



The Ghout Agricultural System: Between Survival and Disappearance

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Abstract

The Ghout is a traditional agrosystem classified among the Globally Important Agricultural Heritage Systems by the FAO. This Saharan artificial ecosystem was created through manual digging of the soil to approach the level of groundwater; date palm trees are planted at about 1 m depth and benefit from water without irrigation. The Ghout, composed of three stratum (palm trees, fruit trees and shrubs, and herbaceous plants), had remarkable floristic and faunal biodiversity. Since the 1980s, this agricultural system has been persistently degraded due to anthropogenic origins in the municipality of El Oued, mainly as a result of urban expansion and fluctuations in the water table level. Until the early 2000s, the phenomenon of rising water levels caused the drowning of palm trees and the disappearance of Ghouts; this was the consequence of the lack of an effective sewage system. However, since the 2010s, the lowering of groundwater levels to a depth exceeding 9 m has led to the drying up of Ghouts; it is due to the high demand for irrigation water. In addition, other factors have contributed to the disappearance of this innovative system, such as the inheritance and amortization of gardens leading to low production, which has resulted in the abandonment of these areas and the lack of interest from the youth to work in this heritage. The degradation of agrobiodiversity and varietal diversity of the date palm are among the characteristics recorded during the last decade, where the two cultivars Deglet Nour and Ghars dominate the Ghouts. Despite these drawbacks, in recent years, the emergence of digging the Ghouts has been recorded in the northeast and southwest of the province of El Oued.

Keywords *Phoenix dactylifera* L. · Ecosystem · Biodiversity · GIAHS · Extinction · Conservation

Introduction

Throughout the world, generations of farmers and herders have created specific agricultural systems and landscapes, shaping and maintaining them. These systems value local natural resources, and their management is based on practices adapted to the local context. These systems have shaped remarkable landscapes, contributed to the development of significant agricultural biodiversity globally, and, above all, have sustainably provided multiple services and goods to society as a whole, ensuring food security and livelihoods as well as quality of life for local populations [5].

In order to safeguard and promote these systems as elements of a global agricultural heritage, the Food and Agriculture Organization of the United Nations (FAO) initiated the Globally Important Agricultural Heritage Systems (GIAHS) program in 2002, which is the main global program specifically dedicated to agricultural heritage systems. It is an initiative aimed at ensuring the conservation and adaptive management of ingenious systems of global agricultural heritage. It seeks to promote international recognition of these ingenious systems of global agricultural heritage, ensuring the conservation and protection of agricultural biodiversity, knowledge systems, peasant cultures, and ultimately preserving food security and livelihoods for populations concerned [5, 17].

The Ghout is an exceptional farming system that dates back to the fifteenth century; it reflects the ingenuity and courage of the inhabitants of the Souf region in south-eastern Algeria [10]. In this arid desert region, oasian engineering has defied the hostile environment by establishing date palm cultivation (*Phoenix dactylifera* L.) in

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sunken basins called “Ghouts” (plural of Ghout). This ingenious system has allowed the survival of local populations for centuries, by adapting their behaviors to the scarcity of water resources [5]. Since 2011, the Ghout has been recognized as a globally important agricultural heritage system by the FAO [19].

This system, classified among the GIAHS sites, has been experiencing continuous degradation since the 1990s [9]. This contribution aims to diagnose the causes of the degradation of the Ghouts in the municipality of El Oued.

Materials and Methods

Study Region

The region of Souf, on the western side of the province of El Oued, is located in the large eastern Erg, which occupies three-quarters of the area of Souf; it is a succession of sand dunes. The region is characterized by the cultivation of date palms, spice crops, and some fruit trees, including olive trees. Souf, located about 500 km from the Algerian capital, is bordered to the north by the Melghir and Merouane chotts, to the south by the extension of the eastern Erg, to the west by Oued Righ, and to the east by the Tunisian border. It is an arid desert region deprived of the incursion of maritime air masses that produce rain, due to its very continental location, where precipitation is both low and episodic, rarely exceeding 100 mm per year, while potential evaporation is high. The average annual air temperature is 22 °C, with a minimum of 11 °C in January and a maximum of 45 °C in August. The dominant winds are from the northeast direction, coming from the Libyan Mediterranean, laden with humidity, known as “El-Bahri”; they blow very strongly in the spring. The average speed is around 45 km/h. Another hot but less frequent wind blows from the south to the north [9, 10]. The provincial capital is the municipality of El Oued (Fig. 1).

