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Original research article

Goods and services provided by native plants in desert ecosystems: Examples from the northwestern coastal desert of Egypt

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ABSTRACT

About one third of the earth's land surface is covered by deserts that have low and variable rainfall, nutrient-poor soils, and little vegetation cover. Here, we focus on the goods and services offered by desert ecosystems using the northwestern coastal desert of Egypt extending from Burg El-Arab to El-Salloum as an example. We conducted field surveys and collected other data to identify the goods services and provided by native plant species. A total of 322 native plant species were compiled. The direct services provided by these native plants included sources of food, medicine, and energy; indirect vegetation services included promotion of biodiversity, water storage, and soil fertility. The plant diversity in this ecosystem provided economic service benefits, such as sources of fodder, fuel-wood, and traditional medicinal plants. Changes in land use and recent ill-managed human activities may influence the availability of these services and strongly impact biodiversity and habitat availability. Although deserts are fragile and support low levels of productivity, they provide a variety of goods and services whose continuing availability is contingent upon the adoption of rational land management practices.

1. Introduction

Natural ecosystems provide numerous services and goods that support human well-being and survival (Costanza et al., 1997; MA, 2005). Deserts provide many benefits that can meet the demands of both the local inhabitants and other surrounding communities. These benefits include water, food supply, medicine and raw materials. However the information available about the services and goods provided by this biome is fragmentary. Consequently, deserts have been overlooked in most of ecosystem valuation studies (De Groot et al., 2012). A key component in desert ecosystems is the vegetation (Fig. 1). Its structure and dynamics control the provision of ecosystem services (Peters et al., 2006; Havstad et al., 2007). Many plant and animal domestications originally occurred in the Middle-East, and many of the wild relatives of domesticated species are still extant in their centers of origin in desert areas (Batanouny, 1999). However, these ancestral forms are gradually disappearing as a result of excessive resource exploitation.

The objectives of the current study were to: (1) identifying the goods and services provided by desert ecosystems with emphasis on those made available by the native plants, (2) highlight the link between the goods and services provided by

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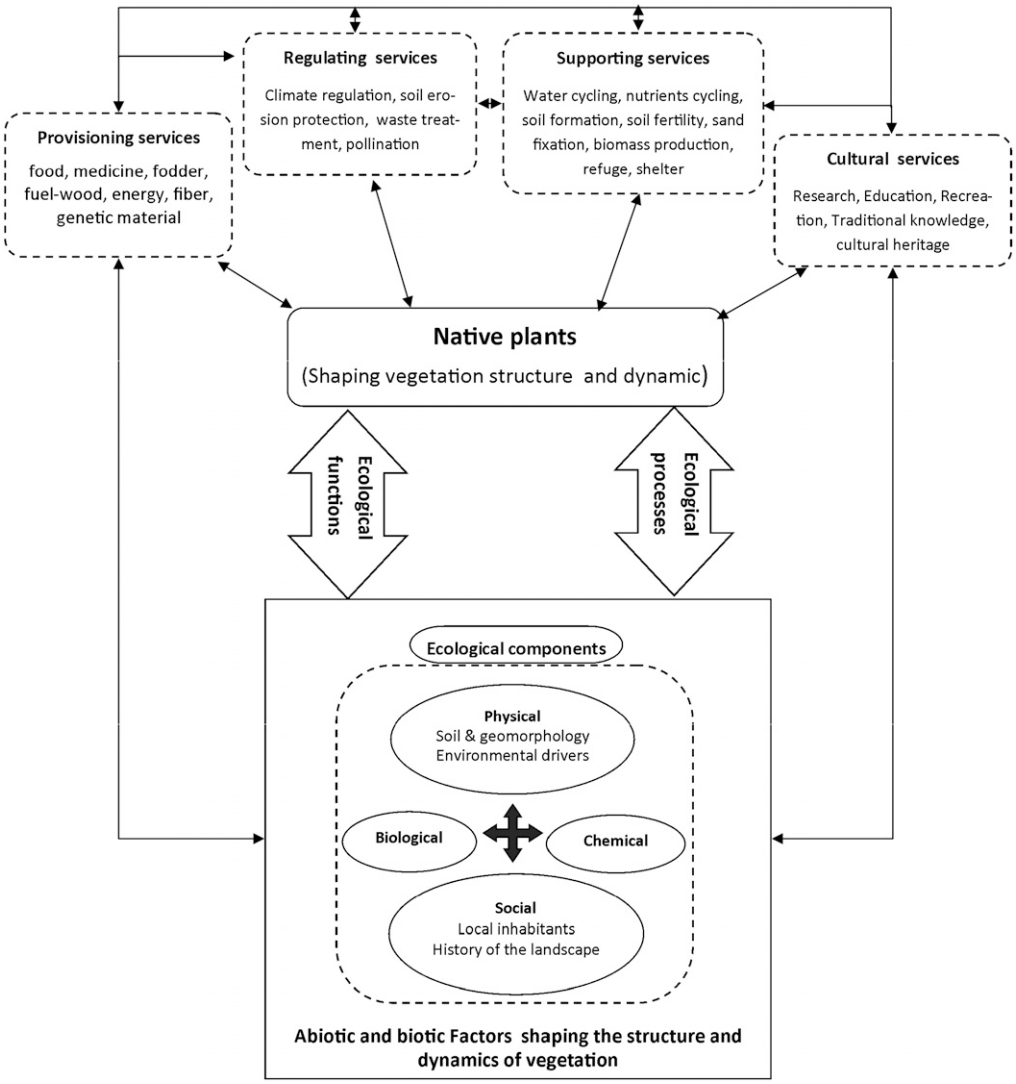

