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ORIGINAL ARTICLE

A literature review of Algerian salt lakes: values, threats and implications

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Abstract Chotts are salt lakes located in the arid regions of Northern Africa. These unique wetlands are recognized for their role in the migration and breeding of waterbirds and economic values generated from mineral extraction, agriculture and tourist activities. Despite their importance for flora and fauna biodiversity, they continue to face important threats due to human activities. This article consolidates a literature review of Algerian chotts from global to local importance. An in-depth view demonstrates the changes in land use of two large chotts in the south-eastern region of Algeria: Chotts Merouane and Melghir. Land use images highlight a net expansion of agricultural lands, a decrease in grazing area around the lakes and a decrease of salt lake surface area. The local focus highlights the threats and changes of Algerian and Northern African chotts and proposes some perspectives for the future.

Keywords Conservation · Chott · Environmental threats · Land use · Salt lakes · Sebkhas

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Introduction

Salt lakes are interior aquatic ecosystems (Donaire 2000) that can be found in all continental areas of Asia, South America, North America, Australia, Europe and Africa. They are isolated from the sea, or were once connected to the sea, but have dried out before being re-flooded by non-marine sources (Williams 2002). Many salt lakes are endorheic drainage basins of tectonic origin, yet some may have periodic outflows during moments of high water levels provoked by intermittent rainfall (Britton and Crivelli 1993). Rivers and deep aquifers serve as natural discharges for salt lakes (Bryant and Rainey 2002). These unique ecosystems are principally limited to arid (average yearly precipitation between 25 and 200 mm) and semiarid regions (yearly precipitation between 200 and 500 mm) (Williams 1998), yet they occupy approximately 30% of the land surface of the world (Gratzfeld 2004).

Salt lakes (chotts) are abundant and limited to the dry region of the world, where evaporation is high and precipitation rare; they are found inland and do not have existing connection with the marine environment. Salt lakes can be either permanent or temporary water bodies with salinities up to 3 g/l (Williams 2001). Similar ions are encountered in salt lakes and in the seas (Kbir-Ariguib et al. 2001); salt concentrations are 10–20 times more important in chotts, ranging from 250 to 330 g/l in Tunisian salt lakes. The water salinity of Chott Merouane was estimated between 230 and 360 g/l (Amarouayache et al. 2009).

Salt lakes are classified as wetlands (Dugan 1990; Britton and Crivelli 1993; Tiner 2003), and as such, they fall under the protection of the Ramsar International Treaty for Wetlands since 1971 (Ramsar 2006). This treaty has played an important role in raising public awareness of the

ecological value of wetlands around the world. Today over 2200 wetlands have been named Ramsar sites, giving them special international wetland protection status (Ramsar 2016). In a study by Jellison et al. (2008), they found that only 10% of the internationally protected wetlands are salt lakes. Different local terms have been given to characterize saline wetlands (Rosen 1994). In Northern Africa and more specifically in Algeria, salt lakes are considered chotts and sebkhas. The terms chotts and sebkhas refer to closed depressions, which are the equivalent of salt lakes (Stone 1967; Coque et al. 1972; Aubert 1976). In 2002, Dubost (2002) described chotts as a salty area surrounding the sebkha (wet areas at the bottom of the depressions). Sebkhas are considered to be closed depressions which are periodically flooded and accumulate salts.

The objective of this article is to highlight the importance and threats to Algerian salt lakes (locally known as chotts, hence used thereafter in this article) through a review of literature from local reports and international scientific literature. We first describe the values and ecological services of chotts in Northern Africa in general; we then focus on the global situation, values and threats of Algerian chotts. An in-depth review of two of the largest Algerian chotts (Chotts Merouane and Melghir) is used to highlight the local situation, values and threats. The purpose of this literature review is to increase the understanding of the values and threats of Algerian chotts specifically and chotts in general while acknowledging a lack of existing scientific information concerning Algerian chotts. This article should help raise interest in North African chotts generally and more specifically Algeria chotts to encourage future in-depth studies and knowledge of these specific wetland ecosystems for improved conservation.

Ecosystem services of North African chotts

The largest known wetlands (>100,000 ha) in the Mediterranean basin are mainly deltas and chotts of North Africa (Perennou et al. 2012). Chotts form a belt in Northern Africa, passing through the arid zones of Tunisia and Algeria (Bryant and Rainey 2002). These basins are discharges for the Bas Saharan Basin, a large aquifer system that underlies most of the Algerian and Tunisian Sahara and extends to Morocco and Libya (Faysse et al. 2011). The surface area and the importance of the ground water in this aquifer system indicate that the management of chotts could potentially have a widespread impact passing beyond the areas directly surrounding the salt lakes. From a biodiversity point of view, the chott belt creates connectivity providing critical stopovers for wintering and migrating waterbirds (Samraoui and Samraoui 2008; Boucheker et al. 2011).

Chotts have considerable economic and noneconomic values at the local and national level (Schuyt 2005; Demnati et al. 2012; Mahafzah 2015) and have attracted interest from many scientific disciplines (Mahowald et al. 2003; Jellison 2005). They are especially recognized for their role in the migration and breeding of waterbirds (Samraoui et al. 2006b, 2011). Mineral extraction contributes to the economic value of chotts; sodium chloride (for human and animal consumption), sodium carbonate (for detergent), magnesium and potassium are the most common minerals mined (Taib 2012; Hamed et al. 2014a). Chotts host a full array of nitrogen-fixing cyanobacteria which act as primary producers in these hyposaline ecosystems (Thajuddin et al. 2002). The cyanobacterium *Spirulina* have been used as a food supplement for fish and humans (Lu and Takeuchi 2004), and as a supplement in the pharmaceutical industry (Belay 2002). Chotts are also home to a large spectrum of large branchiopods (Samraoui et al. 2006a), which play a key role in the functioning of food chains in chotts (Roberts 2013). There is a burgeoning industry built around the crustacean *Artemia salina* (L.) which is widely used as feed in aquaculture (Ozusaglam et al. 2013). These hydro-systems also support important socioeconomic activities such as livestock grazing, hunting, agriculture (Demnati et al. 2012) and tourism.

Algerian Chotts

Values and services of Algerian Chotts

Algeria contains a large number of chotts, with the majority extending across the northern and eastern regions of the country (Mahowald et al. 2003; Samraoui et al. 2006b) (Fig. 1). With the exception of Chott Djerid in Tunisia, Algeria houses the largest chotts in Northern Africa. Size and depth are highly variable, and they range in size from 76 to 850,000 ha (DGF 2004). The depth can range from 20 cm to 4 m. It is important to note that there are high seasonal and annual fluctuations of both depth and surface area (Demnati 2013), making long-term monitoring extremely important. The Algerian chotts are home to threatened, rare and even endangered plant and animal species. In addition, they are breeding, resting and wintering areas for migratory birds. These ecosystems are highly vulnerable due to sparse and sporadic precipitation. The variability and lack of attention given to Algerian chotts (Blanchard and Richard 1890; Samraoui et al. 2006b; Samraoui and Samraoui 2008) limits the availability of detailed and precise information for individual chotts. This lack of information may lead to inappropriate management decisions including overgrazing and the validation of new development projects (Khaznadar et al. 2009).