The Souf, known for its traditional hydro-agricultural system called Ghout, is a potentially agricultural region characterized by five (05) production systems: oasis, market gardening and industrial, cereal, arboricultural, and a last polyculture production system [10, 19].

In addition to the agriculture sector, which employs 42% of the province’s active workforce [9], other sectors also employ the active population, such as services, commerce, construction, and public works. However, the most important sector of activity in the province of El Oued is the public service [2].

The Ghout

The Ghout, which has marked the history of the Souf region, is an agrarian crater rarely exceeding 0.5 ha; the specificity of this farming system was based on planting palm trees at the bottom of vast craters, dug by hand and allowing the palm trees to draw water directly from the water table through their roots. The palm trees are planted in groups of 20 to 100 in the center of an artificial basin about 10 m deep and 80 to 200 m in diameter, with the bottom brought to less than 1 m above the water table (Fig. 2). The oasis dwellers gradually dig into the basin soil so that the palm trees constantly have their roots in the water; thus, they do not need irrigation [10, 21].

Huge quantities of sand are removed by men to create what is called a Ghout. These palm groves form an agronomic model of self-sufficiency, ensuring first and foremost the survival of the operator and his household, far from being oriented toward producing marketable surpluses [14].

According to Faci and Bedjaoui [9], the date palm tree is present in all Ghouts, and fruit trees are planted under this layer, while forage and food crops (vegetables, condiments, etc.) are grown at ground level. However, this lower layer requires surface irrigation, as the roots would not reach the water table, so farmers dig wells. In general, the plant production of these small traditional farms is intended for family self-sufficiency and animal feed. In addition to plants, animals were raised, usually goats and chickens in the Ghout and camels in the surrounding areas.

Date palms in the Souf are characterized by a high varietal diversity. There are more than thirty varieties such as Deglet Nour, Ghars, Takermest, Tafezouine, Tanteboucht, Arechti, Goundi, Ali Ourached, Degla Baidha, Tinissine, and Kentichi. They provide shade, lower the ambient temperature, and thus create a microclimate; therefore, oases are the best place to live in the Sahara and an important tourism destination [5]. The dates from the Ghouts are of very good quality, both in terms of organic quality, taste, resistance during transport, and long shelf life; thus, these dates are sold at a higher price than other dates [10, 18, 21].

Groundwater

In the Sahara, underground water reserves are essential for all human, animals, and plants life. To overcome the scarcity of rainfall, oasis dwellers irrigate their date palm groves with groundwater. Two traditional methods have been practiced in the Algerian Sahara; the first is to bring water to the surface (Foggara and swing wells) and the second is to extend the palm tree roots into the water

