAM S., REPELLA C. (2015). Water Diplomacy: A Negotiated Approach to Manage Complex Water Problems, Journal of Contemporary Water Research & Education, Issue 155, pp. 1-10. https://www.academia.edu/19760165/Islam_and_Repella_UCOWR_2015

JIN G., WANG P., ZHAO T.N., BAI Y., ZHAO C., CHEN D. (2015). Reviews on land use change induced effects on regional hydrological ecosystem services for integrated water resources management, Physics and Chemistry of the Earth, parts A/B/C, Vol. 89-90, pp. 33-39. http://dx.doi.org/10.1016/j.pce.2015.10.011

JORADP (Journal Officiel de la république Algérienne Démocratique et Populaire) (2010). Loi n° 10-02 du 29 juin 2010 portant approbation du schéma national d'aménagement du territoire, Algeria, pp. 21-36. https://www.joradp.dz/ftp/jo-francais/2010/f2010061.pdf

KALLIS G., VIDEIRA N., ANTUNES P. (2006). Participatory methods for water resources planning, Environment and Planning C: Government and Policy, Vol. 24, Issue 2, pp. 215-234. https://doi: 10.1068/c04102s

LOUCKS D.P., BEEK E. (2017). Water Resources Planning and Management: An Overview, Water Resource Systems Planning and Management, Springer, Cham. https://doi.org/10.1007/978-3-319-44234-1_1

MARKOWSKA M., SZALIŃSKA W., DĄBROWSKA., BRZĄKAŁA M. (2015). The concept of a participatory approach to water management on a reservoir in response to wicked problems, Journal of Environmental Management, Vol. 259. https://doi.org/10.1016/j.jenvman.2019.109626

MRE (Ministère des ressources en eau). (2010). Actualisation du plan national de l'eau, rapports sur les ressources et demandes, Algérie.

MUGAGGA F., NABAASA B.B. (2016). The centrality of water resources to the realization of sustainable development goals (SDG), a review of potentials and constraints on the African continent, international soil and water conservation research, vol. 4, issue 3, pp. 215-223. http://dx.doi.org/10.1016/j.iswcr.2016.05.004

MWAMBO F.M., FÜRST C. (2019). A Holistic Method of Assessing Efficiency and Sustainability in Agricultural Production Systems, Journal of Environmental Accounting and Management, Vol. 7, Issue 1, pp. 27-43. https://:10.5890/JEAM.2019.03.003

ROUISSAT B., BEKKOUCHE A., SMAIL N., (2021). Contribution of the requirements engineering to the evaluation of water resources systems efficiency, Applied Water Science, Vol. 11, Issue 29, pp. 1-11. https://doi.org/10.1007/s13201-021-01359-8

SAGUIER M., PILAR G., VILLAR C., VENTURINI V., SANTOS M.A. (2021). Interdisciplinary research networks and science-policy-society interactions in the Uruguay River Basin, Journal environmental Development, Vol. 38, pp. 1-11. https://doi.org/10.1016/j.envdev.2020.100601

SILVA PINTO F., CUNHA MARQUES R. (2017). Desalination projects economic feasibility: A standardization of cost determinants, Renewable and Sustainable Energy Reviews, Vol. 78, pp. 904-915. https://doi.org/10.1016/j.rser.2017.05.024

SILVA PINTO F., CUNHA MARQUES R. (2017). Water services performance: do operational environment and quality factors count, urban water journal, vol. 14, issue 8, pp. 773-781. https://doi.org/10.1080/1573062x.2016.1254254

TURNER J.R., BAKER R.M. (2019). Complexity Theory: An overview with potential applications for the social sciences, Systems, Vol. 7, Issue 1, pp. 1-22. https://doi.org/10.3390/systems7010004.

VON KORFF Y., DANIELL K.A., MOELLENKAMP S., BOTS P., BIJLSMA R.M. (2012). Implementing participatory water management: recent advances in theory, practice, and evaluation, Ecology and Society, Vol. 17, Issue 1, pp. 1-14. http://dx.doi.org/10.5751/ES-04733-170130

WANG G., MANG S., CAI H., LIU S., ZHANG Z., WANG L., INNES J.L. (2016). Integrated watershed management: evolution, development, and emerging trends, Journal of Forestry Research, Vol. 27, pp. 967–994. https://doi.org/10.1007/s11676-016-0293-3

WINZ I., BRIERLEY G., TROWSDALE S. (2009). The Use of System Dynamics Simulation in Water Resources Management, Water Resources Management, Vol. 23, pp. 1301–1323. https://doi.org/10.1007/s11269-008-9328-7