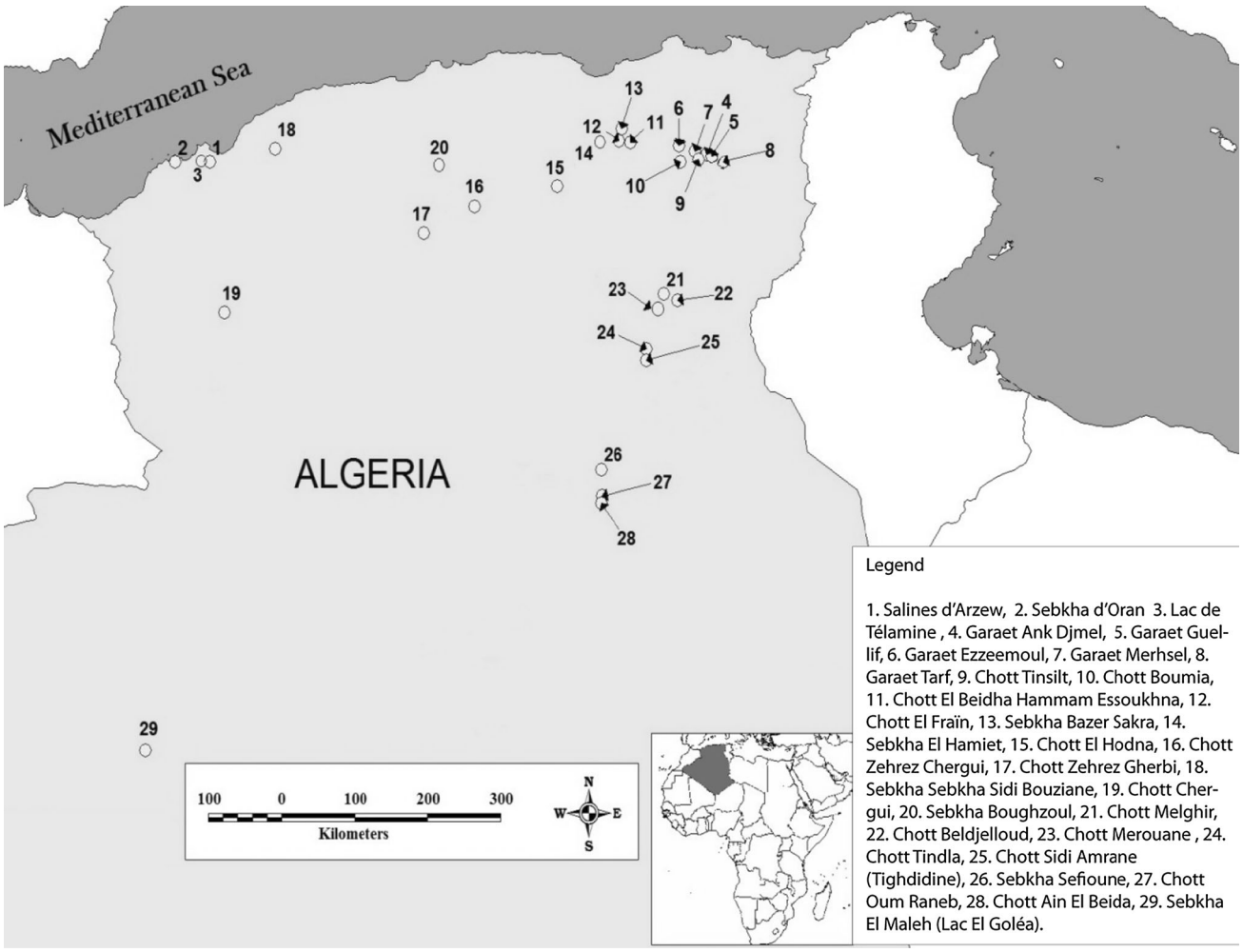


Fig. 1 Geographical location of salts lakes (chotts, sebkhas) of Algeria

Despite extreme temperatures and high salinity concentrations, chotts represent a favorable environment for the development of arthropods. Algerian chotts contain the richest and most diverse crustacean population in Northern Africa with 121 identified species (Mouelhi et al. 2000; Samraoui 2002; Samraoui et al. 2006a; Ghomari et al. 2012). The salinity of the chotts is an important factor controlling crustacean species dynamics (Williams 1998), and Algerian chotts are hosts to a range of species of large branchiopods (Table 1) adapted to various salinity levels (Amarouayache et al. 2009). These biotopes are host to a large number of prokaryotic flora and bacteria phylotypes (Boutaiba et al. 2011). The significant crustacean, prokaryotic and bacteria populations make chotts an important wintering ground for large numbers of flamingos (Johnson and Cézilly 2007) and other waterbird species (Boulekhssaïm et al. 2013). Ornithological inventories demonstrate the diversity and quantity of waterbirds frequenting chotts for breeding or wintering (Table 2) (Samraoui and Samraoui 2008; Samraoui et al. 2011). Chotts are not only important habitats for waterbird populations in Algeria, but also play an essential role for bird population dynamics in the Mediterranean basin (Samraoui et al. 2006b; Boucheker et al. 2011) and are important stopovers for migrating birds from Africa and Europe (Samraoui et al. 2011).

Ecological status of Algerian chotts

Algeria signed the Ramsar Convention and the conservation and management for wetlands officially began in 1997 under the *Direction Générale des Forêts*. The classification of Ramsar sites began in 2001, and today there are 50 official Ramsar sites covering a surface area of 2,991,013 ha. Chotts account for less than half of the Ramsar sites in Algeria (19 out of the 50 sites), yet they make up almost 70% of the Algerian Ramsar protected areas (2,055,522 ha) (Demnati 2013). There is a mix of local terminology for naming salt lakes including chott, sebkha, garaet, salines and lakes (Fig. 1). The site names

Table 1 Main plant and animal species found in the Algerian chotts (Dubuis and Simonneau 1957; Ozenda 1958; Bouabdallah 1990; Samraoui 2002; Samraoui et al. 2006a; DGF 2004; Larafa 2004; De Smet et al. 2007; Berzins and Belbachir 2007; Samraoui and Samraoui 2008; Abaigar et al. 2009; Khaznadar et al. 2009)