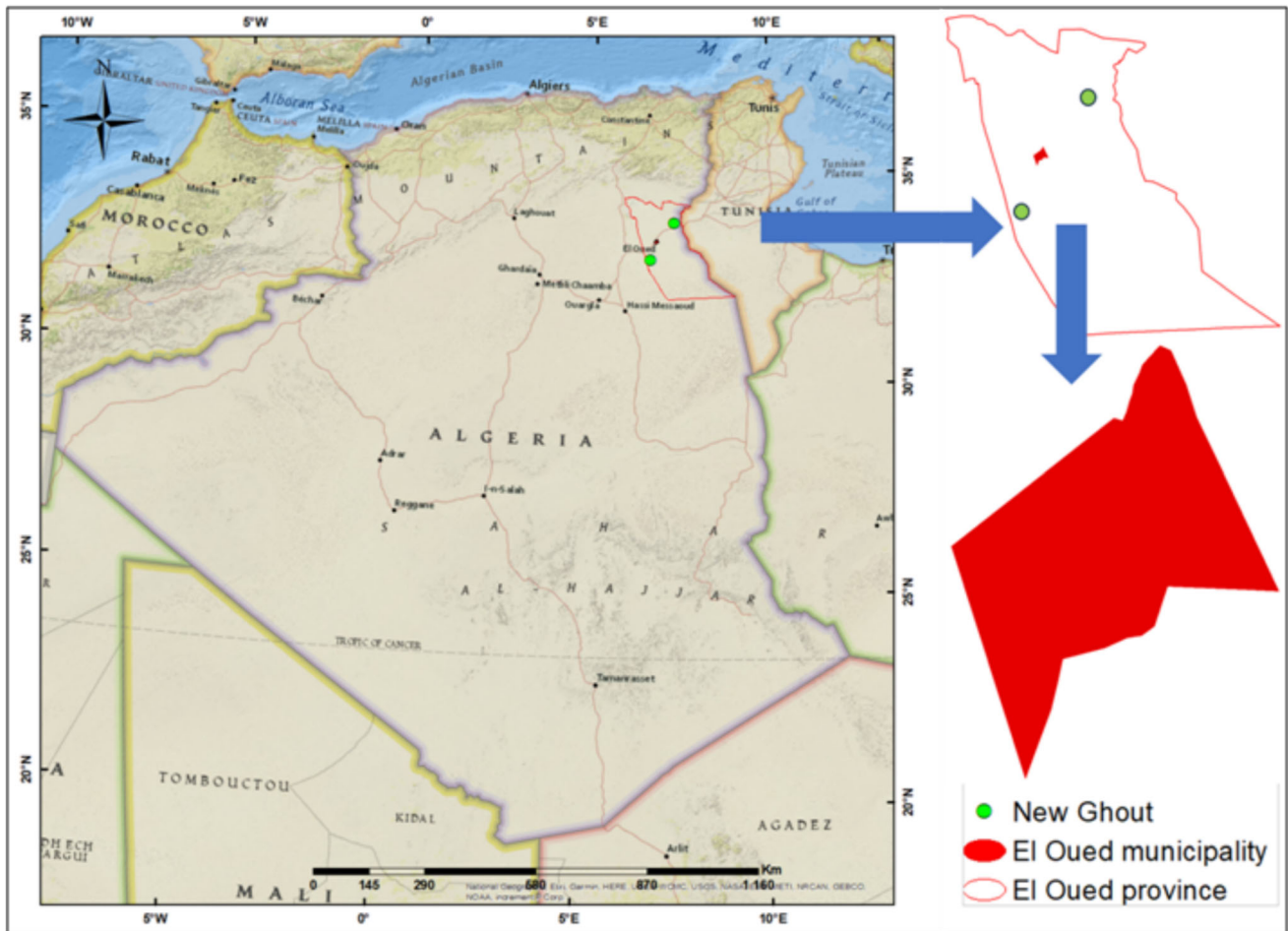


Fig. 1 The study area location map

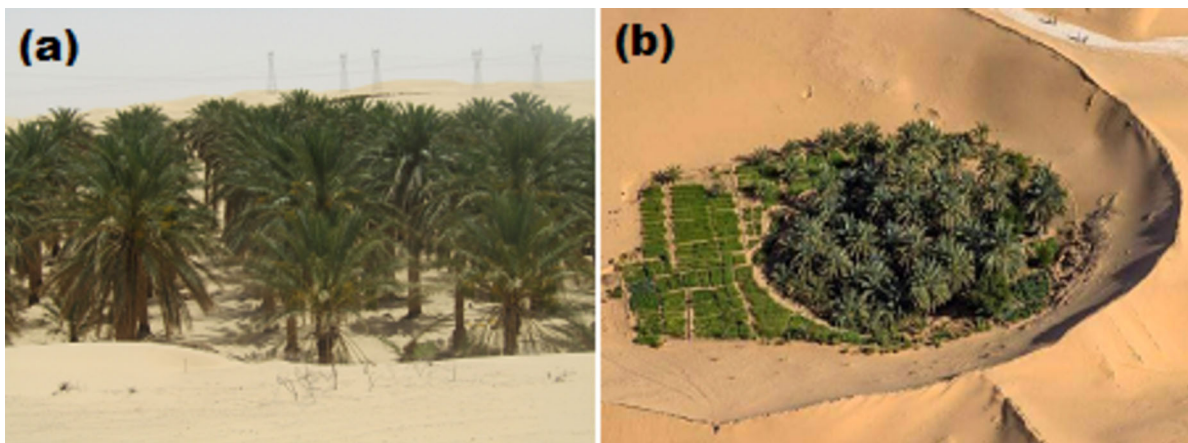


Fig. 2 Ghouts in the El Oued region: **a** monoculture (date palm) and **b** multiculture [13]

table so that they are continually in contact with water (Ghout in El Oued) [18].

In the Souf region, the existing groundwater is in three aquifers, namely, the interlayer continental aquifer (CI), the terminal complex aquifer (CT), and the phreatic

aquifer. The latter aquifer corresponds to the upper part of continental formations deposited at the end of the Quaternary; its depth varies between 2 and 60 m and the dry residue ranges from 2 to 6 g/l depending on the areas [10]. According to Leghrissi and Menni [14], the thickness of

this latter aquifer is variable and can locally reach a hundred meters, while the depth of the CT aquifer ranges from 100 to 600 m and that of the CI aquifer (called Albian) can locally reach 2000 m.

Groundwater is generally located in depressions or valleys. In the 1940s, the groundwater of the palm groves in the Oued Souf valley was the sole source for supplying drinking water to the population and watering livestock, as well as for irrigating food crops [12]. This aquifer is fed by precipitation and temporary runoff, as well as increasingly by drainage water from the palm groves and losses from the networks; their only outlets are the Chotts where water accumulates and evaporates [4]. With the increase in human population and the use of deep wells (CI and CT), a progressive and persistent rise in the water table reached its peak in the 1990s.

The problem of rising groundwater affected about 6200 Ghouts out of the 13,364 that existed in the Souf region, leading to the death of 337,635 palm trees due to asphyxiation, out of 633,615 palm trees planted in the Ghouts [16]. The rising water table also caused flooding in the low-lying areas of the city of El Oued and its outskirts.

