

Using DPSIR framework for the implementation of wetlands observatory: case study Sebkhates of Aures wetlands complex (Northerneast, Algeria)

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Abstract: Wetlands are present within intricate ecological settings, exhibiting dynamic changes over time and across different areas with regard to their functional and structural diversity. Several approaches have been introduced for ecosystem analysis and management since 1990s, where Driver – Pressure – State – Impact – Response (DPSIR) framework is one of the widely used approaches for assessing and managing environmental problems. In this study, we proposed a DPSIR framework as a model in the Sebkhates of Aures wetland complex (SAWC, Northeast of Algeria), in order to create a regional wetland observatory to deliver ecosystem services within current state of changes resulted from socioeconomic drivers. DPSIR facilitates the identification of essential indicators to detect threats to the Sebkahtes of Aures wetlands complex (SAWC), influencing policymakers to enhance the protection and management of these wetlands. In line with the established DPSIR framework. This same approach and methodology could be applied to the other 15 wetlands complexes known in Algeria, culminating in the creation of a national wetland observatory. Furthermore, DPSIR can be employed as an analytical tool for policy making in the context of sustainable management of wetland ecosystems and can serve as a model in the establishment and development of various observatory programs in Algeria.

1. Introduction

Nowadays, pressures on natural resources, especially water resources, continue to rise due to the increasing impact of climate change on one hand, and anthropogenic activities on the other. Mediterranean wetlands are among the 36 biodiversity hotspots globally, characterized by a notably high level of endemism (CEPF, 2017). These ecosystems are home to highly specific plant and animal populations (Dwight, 2001). In the Mediterranean, trends over the last fifty years show a rapid degradation of natural resources, linked to demographic pressure, land use and urbanization, aggravated by global warming (GFN, 2012). Over the past century, the Mediterranean region has lost 50% of its wetlands, areas that are essential for sustainable development in the region (Perennou et al., 2015; MWO, 2018).

To ensure the sustainability of these ecosystems, several inventories, assessments, monitoring and conservation programs have been implemented in Mediterranean countries, including those in the Maghreb. These initiatives are generally part of collaborative projects allowing the promotion of parks and nature reserves, the classification of new Ramsar sites (Chazee et al., 2017). The Mediterranean wetlands

observatory, like many environmental observatories, often uses the DPSIR (Driving forces, Pressures, States, Impacts, and Responses) conceptual framework to understand changes in Mediterranean wetlands and develop appropriate responses (Chazee, 2011).

Moreover, the DPSIR framework was developed in the 1990s by experts from the Organization for Economic Cooperation and Development (OECD) and the European Environmental Agency (EEA) (EEA, 2003), drawing on the concept of environmental impact in an holistic ecosystem approach, to account for a range of environmental problems and policies in similar terms (Fernandez et al., 2014). Based on its foundation in ecosystem research, this framework proposes that there are cause-and-effect relationships between ecological and socio-economic factors, similar to the interactions seen in ecosystem processes like those between different soil types, water quality, and biological diversity (Chazee, 2012; MWO, 2012). Accordingly, this framework has become popular among researchers and decision-makers as a conceptual model for structuring and communicating environmental research (EEA, 2003). DPSIR has been extensively applied, functioning as a tool for assessing the sustainability of social-ecological systems (SES) and covering a wide range of environmental issues (Gari et al., 2015). This includes topics such as urban ecosystems (Zhao et al., 2021), ecotourism (Swangjang and Kornpiphat, 2021), marine and coastal management (Delgado et al., 2021), greenhouse agriculture policies (Liu et al., 2022), desertification (Akbari et al., 2021), and observatories (MedWet, 2019).

In the southern part of the Mediterranean, Algeria, the largest country in Africa, account 50 Ramsar sites (DGF, 2023). Algeria ranks 4th in terms of wetland surface area among 27 Mediterranean countries (Perennou et al. 2012). These wetlands are among the most valuable resources in terms of biological diversity and natural productivity. They play an important role in fundamental processes and are home to important flora, fish and migratory birds (Gherzouli, 2013). In Algeria, wetlands face the adverse consequences of an arid climate on water resources, which are further intensified by climate change and human activities, particularly, agricultural practices, including the pumping of water, intended for domestic use, irrigation of cultivated plots and watering of livestock, is a major pressure on water availability, significantly contributing to the drying out of water bodies. In addition, to this pressure there is also grazing around the sites, the collection of plants, the collection of the eggs of nesting bird species, the extraction of salt as well as the less frequentation for leisure activities, which threaten wetland biodiversity (Benzina et al., 2022). In order to face these increasingly pressing threats, Algeria granted in 2016 the implementation of the Action Plan of the National Wetlands Strategy (2015 – 2030) which relied in its delimitation of 16 wetland complexes. The General Forestry Directorate has launched, with the aim to achieve one of the objectives of the national strategy, a project to create a national wetlands observatory. However, the implementation of the latter is a difficult challenge, given the vastness of the national territory and the lack of skills and experience in the field.