Fauna	
Species	Class
Psammomys obesus (Cretzschmar 1828)	Mammalia
Fennecus zerda (Zimmermann 1780)	
Gerbillus sp.	
Jaculus jaculus (Linnaeus 1758)	
Paraechinus aethiopicus (Ehrenberg 1833)	
Pipisterellus sp.	
Meriones sp.	
Sus scrofa (Linnaeus 1758)	
Caracal caracal (Schreber 1776)	
(**) *Canis aureus* (Linnaeus 1758)	
Lepus capensis (Linnaeus 1758)	
(**) *Hyaena hyaena* (Linnaeus 1758)	
Vulpes rueppellii (Schinz 1825)	
(**) *Vulpes vulpes* (Say 1823)	
Ctenodactylus vali (Thomas 1902)	
Hystrix cristata (Linnaeus 1758)	
Felis silvestris libyca (Forster 1770)	
Acinonyx jubatus (Schreber 1775)	
Panthera pardus (Linnaeus 1758)	
(**) *Paraechinus aethiopicus* (Ehrenberg 1832)	
Gazella dorcas (Linnaeus 1758)	
(**) *G. cuvieri* (Ogilby 1841)	
G. leptoceros (F. Cuvier 1842)	
Ammotragus lervia (Pallas 1777)	
Actitis hypoleucos (Linnaeus 1758)	Aves
Anas acuta (Linnaeus 1758)	
Anas clypeata (Linnaeus 1758)	
Anas angustirostris (Reichenbach 1853)	
Anas crecca (Linnaeus 1758)	
Anas ferina (Linnaeus 1758)	
Anas penelope (Linnaeus 1758)	
Anas platyrhynchos (Linnaeus 1758)	
Anas querquedula (Linnaeus 1758)	
Anas rufina (Pallas 1773)	
Anas strepera (Linnaeus 1758)	
(**) *Anser anser* (Linnaeus 1758)	
Ardea alba (Linnaeus 1758)	
(**) *Ardea cinerea* (Linnaeus 1758)	
Ardea ibis (Linnaeus 1758)	
Ardeola ralloides (Scopoli 1769)	
Aythya ferina (Linnaeus 1758)	
Aythya nyroca (Güldenstädt 1770)	
Aythya fuligula (Linnaeus 1758)	
Burhinus oedicnemus (Linnaeus 1758)	
Calidris alpine (Linnaeus 1758)	
Calidris ferruginea (Pontoppidan 1763)	
Calidris minuta (Leisler 1812)	
Charadrius alexandrinus (Linnaeus 1758)	
Charadrius dubius (Scopoli 1786)	
Charadrius hiaticula (Linnaeus 1758)	
Charadrius morinellus (Linnaeus 1758)	
Chlidonias hybridus (Pallas 1811)	
Chlidonias niger (Linnaeus 1758)	
(**) *Ciconia ciconia (*Linnaeus 1758)	
(**) *Circus aeruginosus* (Pallas 1811)	
(†) *Chlamydotis undulata* (Jacquin 1784)	
Cursorius cursor (Latham 1787)	
(**) *Egretta garzetta* (Linnaeus 1766)	
(**) *Falco Tinnuculus* (Linnaeus 1758)	
Fulica atra (*Linnaeus 1758)*	
Fulica cristata (Gmelin 1789)	
Gallinago gallinago (Linnaeus 1758)	
Gallinula chloropus (Linnaeus 1758)	
Gelochelidon nilotica (Gmelin 1789)	
Glareola pratincola (Linnaeus 1766)	
(**) *Grus grus* (Linnaeus 1758)	
(**) *Himantopus himantopus* (Linnaeus 1758)	
Ixobrychus minutus (Linnaeus 1766)	
Larus genei (Brème 1839)	
Larus michahellis (Naumann 1840)	
Larus ridibundus(Linnaeus 1758)	
Limosa limosa (Linnaeus 1758)	
(!!) *Larus audouinii* (Payraudeau 1826)	
(†) *Marmaronetta angustirostris* (Ménétries 1832)	
(‡) *Neophron percnopterus* (Linnaeus 1758) (EN)	
(†) *Numenius tenuirostris* (Vieillot 1817) (VU)	
Nycticorax nycticorax (Linnaeus 1758)	
(‡) *Oxyura leucocephala* (Scopoli 1769) (EN)	
Pandion haliaetus (Linnaeus 1758)	
Phalacrocorax carbo (Linnaeus 1758)	
Philomachus pugnax (Linnaeus 1758)	
(**) *Phoenicopterus roseus* (Pallas 1811)	
(**) *Platalea leucorodia* Linnaeus 1758)	
Plegadis falcinellus (Linnaeus 1766)	
Plegadis falcinellus (Linnaeus 1766)	
Pluvialis apricaria (Linnaeus 1758)	
Pluvialis squatarola (Linnaeus 1758)	
Podiceps cristatus (Linnaeus 1758)	
Podiceps nigricollis (Brehm 1831)	
Rallus aquaticus (Linnaeus 1758)	
(**) *Recurvirostra avosetta* (Linnaeus 1758)	

Table 1 continued

Fauna	
Species	Class
Sterna nilotica (*Gmelin 1789)*	
Tachybaptus ruficollis (Pallas 1764)	
(**) *Tadorna ferruginea* (Pallas 1764)	
(**) *Tadorna tadorna* (Linnaeus, 1758)	
Tringa erythropus (Pallas 1764)	
Tringa nebularia (Gunnerus 1767)	
Tringa ochropus(Linnaeus 1758)	
Tringa stagnalis (Bechstein 1803)	
Tringa tetanus (Linnaeus 1758)	
(**) *Upupa epops* (Linnaeus 1758)	
Vanellus vanellus (Linnaeus 1758)	
Trapelus mutabilis (Merrem 1820)	Reptilia
Cerastes cerastes (Linnaeus 1758)	
(**) *Chameleo vulgaris* (Laurenti 1768)	
Stenodactylus petrii (Anderson 1896)	
(**) *Uromastix acanthinurus* (Bell 1825)	
(**) *Varanus griseus* (Daudin 1803)	
(**) *Testudo graeca* (Linnaeus 1758)	
Scincus scincus (Linnaeus 1758)	
Acanthodactylus longipes (Boulenger 1918)	
Acanthodactylus boskianus (Daudin 1802)	
Artemia sp.	Branchiopoda
Artemia tunisiana (Bowen and Sterling 1978)	
Branchinella spinosa (H. Milne-Edwards 1840)	
Branchinectella media (Schmankewitsch 1873)	
Streptocephalus torvicornis bucheti (Daday 1910)	
Triops cancriformis simplex (Ghigi 1921)	
Cyzicus tetracerus (Krynicki 1830)	
Flora	
Species	Family
Salicornia fruticosa (L.)	Chenopodiaceae
Suaeda fruticosa (Forsskal)	
Suaeda mollis (Delile)	
Atriplex halimus (L.)	
Salsola vermiculata (L.)	
Salsola foetida (Delile)	
Salsola sibiri (Presl)	
Salsola. Fructicosa (L.)	
Truganum nudatum (Delile)	
Halocnemum strobilaceum (Pallas) Bieb.	
Arthrocnemum macrostachyum (L.)	
Limoniastrum guyonianum (Boissier)	Plumbaginaceae
Zygophyllum album (L.)	Zygophyllaceae
Peganum harmala (L.)	
Tamarix africana (L.)	Tamaricaceae
Tamarix gallica (L.)	