According to Remini [18], the rising water had other consequences on humans and the environment, such as the drowning of septic tanks, the spread of bacterial pollution in the aquifer, and water contamination by nitrates of domestic and agricultural origins. Also, the strong water mineralization caused by intense evaporation from open water bodies and the dissolution of salts is the cause of land subsidence throughout the El Oued region [3], as well as the spread of harmful insects, unpleasant odors, and distortion of the overall view [7].

Mapping

The land use map of the municipality of El Oued was based on an aerial photograph taken in 1958, covering the study area, while the current state map is established from a satellite image captured by Sentinel-2 in 2021 [11] and then adapted according to the needs of this contribution.

For the map of the spatial distribution of water depth during the year 2022, data collected from nine (09) measurement points were utilized. However, for the 2002 map, the results of the study conducted in 2002 by the National Agency for Drinking Water and Industrial and Sanitation [1] were used, through 27 measurement points. The piezometric levels are mapped using the spatial interpolation method, using the inverse distance weighting (IDW) provided by the Analyst Spatial extension under the ArcGIS program [20].

Results

Urbanization

El Oued is among the most populous provinces in the Algerian Sahara; it has experienced urban expansion since the 1980s [9, 18]. The municipality of El Oued is the most populous in the province, with a density of 2069 inhabitants per km² [6] (Djaber 2015); this has accelerated the urban expansion of the city.

In the year 1958, buildings and constructions occupied only 155 ha (Fig. 3), equivalent to 2% of the current administrative division of the municipality of El Oued, while in 2024, the area has multiplied nearly 16 times, reaching 2492 ha, covering 31.2% of the municipality's surface area.