As part of the implementation of the national wetlands strategy, in particular the process of setting up wetland observatories in Algeria, we aim to develop a proposal to set up a local observatory for Sebkhates of Aures wetlands (SAWC). The methodology based on the DPSIR framework above all enables us to identify the necessary indicators allowing the description of threats to wetlands and influencing decision-makers to better protect and manage the wetlands of Aures Sebkahtes complex. The application of the same principle and methodology could be adopted for the other wetlands complexes in Algeria, which would lead to the establishment of a national wetland observatory.

2. Materials and Methods

2.1. Overview of the Sebkhate of Aures wetlands complex (SAWC)

The SAWC is located in the Algerian Eastern highlands: 35°12'14"N; 36°13'37"N and 5°17'42"E; 8°24'00"E, at an altitude of 800 to 1200 m a.s.l. It extends over 100.3 km

(north to south) and 278.0 km (east to west), with an effective surface area of 16,020 km² and a perimeter of 942.3 km (DGF, 2016). This vast region covers the entire watershed of the Constantinois high plateaux (9,578 km) and a large part of the Medjerda basin (7870 km², Algerian part), which extends into Tunisia (Figure 1).

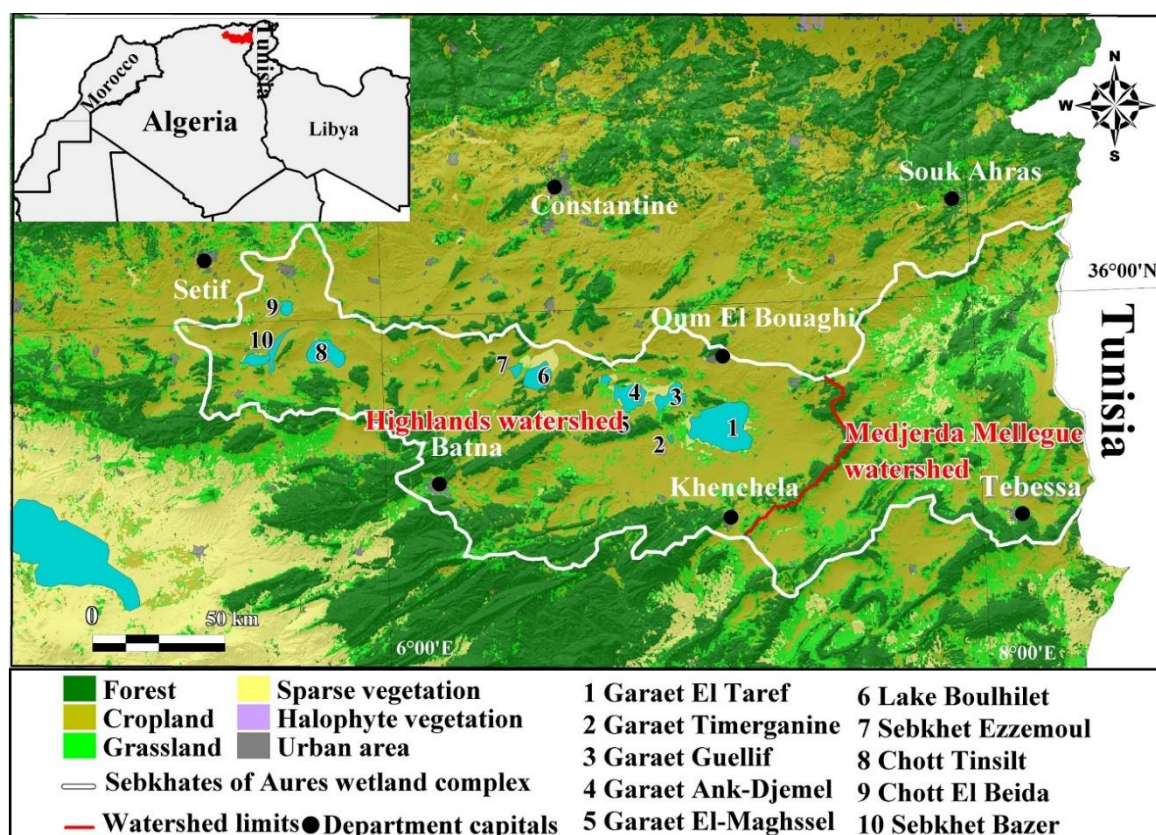


Figure 1. Geographical Location of the Sebkhat of Aures wetlands complex and the 10 Ramsar Sites (Northeastern Algeria) (LULC data source: FAO, 2021).