Table 1 continued

Flora	
Species	Family
Scirpus maritimus (L.)	Cyperaceae
Phragmites communis (Trinius)	Poaceae
Juncus subulatus (Forskal)	Juncaceae
Malcolmia arenaria (Desf.)	Brassicaceae
(*) *Astragalus armatus* (Coss. and Durieu)	Fabaceae
(*) *Melilotus indica* (Allioni)	
(*) *Frankenia thymifolia* (Desf.)	Frankeniaceae
(*) *Helianthemum helianthemoides* (Desf.)	Cistaceae
(*) *Herniaria mauritanica* (Murb.)	Caryophyllaceae
(*) *Hieracium amplexicaule* (L.)	Asteraceae

The species preceded by symbol means: (*) endemic species, (**) protected species, (†) vulnerable species, (‡) endangered species, (!!) near threatened

do not always respect the mentioned definitions established by Briere (2000), with sebkha and chott being used interchangeably. Joly (2006) considered the Mexican playas equivalent to chotts in North Africa. Many chotts in Algeria also hold the conservation status of important bird areas (IBA) in the Birdlife International program (Table 2). Despite the important surface area with conservation status, less than 45% of Algerian chotts are protected for biodiversity conservation objectives (Koopmanschap et al. 2011).

The highly fluctuating water levels and soil salinity are a constraint to the development of plant species. Nevertheless, the soil structure only permits the development and reproduction of native halophytic plants (Khaznadar et al. 2009). The most common species are represented by the family of Amaranthaceae, Zygophyllaceae and Tamaricaceae. These include *Atriplex halimus* (L.), *Suaeda mollis* (Desf.), *S. fructicosa* (L.), *Salsola vermiculata* (L.), *Arthrocnemum macrostachyum* (Moric.), *Halocnemum strobilaceum* (Palla.), *Tetraena alba* (L.F.). This vegetation is an important food source for sheep grazing in Chott Zehrez Chergui (Fig. 1, number 16) and Chott Hodna (Fig. 1, number 15) (Larafa 2004; Ghezlaoui et al. 2011). Perennial halophytic plant species such as *S. fructicosa* are the only permanent and available pasture during camel breeding season (Chehma et al. 2010) and present a grazing area for dromedary, sheep and goats (Chaieb and Zaâfouri 2000). Other species of ecological interest include *Malcolmia arenaria* (Desf.), a rare and endemic species found only in Algeria and Morocco (Dakki et al. 2004) (Table 1). Halophyte communities are also important as they play a crucial role in combating wind erosion (Halis et al. 2012) and desertification. There are concerns that these halophyte communities may be under excessive pressures due to

Table 2 List of Algerian salt lakes with information concerning the status of protection, surface area and bird status

N	Name of lake	Status of lake	Other status	Surface area (ha)	Wintering	Breeding
1	Salines d'Arzew	Ramsar site, 2004	–	5778	+	
2	Sebkha d'Oran	Ramsar site, 2001	IBA	56,870	+	
3	Lac Télamine	Ramsar site, 2004	–	2399	+	+
4/7	G. Ank Djmel and G. Merhsel	Ramsar site, 2004	–	18,140	+	+
5	G. Guelif	Ramsar site, 2004	–	24,000	+	+
6	G. Ezzemoul	Ramsar site, 2009	IBA	6000	+	+
8	Garaet Tarf	Ramsar site, 2004	IBA	33,460	+	+
9	C. Tinsilt	Ramsar site, 2004	IBA	3600	+	+
10	Chott Boumia (Djendli)	Proposed Ramsar site	IBA	3700	+	
11	C. El Beidha Hammam Essoukhna	Ramsar site 2004	–	12,223	+	
12	C. El Fraïn	–	–	1500	+	
13	Sebkha Bazer Saker	Ramsar site, 2004	IBA	4379	+	+
14	S. El Hamiet	Ramsar site, 2004	–	2509	+	
15	C. El Hodna	Ramsar site, 2001	–	12,223	+	+
16	C. Zehrez Chergui	Ramsar site, 2003	–	50,985	+	
17	C. Zehrez Gherbi	Ramsar site, 2003	–	52,200	+	
18	Sebkha Sidi Bouziane	–	–	15,675		
19	C. Chergui	Ramsar site, 2001	–	855,500	+	+
20	S. Boughzoul	–	–		+	+
21	C. Melghir	Ramsar site, 2003	–	551,500	+	
22	C. Beldjelloud	–	–	–	–	–
23	C. Merouane	Ramsar site, 2001	IBA	337,700	+	+
24	C. Tindla	–	–	600	+	
25	C. Sidi Amrane (C. Tighdidine)	–	–	200	+	
26	Sebkha Safioune	–	–	8000	+	+
27	Sebkha Oum Raneb	Ramsar site, 2004	–	7155	+	
28	Chott Ain El Beïda	Ramsar site 2004	–	6853	+	+
29	Sebkha El Melah (Lac d'El Goléa)	Ramsar site, 2004	–	18,947	+	+

Data for bird status are taken from Samraoui and Samraoui (2008)

G., S. and C. stand for Garaet, Sebkha/Sebkhet and Chott, respectively

overgrazing (Halis et al. 2012; Nedjimi et al. 2012) and climate change. Concerning the fauna richness, little work has been done in this area; the most observed species are listed in Table 1.

Anthropogenic and non-anthropogenic pressures to Algerian Chotts

Despite their exceptional biodiversity, chotts are poorly protected by conservation measures (Bouldjedri et al. 2011; Nedjimi et al. 2012). Like many other salt lakes around the world, Algerian chotts are threatened and affected by human activities (Béchet and Samraoui 2010). The private nature of surrounding land holdings in addition to the lack of knowledge and awareness about their importance by the local population increases the threats (Nedjimi et al. 2012). The basic threats for chotts in Algeria are the diversion of surface water flows, mineral extraction, land conversion and pollution (Ghalibaf and Moussavi 2014; Hamed et al. 2014b). Agricultural irrigation and water runoff are partially responsible for the contamination of groundwater sources with excessive amounts of nitrates (Khadraoui 2010; Abdesselam et al. 2013). Contamination of groundwater by saltwater from the chotts constitutes an additional risk for the potential use of these water systems in the future (OSS 2008). Chotts are threatened by human activities, such as excess salty water drained from palm groves, increasing the salt content of the ground water. Anthropogenic pressure around Chott El Beidha Hammam Essoukhna (Fig. 1, number 11) has caused native vegetation to recede, increasing risks of desertification (Oussedik et al. 2003; Khaznadar et al. 2009). The unique landscape and climatic conditions of Algerian chotts have created a specific biodiversity, hosting endemic and rare flora and

fauna. Their location and size also offer unique breeding, resting and wintering areas for migratory birds. The lands around chotts were previously covered with spontaneous plants. Over time, the herders increasingly introduced different crops, particularly fodder species. This land is used as a grazing area for large numbers of livestock, thus accentuating the zoogenic pressure on the grazing lands (Le Houérou 1993). Wastewater discharge in these basins is another substantial hazard to these ecosystems (Khadraoui 2010), due mainly to lack of wastewater treatment discharged in chotts (Demnati et al. 2012). Bensaci et al. (2014) demonstrated excessive levels of heavy metals such as cadmium and lead in chott El Hodna (Fig. 1, number 15) originating from urban (domestic wastewater) and industrial pollution and farming areas; through irrigation. These elements exceed the standard of the World Health Organization of 0.003 and 0.01 mg/l, respectively. Salt extraction is the most common industrial activity in the chotts. The rejection of salt washing water during the extraction process can increase the concentration of certain elements like magnesium salts (GM 1998). Climate change and increased urbanization intensify the threats to Algerian chotts through habitat fragmentation (Bensaci et al. 2013).