The maps show the disappearance of the Ghouts, which occupied approximately 1311 ha in 1958, in favor of urban expansion areas and the establishment of irrigated crops. These crops currently cover an area of 629 ha, representing the disappearance of 48% of cultivated agricultural land, while the surface area of Chott located near the city is approximately 9.5 ha, unlike in the 1950s when it did not exist.

Groundwater Drawdown

In the study area, the depth of groundwater has decreased by an average of 7 m over a time interval of 20 years (2002–2022). It varied between 1 and 12 m in the year 2002 (Fig. 3); however, in 2022 the variation was between 9 and 15 m.

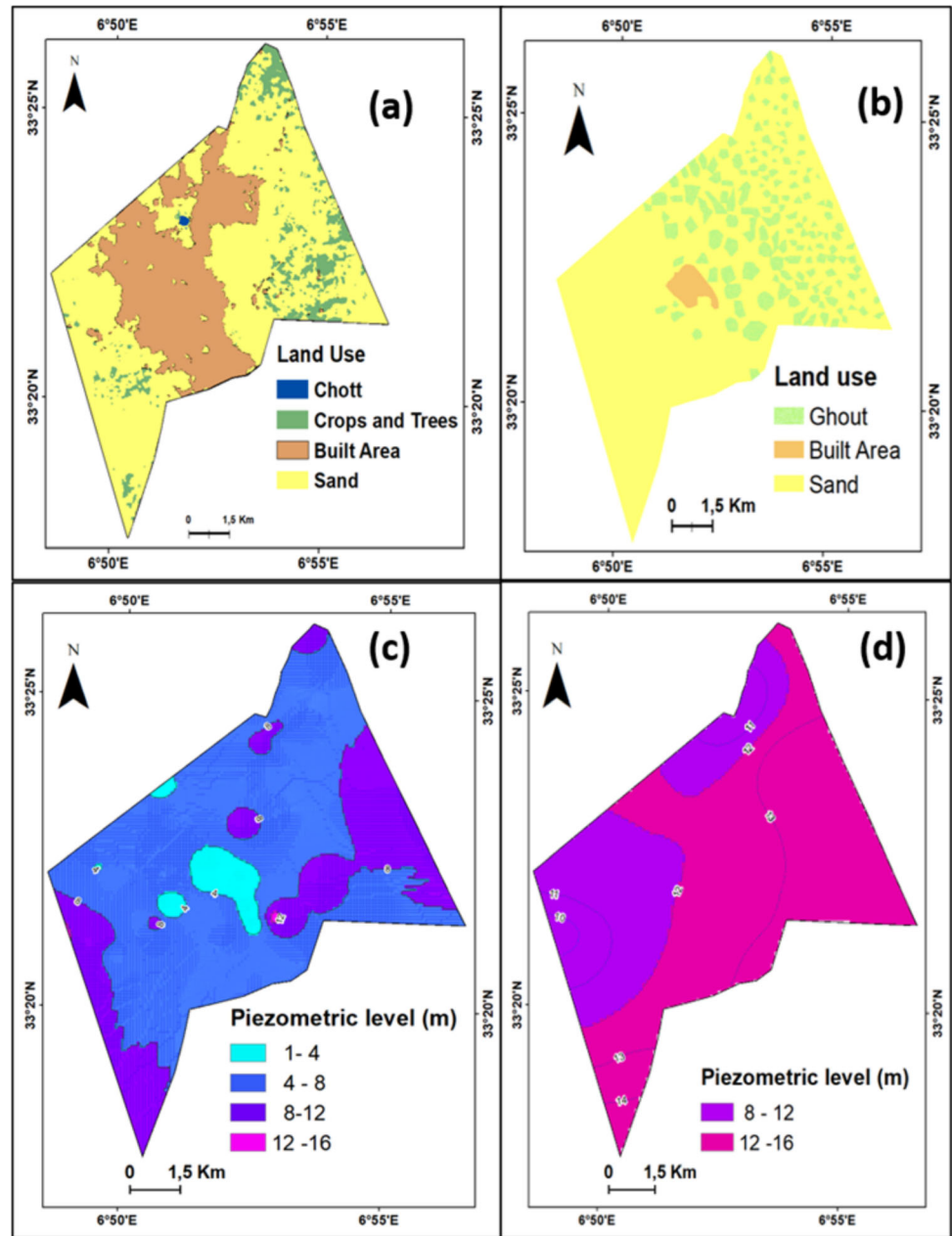
New Ghout Emergence Zones

Although the region of Souf is the cradle of the famous "Ghout" heritage, due to the situation experienced and the persistent degradation of this agroecosystem, young farmers have started installing Ghouts in other areas outside Souf for the past decade. They use modern equipment for digging the basins.