The weather of the region is influenced by its location in an ecotone region, straddling between semi-arid and arid climate with humid variants in high altitude. The area suffers a long period of summer drought which dries out wetlands from May to November. Over the past 20 years, the mean of daily maximum temperatures (\pm SD) were $36.9 \pm 2.04^\circ\text{C}$, and minima were $8.94 \pm 0.38^\circ\text{C}$. Annual precipitation varies from year to year (160.8 to 362.2 mm), with a very irregular seasonal distribution (Bougoffa et al., 2023).

The SAWC complex, a string of mostly brackish to saline bodies of water, once referred to by geographers as "the Great Land of Lakes", stretches across a vast plain surrounded by hills and plateaus (Si Bachir, 1991). The complex includes numerous natural wetlands (garaets, sebkhet and chotts) and artificial wetlands (dams, hill reservoirs, basins), the majority of which are shallow, ranging in size from a 2.41 km² to 210.98 km² (Bentrchia, 2022). Given the great biodiversity, plant, animal and ecosystem sheltered by the sites of the complex, 10 wetlands have been considered of international importance and classified as Ramsar sites: Garaet El Taref, Garaet Timerganine, Garaet Guellif, Garaet Annk Djemel and El Merhsel, Lake Boulhilet, Sebkhet Ezzemoul, Chott Tinsilt, Chott El Beïdha-Hammam Essoukhna, Sebkhet Bazer, and Sebkhet El Hamiet. These wetlands represent a significant part of the Ramsar wetlands in Algeria, 10 sites out of the 50 classified and 10 194 km² on 30 328,13 km² of the country (DGF, 2020). These wetlands are home to a rich biodiversity, both flora, fauna and habitats. As an indication, Benzina et al. (2022) identified 56 waterbird species, covering 8 orders and 15 families. According to the IUCN Red List, Benzina et al (2022) indicated the presence of *Oxyura leucocephala* in the SAWC (endangered species) and

formerly *Numenius tenuirostris* (critically endangered). In addition, four species are considered near threatened and 3 species are classified vulnerable.

According to the administrative division, the complex is spread over a set of 7 wilayas (administrative departments): Oum El Bouaghi, Tebessa, Batna, Khenchela, Sétif, Souk Ahras, and Mila. In addition, the SAWC extends to the Algerian-Tunisian border with the Medjerda watershed (23,000 km², 32% of which is located in eastern Algeria) (Barour, 2015). The estimated population of the main agglomerations surrounding the wetlands increased from 10-50 inhabitants/km² in 1971 to 50-100 inhabitants/km² in 2019 with a greater or lesser density in the northern part of the complex. This density continued to evolve, exceeding 150 inhabitants per km² in 2024. The main activities of the inhabitants are cereal farming, vegetable crops, sheep farming, poultry, beekeeping, etc.). Furthermore, the inhabitants practice other various activities, consisting mainly of small trades and pottery. The average annual incomes of households were 235,076.56 Algerian Dinars in 2023 (i.e. 1710.52 US \$) (Bougoffa et al., 2023). Several ecosystem services both economic and ecologic which are considered respectively direct and indirect services were identified: water uses, grazing, agriculture, salt mining, plants and egg collection; recreation area, water treatment/flood control and water purification (Demnati et al 2020). The wetlands in the region, as is the case throughout the country, are under the jurisdiction of the General Directorate of Forests at the central level (Ministry of Agriculture) and the forest direction of departments at the local level.

2.2. DPSIR framework application

An Observatory is a body, generally public or associative (non-governmental), that collects environmental data, in the form of indicators, for environmental biomonitoring and the management and evaluation of environmental policies (GIZ, 2012). In this context, the methodology advocated here for the creation of a regional wetlands observatory in Algeria draws its essence from the DPSIR model (Driving Forces, Pressures, States, Impacts, and Responses), which provides a framework for analyzing the interactions between society and the environment. The DPSIR model, is a tool created for the adaptive management of social-ecological systems, presuming cause-and-effect relationships between the components of socio-economic and environmental systems (Lu et al., 2019) (Figure 2). This analytical framework, employed to establish and assess an observatory, helps in selecting a range of indicators to convey the evaluation results. The European Economic Area (EEA) employs an expanded edition of the widely recognized Organization for Economic Co-operation and Development (OECD) model to evaluate how human activities affect the environment (EEA, 2003). Its effectiveness lies on its capacity to make it easier to use the information from the observatory for policy and management decisions (Geijzendorffer et al., 2019).

To this purpose, we gathered information on the various conceptual frameworks for the indicators and compiling all kinds of data related to the SAWC region. Our data was based on a bibliographic search from up to 200 available references (theses, dissertations, scientific publications, cartography, and reports). This information was supported by up-to-date data, results from studies conducted within the "Biodiversity, Biotechnology, and Sustainable Development" laboratory, including findings from several scientific papers, theses and dissertations. This also falls within the framework of the surveys carried out with our involvement in the French Development Agency and the Fond Français pour l'Environnement Mondial (AFD-FFEM) project on civil society organizations and sustainable wetland management in the Mediterranean over 5 years (2018-2021). We carried out several field trips; enrich flora and fauna inventories, waterbirds monitoring, socio-economic survey with local residents of the 10 wetlands and the people involved in the management and conservation of these sites.