In the twentieth century, temperatures have increased by 0.74 °C globally, while in Algeria it increased by 1.5–2 °C. Temperature changes between 1930 and 2000 include increases in average temperatures, changes in minimum and maximum temperatures during the winter and autumn, and increases in monthly maximum temperatures. At the same time, rainfall has declined by 10 and 20%. The study of precipitation levels has shown decreasing rains in autumn, winter and spring (Chabane 2012).

Natural resources including lakes, ponds, sebkhas and chotts, and adjacent land are subjected to serious threats due to climate change combined with a significant human pressures such as deforestation, intensive modes of production, pollution, urbanization and anthropogenic interventions in rural areas, etc. Conservation of natural environments and biodiversity is a relatively new concept in Algeria, enacted into law on environmental protection in 1983. Since 1983, several legislative texts have been put in place to favor environmental protection; however, field reality contrasted with government policy, because the environmental situation has continued to deteriorate (Si Bachir 2013).

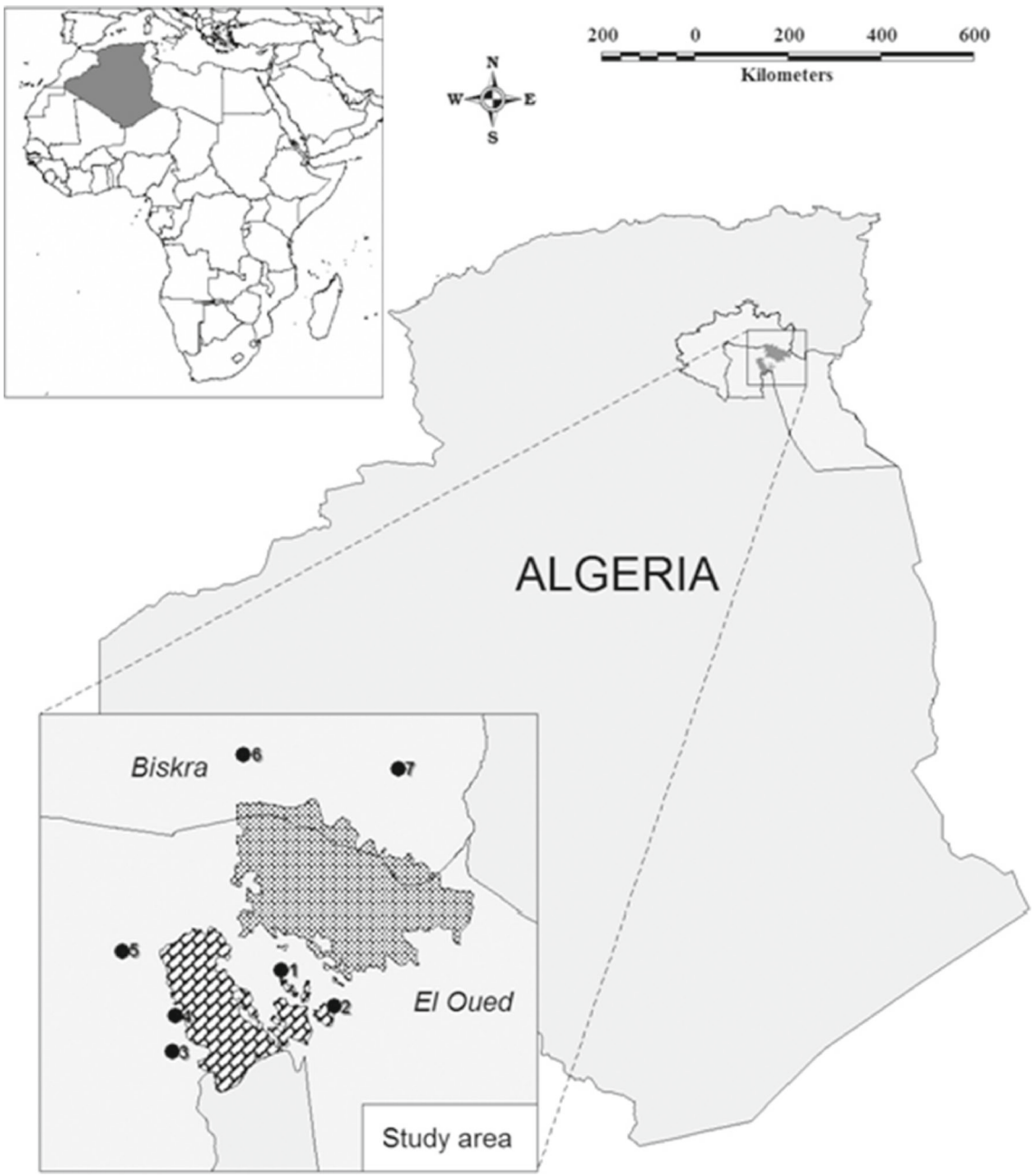
Focus on Chotts Merouane and Melghir

Chotts Melghir (34°15′N, 06°17′E) (Fig. 1, number 21) and Merouane (34°10.63′N, 6°17.32′E) (Fig. 1, number 23) are the largest salt lakes in Algeria. They are located in the northeast of the Algerian Sahara and cover a surface area from 551,500 and 337,700 ha, respectively (Demnati 2013) (Fig. 2). Chott Melghir is located between three municipal districts (El Oued, Biskra and Khenchela); the greater part of this area is located in the municipal district of El Oued and Biskra. Chott Merouane is in the municipal district of El Oued; it is delimited by the municipality of Hamraia in the north and east, by R'guiba municipality (Sif El Menadi) in the southeast and by Oum El Thiour and M'ghaire municipalities (Nessigha and Dendouga) in the west. These chotts play an essential ecological role and have important landscape, cultural and economic values (Demnati et al. 2012). Both sites are internationally protected; Chott Merouane was classified as a Ramsar Site in 2001, and Chott Melghir was classified as a Ramsar site in 2003.

The Chotts Merouane and Melghir are the lowest points of the basin. According to Table 3, the population density is highest in El Feidh and Oum Thiour, and the lowest at Sif El Menadi and Sidi Mohamed Moussa. Although the population size and density per km^2 appeared low, the evacuation discharge of the households flows into the chotts. Other activities located around these areas, such as salt and sand mining, also have negative impacts on the chotts. According to UNESCO (1972) and OSS (2003), the main water flow is toward chotts given the lower elevation levels. This indicates that major cities such Jamaâ and M'ghaire (Oued Righ Valley) situated in the west and El Oued in the east can have important impacts on the chotts despite the distance.