The spread of the Ghout system is remarkable in two distinct areas; the first is about 70 km northeast of El Oued (around the village Sebais, administratively attached to the municipality of Taleb Larbi) (Fig. 1).

The second area is located in the middle of the sand dunes, about 50 km southwest of El Oued and 30 km south of the municipality of Mih Ouansa (Fig. 4).

Fig. 3 Change in land use (LU) and piezometric depth level (PDL) in the municipality of El Oued: **a** LU during the year 2024, **b** LU in 1958, **c** PDL in 2002 [1], and **d** PDL in 2022



Discussion

According to Djellabi and Djoudi [7], during the last years, the rate of self-irrigated Ghouts, where the palm tree roots directly exploit groundwater, did not exceed 29%. While about 39% are irrigated and the rest do not benefit from irrigation water; according to the same authors, the number of self-irrigated Ghouts in the Souf region does not exceed 400. The Bours or Baali Ghouts (both terms mean that the date palm is not irrigated and it consumes groundwater) have completely disappeared from the municipality of El Oued [15]. This is confirmed by the land use map of the year 2024, carried out during the preparation of this study.

The significant demographic growth recorded in the Souf region from the 1960s, following the sedentarization of the local population, was concentrated in the municipality of El Oued, a situation that led to significant urban expansion. The urbanized area experienced an increase of 1609%, reaching approximately 2500 ha in 2024.

Previously, there was a balance between the water capacity brought in and that evacuated; there was a balance between withdrawals and discharges, and the piezometric level of the aquifer remained stable. But starting from the 1960s, the water level of the groundwater gradually rose due to the absence of sewage treatment plants and natural outlets, thus imposing only one possible path for

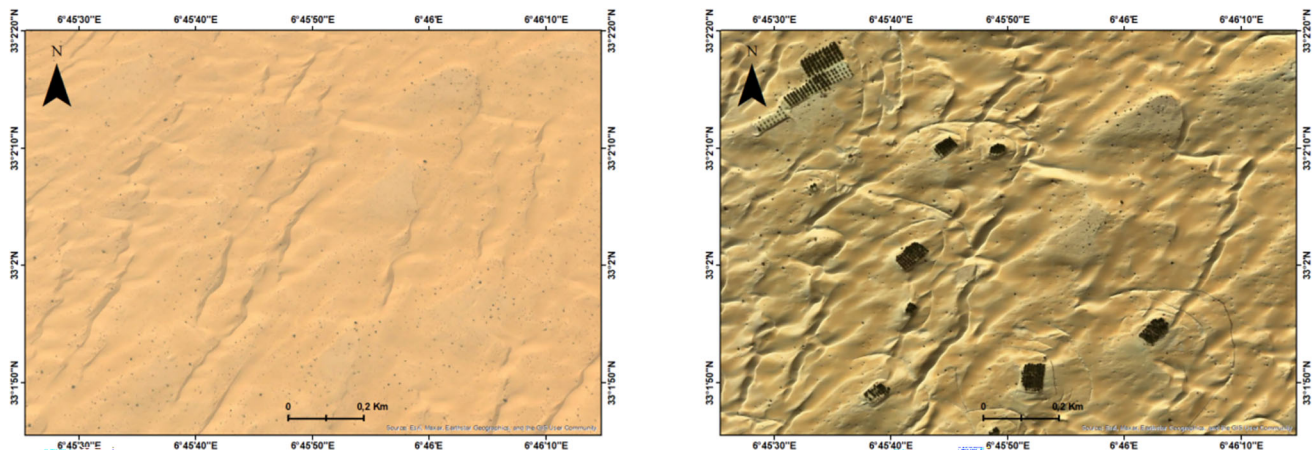


Fig. 4 Land occupation in an area 50 km southwest of the province of El Oued, between the year 2007 (on the left) and the year 2024 (on the right): Creation of Ghouts. (Source Google Earth Pro)