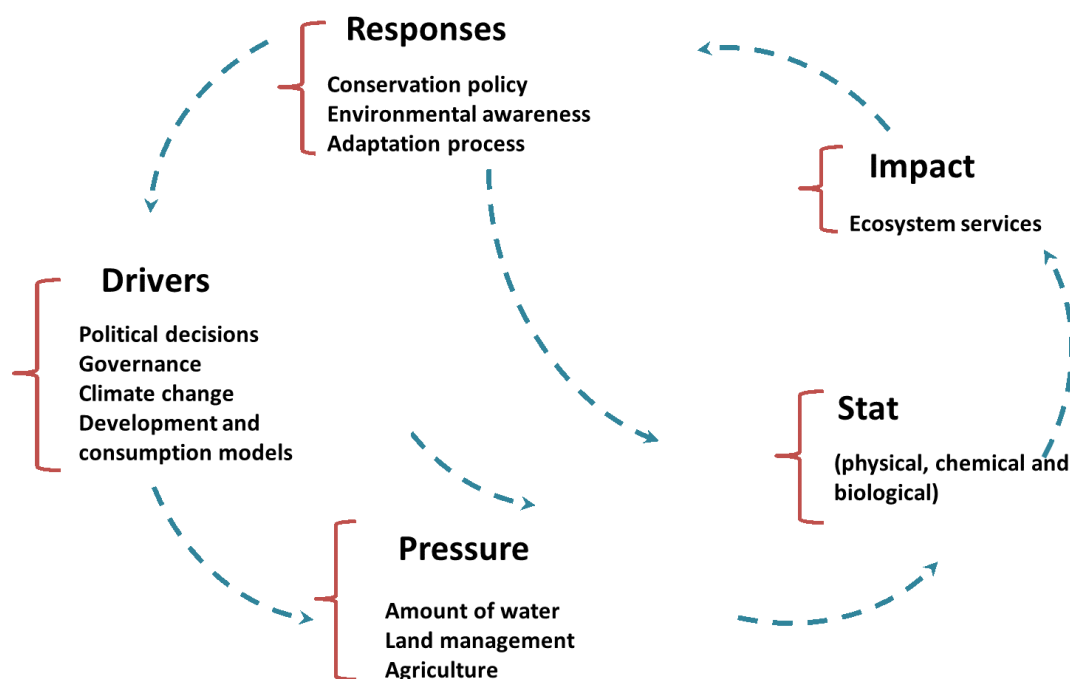


Figure 2. DPSIR model for the wetland monitoring framework (Eurostat, 1997)

3. Results and discussion

3.1. DPSIR framework for the SAWC observatory

After a thorough review of existing literature, data and field surveys, a preliminary set of DPSIR indicators for the sustainable management and conservation of the wetlands of Aures complex has been compiled (Table 1).

Table 1. DPSIR framework components and developed indicators for the SAWC observatory

DPSIR framework	DPSIR Component	Indicators
Driver (D)	Climate variation/change	- Long-term changes in temperature and precipitation patterns
	Socio-economic characteristics	- Human demographics (numbers of inhabitants, density, temporal and spatial changes) - Trends of income and livelihood of the locals - Expansion of infrastructure and services (through LULC: see below under "Pressure")
Pressure (P)	Drought and pollution	- Amount of water used by local residents, diverted or stored upstream - Contamination of the sebkhat by solid waste and pesticides
	Agricultural land & urban/infrastructure extension	- Land use and land cover change (LULC) at the SAWC level, particularly in the 10 Ramsar sites (1970-2022) - Surface area of natural habitats loss and fragmentation (1970-2022) - Surface area of natural wetland loss and conversion to other land-cover (Agriculture, urban; artificial Wetlands...) (1970-2022)