Despite the arid conditions, the local population has developed different socioeconomic activities in and around Chotts Merouane and Melghir, like agriculture (palm groves, intercropping cultivation), livestock farming and salt production (Demnati et al. 2012). The primary economic activity is agriculture, followed by services (transport) and public administration employment (education, mail service, agricultural services, and forest protection, municipal and state services) (Fig. 3). Agriculture is dominated by date production, flourishing around the chotts since the 1980s (Demnati 2013). The agricultural land reform and legislation concerning agricultural concessions in the beginning of 2000 has further encouraged the extension of date and other agricultural irrigated crops (Abdelhamid 2009), replacing traditional rain-fed cereal crops.

As part of the new rural development policy in Algeria and in order to provide solutions to problems that have constrained farming development during the liberal management phase, a national agricultural and rural development plan (*Plan National de Développement Agricole et Rural*, PNDRA) was developed by the Ministry of Agriculture and Rural Development containing several programs; among this program the development by concessions. The concessions give Algerian operators the right to use agricultural lands and goods within the private



Legend

Chott Melghir

Chott Marouane

1. Hamraia **2.** Sif El Menadi **3.** Dendouga **4.** Nessigha

5. Oum El Thiour **6.** Sidi Mohamed Moussa **7.** El Feidh

Fig. 2 Geographical localization of Chotts Merouane and Melghir

Table 3 Density and population size of the studied localities in Chotts Merouane and Melghir (Demnati 2013)

Site	Total population size	Population village number	District surface km^2	Density (inhabitants/km^2)
1. Hamraia	58,000	5800	2440	1.15
2. Sif El Menadi (Reguiba)[a]	40,367	29	1529	0.02
3. Dendouga (M'ghaire)[a]	51,007	1467	1399.3	1.05
4. Nessigha (M'ghaire)[a]	51,007	7092	1399.3	35.58
5. Oum El Thiour	12,359	12,359	2023.39	6.11
6. Sidi Mohamed Moussa (El Haouch)[a]	4422	700	742	0.94
7. El Feidh	12,602	12,600	1379.1	9.14

[a] In brackets in the first column were mentioned some district names, of small localities (or villages). The sites considered are the nearest localities to the Chotts Merouane or Melghir

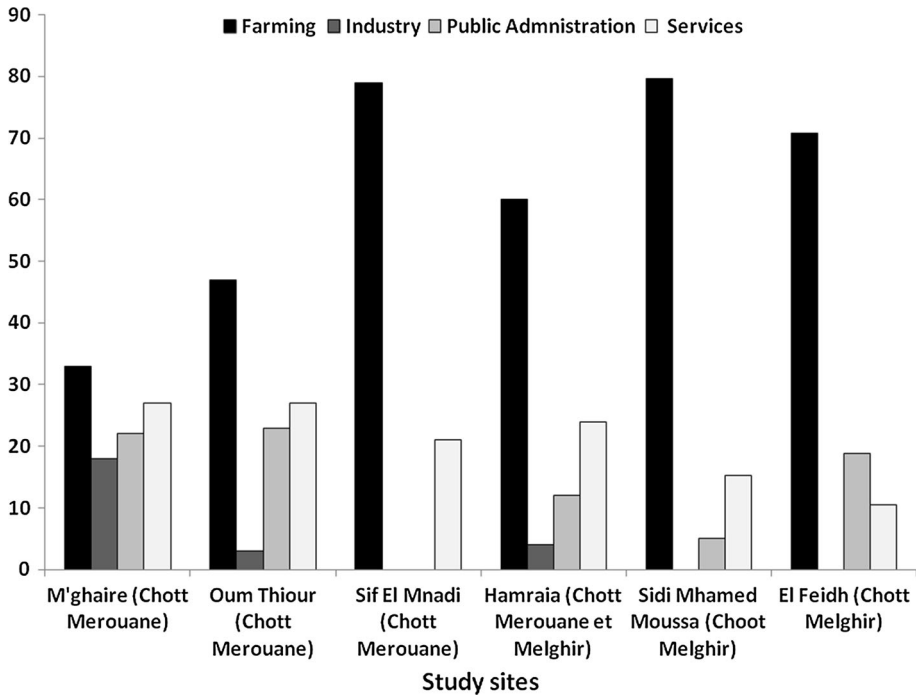


Fig. 3 Importance of economic sectors of activity for the Chotts of Merouane and Melghir grouped by municipality

domain of the State. The concessions are given for forty years and are renewable, and this means that the current practices can continue over the long term. Adaptive management plans including different stakeholders (salt miners, farmers and herders) could be an effective way of increasing conservation for the site.

Khadraoui (2010) has highlighted that the extension of date plantations has not incorporated adequate feasibility studies including soil structure, irrigation pumping and draining impacts, raising concerns on the sustainability of the activities and their impacts on the biodiversity of the chotts (Bouaguel et al. 2014). As a result, certain areas are impacted with intense salinization of the soil and water tables, thus affecting both agricultural and domestic water supplies. The increase in agricultural production and—more specifically date production—has put additional stress on ground water supplies (Sutton and Zaimeche 1992). This intensive agriculture involves increased chemical use (Demnati et al. 2012).

Animal livestock and grazing are important cultural and economic activities in the area. There are over 103,000 animals grazing in and around Chotts Merouane and Melghir (Demnati 2013), made up in majority of sheep herds, followed by dromedary and goat herds. Nomadism and transhumance are the main forms of animal breeding, the frequent movement and short-term grazing compensate for the arid climatic conditions. There has been a decrease in the surface area available for pastoral activities due to increased agricultural production, political reforms and climate change (droughts) (Kanoun et al. 2007). This has had an impact on plant biomass and floristic composition due to the selective grazing preferences of each species.

Domestic grazing plays an important role in keeping wetland habitats open, yet if the grazing is too intensive, the plant cover decreases, bare soil increases and overall biodiversity decreases (Teuber et al. 2013). The risk of vegetative cover reduction is more pronounced in Chotts Merouane and Melghir as there are three different species present (sheep, camels and goats) (Chaieb and Zaâfouri 2000).

Salt production is 149,000 tons per annum (DGM 2009), creating an important economic sector for the region (Taib 2012). There are two principle types of salt production in the chotts: intensive salt production by government institutions and newly established artisanal production by the private sector (Demnati et al. 2012). The artisanal salt production, directly extracting salt, may result in magnesium pollution as can be observed in Chott Merouane (Générale des Mines (GM) 1998). This is important because as Timms (2005) shows secondary salinization (by magnesium) can impact the biodiversity of salt lakes.

In order to study the change of the chotts, we used the results from a remote sensing analysis that considered land use maps from 1987 and 2007 produced under the Globwetland project (2010–2014) (Guelmami 2014). The maps from the study area showed an important extension of agricultural land (more than 40 km^2 in Chott Merouane (Fig. 4; Table 4). There was also a reduction of natural wetlands in both sites (with a decrease of over 32 km^2 of natural wetlands in Chott Merouane and 11 km^2 in Chott Melghir. These trends emphasize the impact of the agricultural reform (A new farm restructuring from 1987 to 1999 and the National Agricultural and Rural development Program from 2000 to the present) favoring agricultural extension at the expense of salt lakes and grazing lands (Laoubi and Yamao 2012).