wastewater, which was infiltration into the groundwater, leading to its overfeeding and an excess of water for the palm tree. The problem of rising water levels became significant during the 1980s, when the Ghouts were transformed into a receptacle of stagnant saltwater and various waste [3, 10, 16, 18, 21]. According to Leghrissi and Menni [14], the healthy Ghouts (not waterlogged) were generally those located far from urban areas.

To combat this situation, four operations were undertaken: (i) sealing of wells, (ii) filling of Ghouts that were in a very advanced state of degradation to minimize environmental pollution, (iii) expanding the city's sanitation network and installing treatment plants, and (iv) creating a green belt around the city of El Oued [10, 18]. Other decisions were made, such as stopping irrigation from new wells from the CT and CI aquifers and replacing them with wells from the water table, reusing treated wastewater for irrigation, reducing the water supply for residents, and better management of irrigation programs [3].

According to the physico-chemical analyses carried out by Bouselsal and Belksier [3], the treated wastewater is not suitable for the irrigation of agricultural lands. Consequently, and due to the high demand for irrigation water because of the expansion of agricultural lands, and the prohibition of using water from the CT and CI, farmers have resorted to massive exploitation of water table. This has led to the lowering of the water level of this aquifer, resulting in situations of water depletion in the Ghouts far from urban centers. However, with the increase in agricultural areas, mainly occupied by potatoes and vegetable crops, the volume of groundwater pumped for irrigation has significantly risen, causing a decrease in water table levels in certain areas and the drying up of Ghouts in other areas. This situation has led to the drying up of a large number of Ghouts and the transformation of the remaining ones into irrigated gardens. On the other

hand, during the 1990s and the early 2000s, poor drainage in some areas led to the drowning of a significant number of Ghouts and the suffocation of palm trees, especially in the municipality of El Oued [9].

According to Bouselsal and Belksier [3], the upper part of the water table is located in the southwest of the Souf region, with an elevation of about 76 m and a lower area in the northeast, with an elevation of 56 m, where the flow of the water table generally goes from southwest to northeast. The hydraulic gradient varies between 0.66 and 0.08%. However, comparing with data from 2010 shows a decrease in piezometric level of about 4m in the northeast part, due to pumping effects in the vertical drainage network of the city of El Oued where water supply decreases toward the direction of flow (in the Trifaoui area). In this area, after the vertical drainage network was put into operation (51 wells equipped with pumps for a total operating flow rate of 348 l/s), there is no longer a natural state of the water table. Currently, the water is at a depth exceeding 9 m.

Nowadays, the Ghouts are facing the phenomenon of groundwater-level drawdown, for about a decade, and it continues to increase every year, because the Souf has become a major agricultural production center, such as vegetables, tobacco, peanuts, fruit trees with the introduction of olive trees, as well as potatoes which are experiencing unlimited expansion. According to Leghrissi and Menni [14], with this intensive trend of a so-called modern agriculture, irrigated potatoes are often grown under locally made mini-pivots without respect for the scientific parameters of irrigation frequency and dosage, with presumed water abundance and considerable yields from this crop; these elements will accelerate the depletion of the water table. Especially that in Souf, potato cultivation consumes $500 \text{ m}^3/\text{ha}/\text{cycle}$ in farms using drip irrigation systems, for an average cycle of about 120 days, while it

can reach, in some cases, up to 10,000 m³ under pivot irrigation. These quantities exceed the average standards estimated at 300 m³. Some farmers have even gone so far as to exploit their Ghouts, where they have leveled the ground and planted this crop [14].