DPSIR framework	DPSIR Component	Indicators
State (S)	Sector management	<ul style="list-style-type: none"> - Baseline data before and after the SAWC observatory implementation to compare changes - Changes in household incomes, agricultural revenues, and overall economic output in the SAWC area - Agricultural intensification, new technologies and impact on productivity and cost-efficiency in the SAWC area - Number of leisure and mass tourism infrastructures around the wetlands
	Water quantity and quality	<ul style="list-style-type: none"> - Quantity and flows of water - Physico-chemical and biological parameters of water - Balance between wetland inflow and outflow, groundwater interactions, and water levels
	Soil quality	<ul style="list-style-type: none"> - Soil salinity - Nutrient levels (nitrates, phosphorus, potassium)
	State and trend of biodiversity	<ul style="list-style-type: none"> - Specific richness indices (flora and fauna) in the 10 Ramsar sites - Abundance of water birds, both wintering and breeding species - Distribution and number of endemic species (flora and fauna) - Expansion of invasive species (aquatic birds and fishes) - Number and surface areas of Key Biodiversity Areas (KBA)
Impact (I)	Ecosystem services	<ul style="list-style-type: none"> - Ecosystem services provided by wetlands (water uses, livestock grazing, plants and egg collection, recreation and salt mining) - Impact of human activities on the SAWC wetlands
	Biodiversity and ecosystems resilience	<ul style="list-style-type: none"> - Number of water reservoirs constructed upstream of wetlands - Movement degree of aquatic bird species and the flow of resources - Impact of hill reservoirs built in Algeria on the functioning of wetlands located in Tunisia (shared Madjerda watershed)
	Sustainability	<ul style="list-style-type: none"> - Number of people and stakeholders committed to wetland conservation (SAWC network) - Quality and number of non-state participants in meetings/conservation activities of wetland areas (clean-up events, monitoring, or restoration projects....) - Equitable access to wetland resources among community members - Level of education, awareness and perception of ecosystem services among the local population
	National nature conservation strategy	<ul style="list-style-type: none"> - Assess future abiotic and biotic conditions (data collection and analysis, ecological modeling, scenario planning) - Number of community members trained in wetland monitoring, conservation techniques and sustainable resource use - Number of Ramsar sites designated
Governance		<ul style="list-style-type: none"> - Legislation on wetlands and environment (policies and conventions) - Number of cases of offenses and damage suffered by wetlands (water diversion, land use, pollution, illegal killing, ...) - Number of political conventions held by Algerian and Tunisian governments to achieve an agreement on the use of the Madjerda watershed

The conceptual framework for the SAWC observatory has been designed to facilitate an understanding of the cause-and-effect relationships between driving forces and socioeconomic consequences. To this end, we detail below each of the elements, which made it possible to construct our DPSIR logical framework:

Drivers

Climate change and socio-economic development drivers, including human population growth and increased demand for goods and services, urbanization and industrialization patterns were identified as being important drivers of change within the SAWC region. In fact, the population grew by 230% between 1970 and 2000 and by 150% between 2000 and 2022, in line with the demographics of the country as a whole (GRIDA, 2023). Hence, even though the SAWC region is highly susceptible to climate changes, which could endanger the future provision of ecosystem services, forecasts regarding the patterns of ecosystem services supply exhibit considerable levels of unpredictability (Cramer et al., 2018). Changes in precipitation patterns are often associated with climate change and can involve an increase or decrease in the overall amount of precipitation received in the SAWC region, leading to wetter or drier conditions. Furthermore, the region have suffered from changes in temperature patterns in the past 20 years, influencing various ecological processes, such as plant growth, water temperature, and the behavior of aquatic and terrestrial species. This represents one of the major challenges, key issues, and important questions in conservation research (Taylor et al., 2021; Touitou and Abul Quasem, 2023).

Socio-economic activities and strategies were employed by individuals and communities living within or near the SAWC wetlands to support their livelihoods. These activities often revolve around the unique opportunities and challenges presented by wetland environments. Many communities in the SAWC region rely directly on wetland resources for their incomes. This includes activities like fishing, hunting, collecting plants and traditional agriculture practices that depend on wetland water for irrigation (Bougoffa et al., 2023).

Algeria has shown a commitment to wetland conservation through its participation in international agreements and the development of national policies and strategies including Ramsar convention (DGF, 2016). The effectiveness of these policies and its enforcement in the field depends on their combination and on their implementation and enforcement at the local and national levels.

Pressures

The drought conditions suffered by the SAWC region in the past years, have led to the practice of diverting and storing water upstream during periods of reduced rainfall and water scarcity. We point out deviations and retentions of water carried by the watercourses supplying the sites, following the numerous hill reservoirs and basins erected upstream. Farmers also pump water (domestic use, irrigation of crops and watering of livestock) which leads to the partial and sometimes total drying out of the wetlands in the region. Droughts are expected to have additional effects on the Mediterranean Basin, including high plant mortality, diminished surface water quality, decreased productivity within ecosystems, and an increased likelihood of pest and disease outbreaks (Vayreda et al. 2012; MWO, 2018). Monitoring water use and upstream activities is essential to knowing the balance between human needs and wetland conservation.

Discharge of waste on SAWC sites (solid waste) and the perception of the site as an unsanitary environment by local residents are the major causes of water pollutions. The degree of water pollution is aggravated by the aridity of the region, particularly with the drop in water levels (Benzina et al., 2021). The extension of agricultural land around and sometimes even inside the sites (during periods of total drought) and the use of chemical

inputs cause water pollution. The growth of human populations near wetlands is a significant factor contributing to wetland deterioration (Geijzendorffer et al., 2019). This can occur through direct means, such as the unsustainable utilization of wetland ecosystem services (e.g., excessive water extraction, agriculture, and overgrazing), or indirectly, including instances of water contamination and the conversion of natural wetland habitats into agricultural fields or constructed wetlands.