In Algeria, efforts have been made toward recognition of the functions and values of wetlands; however, there is still progress to be made at all levels. The strategy of wetland conservation consists in preparing of management plans of natural resources of these areas. A policy is adopted to prevent their degradation and loss, to ensure their sustainable use and support research for measuring their value. There has been both the acceptation of international legislation (Ramsar Convention, the Convention on Biological Diversity and The United Nations Convention on Climate Change) and the creation of national legislation (Gherzouli 2013). Despite the large number of statutory instruments and control bodies, this regulation is not applied on the ground (Raachi 2007). Often the operators are unaware of existing legislation, generating problems between the various sectors operating in the

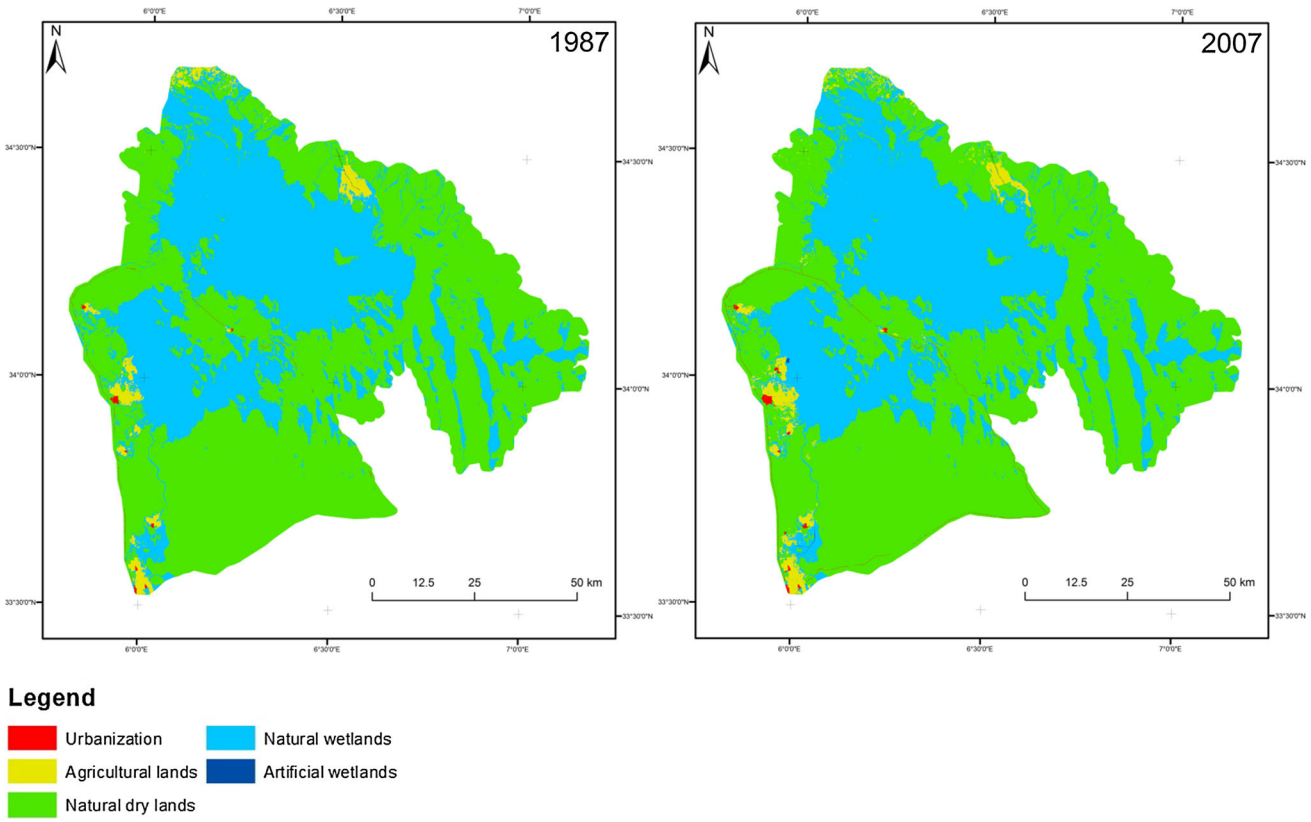


Fig. 4 Land use maps for Chotts Merouane and Melghir in 1987 and 2007 (Guelmami 2014)

Table 4 Analysis of land use changes from 1987 to 2007 using satellite imagery for Chott Merouane and Chott Melghir (Guelmami 2014)

	Km^2 in 1987	Km^2 in 2007	Change in km^2
Chott Merouane			
Urbanization	10.57	22.44	11.87
Agricultural land	83.53	123.80	40.27
Natural dry land	2445.98	2413.61	−32.37
Natural wetlands	962.05	940.77	−21.28
Artificial wetlands	0.00	1.64	1.64
Chott Melghir			
Urbanization	1.69	3.69	2.00
Agricultural land	67.44	66.87	−0.56
Natural dry land	3213.47	3223.99	10.52
Natural wetlands	2557.81	2546.08	−11.74
Artificial wetlands	0.78	0.55	−0.22

management field, protection and exploitation of water resources globally, and chotts specifically (Demnati 2013).

There have been initiatives to increase public awareness of chotts in northern Algeria through awareness campaigns and school programs, and unfortunately, these initiatives are led by environmental NGO, who are not present around Chotts Merouane and Melghir. Despite the lack of formal environmental NGO, Demnati et al. (2012) have shown that the main stakeholders are disposed to take part in conservation efforts to protect the chotts and to preserve these very fragile environments.

Future perspectives

Although there is legislation in place to protect Ramsar sites, it is not always respected when creating new projects and exploiting natural resources (Khaznadar et al. 2009). This situation is aggravated as some administrative bodies are missing in the area of Chotts Merouane and Melghir, with the absence of the District of Agricultural Services (DSA) and Local Forest Conservation Service (CFW). The lack of administrative structures and implementation of laws has led to poorly planned socioeconomic development. As a result, much of the national legislation that should aid in sustainable development is not enforced at the local or regional level (Nedjimi et al. 2012). A more integrated management approach may help promote local development while ensuring the sustainable use of the natural resources. In the absence of effective intersectorial management, we would recommend putting in place a formal administrative structure that includes a two-tier structure made up of a scientific council and an administrative committee. This structure could benefit the short-term and long-term management of Chotts Merouane and Melghir and set an example for other Algerian chotts.

Our literature review highlights the need for more detailed scientific studies on Algerian chotts. The seasonal and annual fluctuations in these biotopes make long-term studies essential to better understand the changes and progression in the sites. Other research that should be carried out includes a study of the vegetation biomass cover and pasture management to improve the sustainability of grazing activities in and around the chotts. Feasibility studies are also imperative before developing additional agricultural activities. In accordance with the suggestions of Nedjimi et al. (2012), we also recommend more intensive agricultural training to reduce the agricultural irrigation runoff in the chotts and contamination of the groundwater.