According to Faci and Bedjaoui [9], other factors have exacerbated the decline of the Ghout ecosystem in the Souf region, such as the aging of the workforce, the inheritance and amortization of date palm gardens, and the disinterest of young people in working in this agroecosystem, where they prefer to move toward other profitable activities, such as trade and new farms, also sand advancement. The problem of transporting sand inside these craters represents a difficult operation for the Ghoutis (farmers who work in the Ghouts area) [10, 18].

In addition to external factors, internal factors specific to this traditional agricultural system have exacerbated the abandonment of the Ghouts by farmers, including the aging of palm trees and the degradation of agrobiodiversity and varietal diversity, thus generating low financial returns [9]. According to a study by Djellabi and Djoudi [7], 82% of the Ghouts are mainly composed of date palm trees. The varietal biodiversity of this species is limited mainly to two cultivars, Deglet Nour and Ghars, while the number of the other cultivars is low [9]. These factors weigh on the viability and sustainability of this oasis ecosystem, which is becoming increasingly fragile [2].

Despite the catastrophic situation of the Ghouts in the municipality of El Oued, it is still possible to preserve the traditional Ghouts (non-irrigated) of other municipalities in the Souf region, through the recharge of the water table by (i) the waters of the CT and CI [7], provided that the exploitation is limited and controlled, and (ii) the treated waters that will be used for agricultural irrigation, but which must be of good quality. On the other hand, it is necessary to plant young date palms while ensuring varietal biodiversity and the planting of other fruit trees and other underlying crops. Also, it is necessary to exploit the “Ghout” heritage to promote agrotourism.

This study has indicated the spread of Ghouts to other areas beyond Souf, mainly to the northeast and southwest of the province of El Oued, due to the availability of groundwater close to the surface at a depth of 3 to 5 m. However, Faci [8] has reported the existence of palm groves benefiting from the proximity of the water table in the province of Ouargla (regions of N’gouça and Sidi Khouiled), locally known as “palm grove Bour”; also, in the province of Touggourt, there are small date palm gardens in the Taibet region that are directly supplied by groundwater. These regions are located approximately 220 km and 55 km southwest of El Oued, respectively, as the crow flies.

Conclusions

The traditional agro-system “Ghout” of Oued Souf, classified by the FAO among the GIAHS sites, has been undergoing continuous degradation since the 1980s. The Ghouts of the municipality of El Oued have been most affected by this decline, mainly due to the sedentarization of the population starting from the 1960s; since then, the city has experienced significant urban expansion. The city, which covered an area of 155 ha in 1958, has expanded 16 times more.

This urban expansion, not accompanied by the installation of sanitation and agricultural drainage networks, has caused the rise of the water table in some areas up to ground level. The impact has been fatal on the Ghouts of the municipality of El Oued, as the date palms planted in these artificial craters, dug by the hands of ancient farmers, have suffered from these drownings, where few palm trees have been able to survive.

Since 2011, the piezometric level has started to decrease, following measures applied to reduce the negative effects of the rising waters. However, the lowering of the water table has continued due to overexploitation of water for agricultural irrigation, as agriculture in the region has experienced unprecedented prosperity. Currently, the water levels closest to the ground in the municipality of El Oued are at a depth of over 9 m.

This situation has led to the disappearance of the remaining Baali Ghouts in the study area, where only a few irrigated or abandoned (dead) Ghouts remain, while in the neighboring municipalities of El Oued, there is a trend to transform the Ghouts into an irrigated agricultural system, mainly composed of a single stratum (*Phoenix dactylifera* L.), while the other strata are disappearing (arboreal and underlying). Despite this, there is a possibility to preserve this old agroecosystem through the controlled recharge of the water table, either by reusing treated water for agricultural irrigation and/or by exploiting the water from the CT and CI aquifers.

Outside the region of Oued Souf, the digging of Ghouts has taken place in the northeast and southwest of the province, a situation that requires the support of these farmers, especially since the majority of them are young, hence the need to accompany them by the relevant services to ensure the sustainability of this cultural and agricultural heritage that produces organic fruits and vegetables, as well as the generation of financial income.

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Declarations

Conflict of interest The authors have no relevant financial or non-financial interests to disclose.

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