Several studies carried out in the SAWC region on water quality have shown that concentrations of mineral elements (nitrates, ammonium, phosphates, calcium and magnesium) often exceed the required standards, indicating the presence of chemical and microbiological substances (contamination fecal with high concentrations of fecal coliforms, fecal streptococci) reflecting the pollution suffered by water bodies (Guergueb, 2012; Charfi, 2017). Pollution of water, air and groundwater in and around urban and industrial centers by various industrial and household discharges into wetlands. This often leads to imperative modifications of these ecosystems and their functioning (Benzizerara, 2014).

The construction of many traffic routes all over the SAWC area has been another source of pollution and perturbation. Whereas, the extremely busy roads leads to ecosystems fragmentation and increase the already high mortality rates of vulnerable and endangered species through car collisions. These traffics are also a major source of noise that has harmful impacts on biodiversity (McClure, 2021).

Governance indicators help assess the robustness of governance structures and practices in wetland management. Effective wetlands sector management in the SAWC region requires a multidisciplinary approach that considers ecological, social, economic, and cultural factors. It aims to balance the conservation of wetland ecosystems with the sustainable use of their resources to meet the needs of both present and future generations. In particular, the General direction of forests has developed the National Wetlands Strategy 2015-2030 in Algeria. This strategy includes a plan management and collaborative approach involving governments, communities, industries, and environmental organizations (DGF, 2016). The adoption of international environmental agreements positively influences the trends in water bird populations and aids in the adaptation of their communities to climate warming (Gaget et al., 2018). Likewise, wetlands restoration projects demonstrated an expansion of natural wetland habitats (Santamaría et al., 2006).

By its large area (16,020 km²) and wealth in natural and artificial wetlands and land diversity, the SAWC attract visitors, tourists and nature enthusiasts in recent years. Income generation in such areas can involve running ecotourism businesses, offering guided tours, operating lodging facilities, and selling handicrafts or local products to visitors. Ecotourism is therefore capable of reconciling economic development, environmental protection and the well-being of these communities (Leroux, 2010).

Drivers and pressures frequently interact in a synergistic manner (Doblas-Miranda et al., 2016) rather than following a linear path, thereby elevating the intricacy involved in assessing their impact on ecosystems.

State

The SAWC wetlands often experience seasonal fluctuations in water depth due to factors like rainfall, snowmelt, and evaporation. Then, assessing water quality of the SAWC wetlands, comprehensive water quality monitoring programs and studies would be necessary. These programs typically measure parameters such as nutrient levels, chemical contaminants, turbidity, pH, dissolved oxygen, and the presence of specific pollutants. Local and national authorities, as well as environmental organizations, often conduct such monitoring to ensure the protection and sustainable management of wetlands in Algeria. The water levels also influences the suitability of wetland habitats for various species (Cheng et al., 2022). For example, wetland use by waterbirds is

highly dependent on water depth, and depth requirements generally vary among species (Bolduc and Afton, 2008).

In addition, soils of the SAWC region are subject to severe erosion. The predominance of bare soils combined with heavy rainfall, generally received in short periods, rapidly erodes the soils, which eventually form badlands (gullies). The combination of natural and anthropogenic factors, along with precipitation fluctuations, leads to the land being occupied by natural formations where species adapted to the environmental conditions and its mode of exploitation predominate (Si Tayeb and Benabdeli, 2008). Soil salinity has actually increased in the studied area due to the lack of water, which pressures some farmers to reuse drainage water (Aliat et al., 2016). For example, Sebkhet Ezzmoul occasionally experiences periods of higher salinity under natural conditions, due to high evaporation and variability of inputs in this semi-arid region. Furthermore, harvesting salt in the area for several years can cause pollution of the site by secondary elements mainly magnesium salt (Demnati et al., 2020).

Observing the variation of water levels, helps understand wetland dynamics and their role in the landscape. Monitoring species abundance in wetlands often involves field surveys, data collection, and analysis. The use of various sampling methods to count and record the presence and abundance of plants, animals, and microorganisms in wetland habitats are essential. In addition to monitoring native species, some of which are probably endemic, there are a few exotic species introduced, in particular for fish farming purposes. In the long term, these introduced species can prove invasive, as has been described in several parts of the world, including Algeria (Grimes et al., 2018).

Impact

The SAWC wetlands are very important for the multiple uses of the local population, representing the main ecosystem services and exploited by a population experiencing galloping demographics. Data collected in the SAWC area allowed to identify several main ecosystem services: water pumping, livestock watering and crop irrigation, grazing, agriculture, egg collection, plant collection, water treatment/flood control and salt mining. The importance of indirect ecosystem services provided by the wetlands (water purification, flood control) are unknown by the majority of the population (Bougoffa et al., 2023). Providing valuable information on these pressures is a key for making informed decisions that balance the needs of society with the preservation in and around the SAWC wetlands.