A proposal for protection and conservation of Algerian chotts (Fig. 5) suggests the important role that the government must assure for the collaboration between the various socioeconomic and administrative stakeholders. This collaboration would help to ensure the application of the existing legislation and promote more informed decision making on socioeconomic development and the adoption of laws protecting chotts. Decisions should be taken after consultation with the relevant ministries with an intersectorial approach. The ministries should also ensure environmental respect by the socioeconomic stakeholders operating in these areas, by working together, making consultations and taking preliminary decisions based on the scientific reports. Scientific studies and feasibility studies should not only include the participation of not only scientific bodies, but also include the implication of different environmental associations and the local population. Academic and applied research is also essential for the conservation of these habitats. Environmental associations have an important role to play in environmental education of local residents and socioeconomic stakeholders on the ground, in order to encourage management changes and conservation actions. Associations should involve local populations in the protection and conservation efforts. Information exchange between environmental associations and the scientific community is important to establish sustainable management of chotts, creating a multi-level and multi-sector approach. A two way exchange is extremely important between the ministry and the scientific research, with scientific institutions both initiating new research and implementing proposed studies. The government should support this process through information exchanges and funding opportunities.

The ultimate purpose is to raise the value and services of this fragile environment, through awareness, protection and conservation.

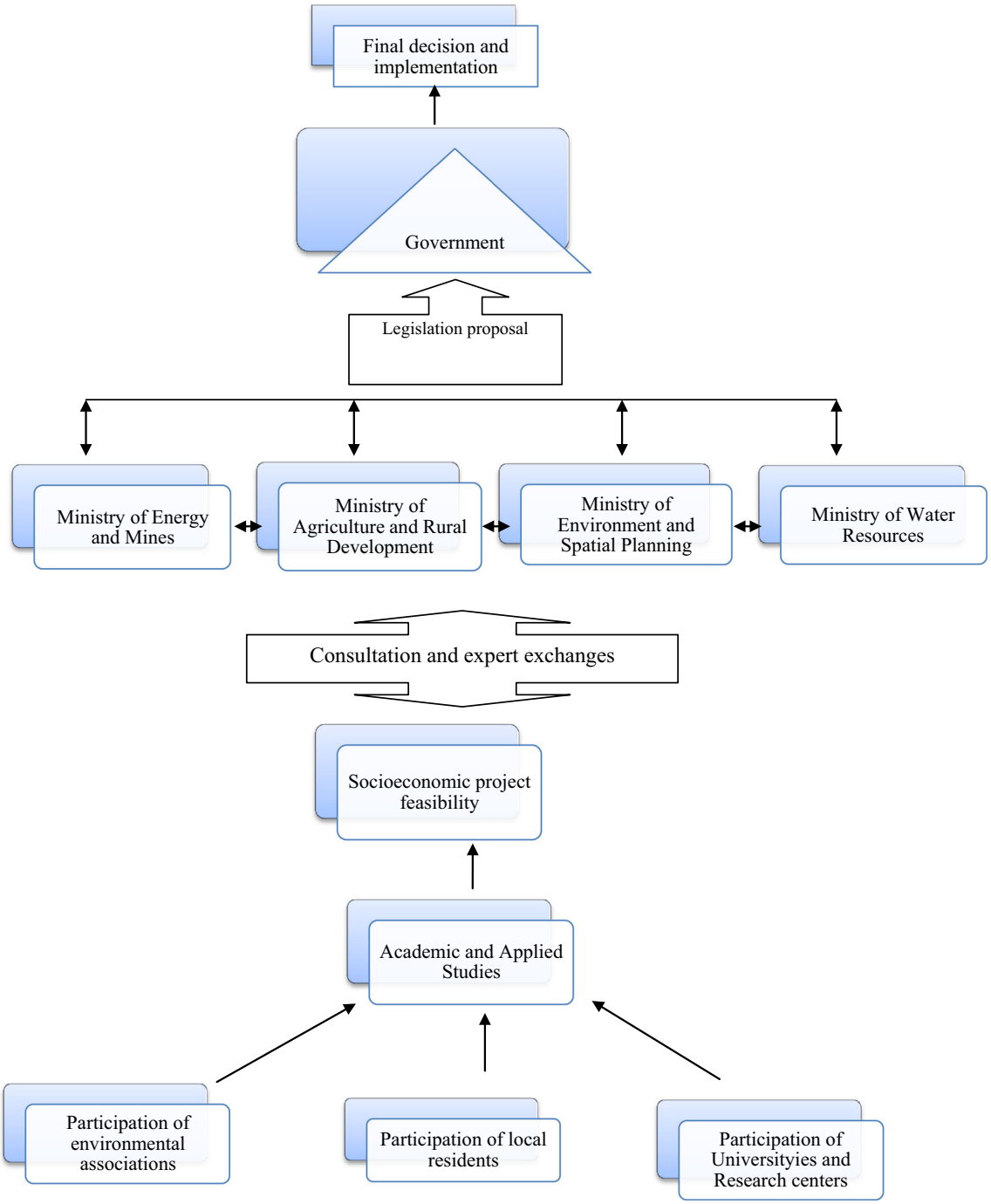


Fig. 5 Suggested step with the different actors for protecting and conserving Algerian chotts

Conclusion

Algerian chotts are important wetland habitats for their natural, economic, scientific and social capital. Despite their values, many human activities threaten or affect the chotts including agricultural activities, diversion of water flows and mineral extraction. Climate change (with more intense drought periods) could further impact these delicate wetlands. In order to improve the conservation of chotts, awareness must be increased on the nature of human threats and their impact on these habitats. New strategies must be implemented to achieve sustainable conservation and management. Integrated management, with an emphasis on combining economic development

(agriculture), mining and conservation planning, could be a useful strategy to promote a balanced use of the natural resources with sustainable land use practices.

Some recommendations to improve the management and conservation of chotts include:

- Encourage researchers' interests in all aspects of chotts from water dynamics passing through micro- and macrofauna, and micro- and macroflora,etc.
- Installation of research centers to facilitate long-term monitoring of fauna and flora; population dynamics studies, and climatic studies.
- The salt mining activity should not be done in the sebkha itself or around the chott. This activity should be far from the chott to ensure a refuge for flora and fauna. Salt mining should also be located in areas where it is not detrimental to agricultural activities.
- The salt washing water should not be discharged directly into the chott, because this water contains harmful secondary salts; these extractive companies must make retention ponds and explore alternative uses for these salts.
- The amount of salts extracted must be defined annually according to recommendations established by the annual reports of researchers on each chott.
- Most Algerian chotts contain endemic plant species; on this point, the authorities like the Ministry of Agriculture and Rural Development and the Ministry of Environment and Spatial Planning, should provide the financial and human resources in order to preserve this richness, and appropriately identify preservation zones.
- The grazing on the edge of chotts provides good fodder for sheep, goats and camels. Livestock grazing in these areas must be regulated and controlled. The use of rangeland zoning and control can encourage vegetative cover and plant production.
- Prohibit sand mining companies from extracting sand in chotts, and thus attempt fixing these dunes by vegetation adapted to these environments.

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