The resilience of the SAWC area is subject of a range of stressors, requiring determined actions and habitat integrity indicators to preserve its biodiversity. As climate change and new environmental risks become more pressing in the area, research efforts must be directed towards filling the gaps in conservation strategies (Gao et al., 2023).

Biodiversity can create positive or negative feedback loops within wetland ecosystems (Meli et al., 2014). For this purpose, it is important to conduct regular biodiversity assessments and monitoring in wetlands to track the presence and abundance of indicator species. The SAWC region is known by housing a variety of plant and animal species, some of which can act as indicators of wetland conditions such as the Flamingo *Phoenicopterus ruber roseus*.

Besides, the importance of cross-border water resource management in fostering sustainable development and shaping the socio-economic trajectory of the SAWC region is a case in point, given that the Medjerda River (watershed running through the complex) is shared by Algeria and Tunisia. In this case, bilateral cooperation between the two countries needs to be strengthened, and effective cross-border cooperation requires a strong and unequivocal political commitment (Rajosoa et al., 2021).

Because of insufficient awareness and education, SAWC wetlands are experiencing degradation caused by both human activities and their inadequate utilization or excessive exploitation when it comes to utilizing their natural resources. Consequently, the Algerian Ministry of Environment has established Environmental Centers, primarily

tasked with educating, informing, and raising awareness about environmental protection and conservation as a whole (Alaoua et al., 2019). As part of the AFD-FFEM project, several training workshops, which targeted small NGOs aiming to enhance the knowledge of these associations about wetlands, were carried out across the country, including the SAWC region, to strengthen their capacities for better management and conservation of these ecosystems, which are rich in ecosystem services but remain very fragile. Musasa et al. (2023) showed that stakeholders play a pivotal and essential role in wetland use and conservation if sustainability is to be achieved. Our study therefore recommends that the government invest in programs that involve various stakeholders in policy development and implementation. However, as biodiversity and ecosystem function are not monitored in the majority of the SAWC sites, ecological change is poorly reported. Remote sensing tools, training, and capacity building of citizen scientists and expert missions at specific intervals could provide complementary solutions to a more permanent infrastructure (Navarro et al., 2017).

Response

Integrative approaches to assess future conditions of a wetland involve combining various methods and tools to understand and predict the changes that may occur in wetland ecosystems. These approaches typically encompass data collection and analysis (baseline data, historical data, remote sensing); ecological modeling (hydrological, ecosystem, models, and land use models) and; scenario planning of the wetlands (potential future conditions, wetlands impact assessment, identify strategies for adaptive management, stakeholder engagement). By integrating these approaches, researchers and wetland managers can gain a more holistic understanding of how wetlands may evolve in the face of environmental and human-driven changes (Maltby, 2022).

From 1983 to date, Algeria has classified 50 Ramsar wetlands. The first two Ramsar sites were classified in 1983. This number reached 42 sites in 2004. Since then, this important development has stagnated, because only 8 sites were designated between 2004 and 2011 and no site has been included on the Ramsar list since 2011. In 2016, an action plan of the national wetlands strategy was implemented, which emphasizes the establishment of national observatories to facilitate monitoring and management of wetlands (Benzina et al., 2022). Unfortunately, this seemed a difficult challenge, given the vastness of the national territory and the lack of resources and of management experience. Our proposal in this context is to start by monitoring the application and efficiency of the jurisdiction dedicated to water and wetlands and guarantee these regulations are up to date and comprehensive. Ensure transparency in data collection, management and reporting. This includes inspections, compliance checks, and penalties for violations, inspect development projects near wetlands to ensure proper mitigation measures are in place. A collaboration with neighboring jurisdictions and agencies is also critical when dealing with transboundary water resource as is the case of the Madjerda watershed (Tayia, 2019). Implementing these steps requires a dedicated effort from government agencies, communities, NGOs, and other stakeholders (MAW, 2022).

Throughout the present study, we can say that the SAWC is an interconnected patch of suitable habitat, including wetlands, forests, grasslands, and water bodies, which represent a veritable corridor, in particular by taking into consideration the extension of the SAWC complex into Tunisian lands.

3.2. Proposal for set up and develop an observatory of Sebhat of Aures wetland complex

The creation of the SAWC observatory begins with the implementation of the 16 conventional steps recommended in the framework of observatories created in the Mediterranean basin (MAW, 2022). The proposed steps are described, one by one, according to the DPSIR logical framework (Table 2). The steps involved in setting up the SAWC will be carried out in a participatory manner with institutional and technical

partners, as well as users (the local population), to ensure compliance with the observatory's founding principles. The creation of the SAWC observatory will make it possible to value and manage wetlands and their biodiversity by reconciling the conservation of wetlands with the search for socio-economic development. It will also contribute to improving the perception, valorization and integrated management of wetland ecosystems, and to perfecting methods, regulations and policies for managing natural resources with a vision of sustainability.

Table 2. The 16 steps in the implementation of the Sebkhat des Aures wetlands observatory

N°	Steps	Sebkhat des Aures wetlands observatory SAWC
1	Give mandate/authority to an organization (or consortium)	General Direction of Forest (DGF) (national point) Direction of forests Wilaya of Batna (focal point) NGO partner: Algerian National Association of Ornithology "ANAO"
2	Defining the scope and themes of the observatory	Thematic scope: Environmental observatory Geographic scope: Sebkhat des Aures complex Administrative area: Wilayas (departments/) of Batna, Khenchela, Oum El Bouaghi, Sétif, Tebessa, Souk Ahras and Mila
3	Define objectives and targets	Objectives: - Analyze wetland status and ecosystem services - Promote adaptive and sustainable management (reconciling conservation and socio-economics) - Define the indicators to be used - Sound the alarm on the basis of this knowledge - Rerate a database of all existing data Targets: - General public - Local users - National and local decision-makers - International community - Scientists - Civil society organizations
4	Defining the observatory's principles	Principles of efficiency: - Take account of possibilities in relation to the reality on the ground Operating principles: - Sharing experience and knowledge with partners - Communication
5	Logical framework for the observatory (DPSIR)	- Driving forces: climate change, socio-economic development research, governance - Pressures: pollution, agricultural expansion, sectoral management - State: water quality, soil and climate - Impacts: ecosystem services, resilience, sustainability - Responses: national nature conservation strategy
6	Define specific themes to achieve objectives	- Wetland monitoring: water, soil, climate, functional biodiversity, habitats - Ecological services and socio-economic demand, pressures on wetlands and drivers - Indicators - Responses to wetland degradation and loss
7	Efforts monitoring	- Literature to acquire accumulated knowledge - List all monitoring and completed projects - Communicate with the locals
8	Governance and partnership structure	- Governance (coordinating units): central unit (DGF, ANAO, Wilaya of Batna forest department) and the 7 departmental units (local: forest

N°	Steps	Sebkhat of Aures wetlands observatory SAWC
		<ul style="list-style-type: none"> conservations, environmental departments, universities and local NGOs) - Financial partner: General Direction of Forest, ministry of the environment, national and international donors
9	Defining a communication strategy	<ul style="list-style-type: none"> - Targets: scientists, local population and local authorities - Regular meetings with stakeholders - Conferences for the scientific community - Electronic/paper journals - Local/national radio stations - Website: set up a specific web page with a forum for discussion and exchange - Social networks (facebook, twitter, instagram, etc.)
10	Define indicators	<ul style="list-style-type: none"> - Changes in climate variation, particularly temperature and precipitation patterns - Quality of water, considering physico-chemical and biological parameters - Balance between wetland inflow and outflow, groundwater interactions, and water levels - Abundance of waterbirds, both wintering and breeding species - Land use and land cover change (LULC) at the SAWC level, particularly in the 10 Ramsar sites - Commitment of stakeholder engagement to wetland conservation - Application and efficiency of the jurisdiction dedicated to water and wetlands
11	Databases, methodologies for monitoring environmental status and indicators	<ul style="list-style-type: none"> - Seasonal and regular monitoring - <i>In situ</i> and laboratory sampling and analysis - Waterbird census - Cartography and GIS geographic information system - Socio-economic survey
12	Data storage planning	<ul style="list-style-type: none"> - Modern, interactive and operational database - Excel, Access and ArcGis software
13	Data collection and storage	<ul style="list-style-type: none"> - Seasonal and regular monitoring data - Bibliography, personal contacts - Reports from university interns and CSOs - General direction of forests
14	Data analysis	<ul style="list-style-type: none"> - Tools already known according to the data - Implementing a good protocol and the questions to be evaluated
15	Communicating and disseminating results	<ul style="list-style-type: none"> - Scientific publications, conferences, website, Facebook pages, reports, radio broadcasts, headlines in the print media (local/national) - International communication and information dissemination (MWO, MedWet, World Wetland Network "WWN", etc.)
16	Evaluating the observatory	<ul style="list-style-type: none"> - Internal and external audit - Observatory participation in the Mediterranean Wetlands Alliance

4. Conclusions

The establishment of the SAWC observatory with DPSIR approach, with its defined structure, organization, objectives, principles and operation, constitute an opportunity to better value and manage wetlands of the area and their biodiversity. The latter and the ecosystem services will be perceived not only as natural resources to be used, but also as a national and universal heritage to be preserved and bequeathed to future generations. In particular, this will help to improve the perception, enhancement and integrated management of wetland ecosystems, and to perfect natural resource management methods, regulations and management policy. In addition, it will provide

an exceptional model to be replicated across the country's 16 complexes taking into account certain regional specificities and, on a larger scale, the creation of a national observatory.

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