Fig. 1. Important factors of desert ecosystems interacting to shape vegetation structure and dynamics, and influencing the provision of goods and services (after Havstad et al., 2007).

the ecosystems and socioeconomic benefits for the local communities, and (3) identify the main stresses and threats to the ecosystems that may hinder the sustained delivery of the goods and services.

1.1. Characteristics of northwestern coastal deserts

The northwestern coastal region of Egypt covers an area of approximately 2.4 million ha (Abd El Kader and Ahmed, 1981), representing about 16.6% of the total national terrain. This region may be subdivided into three geomorphologic divisions (Gad et al., 1999): a northern coastal plain, an intermediate pediment plain and a southern tableland plateau. The northern coastal plain is generally subdivided into two distinct physiographic areas each with its own particular topographical features (FAO, 1970): (a) the area from Alexandria to El-Alamein, which includes three main ridges running parallel to the coast and flat depressions between them (the eastern province), and (b) The area from El-Alamein to Ras El-Hikma (the western province), which consists of an irregular succession of alternating low hills and closed depressions sloping in a south–north orientation. There is an almost continuous range of dunes running along the coast. Morphological characteristics of the major geomorphic units in the eastern and western provinces of the study area are summarized in Table 1.

1.1.1. Soils

The soils of the northwestern coast are very calcareous. There are at least four sources of soil parent materials (Gad et al., 1999). The lower coastal plain includes loose sand dunes and sheets, which are considered best-suited for fig cultivation.

Table 1
Morphological characteristics of the major geomorphic units in the eastern and western provinces within the study area (after Shaltout, 1983).

Geomorphic units	Eastern province	Western province
Coastal plain	Wide (about 6 km); more than one oolitic limestone ridge present; highly dissected by drainage lines.	Narrow (few meters to 1 km); one oolitic limestone ridge present; slightly dissected by drainage lines.
Piedmont plain	Facing the high cliffs of the tableland; covered by a thick mantle of alluvial deposits; wide; highly dissected by drainage lines.	Merges gradually through the tableland; covered by relatively thin mantle of alluvial deposits; narrow; slightly dissected by drainage lines.
Tableland	Abrupt tilting toward the north; cliffs facing the Mediterranean Sea; highly dissected by drainage lines.	Gradual tilting toward the north; no cliffs; slightly dissected by drainage lines.
Drainage basins	Large differences in elevation relative to the piedmont plain (±50 m); numerous structural noses; long, dense, deep, complex; numerous meanders.	Small differences in elevation relative to piedmont plain (few meters); few structural noses; short, slight, shallow, simple; no slight meanders.

Oolitic sand ridges, locally covered with shifting oolitic sand, are much older and cementation is therefore pronounced. The inter-ridges depressions and slopes have relatively weathered soils with resulting loamy sand textures. The upper coastal plain includes former ridges, inland dunes, inter-ridge depressions and plains, windblown sand formation, rocky ridges and complex areas. The topography of former ridges and inland dunes ranges from almost flat to undulating. The calcium carbonate content is relatively low compared with soils of the coastal ridges. The land is covered with relatively dense vegetation. The inter-ridges and plains have the best fine loamy soils across the area. The calcareous loamy material is brought down as alluvial and colluvial deposits from neighboring high lands. The deepest soils in this landscape are suitable for grain crops, vegetables, vineyards and olive plantations, which are presently in production in some locations. The shallower soils of the region are suitable for grazing or limited cultivation, but erosion control is an issue for agriculture in any form.

The topography of the rocky ridges is generally undulating to rolling. The uppermost sections of the ridges may be rocky, but in lower sections the sand grains are firm when wet and slightly hard when dry. The soils have poor potential for agriculture, although they can be moderately improved by specific agricultural practices (Rashad, 2002).

1.1.2. Water resources

The ecological service that most directly links growing human populations to arid-land ecosystems is water supply (Havstad et al., 2007). Apart from the coastal strip, most of the northwestern desert is within the arid region. Water resources are scarce and variable. The local populace has developed a wide range of strategies for managing and harvesting water resources in this region, which has a diversity of water sources and varied irrigation schemes. Rainwater and groundwater were once the basis of life and economic activity in the coastal territories. Groundwater makes a substantial contribution to the natural water supply in the region. Rainfall is irregular and variable, with an annual average of 150 mm (Migahid et al., 1971).

Some of the runoff water is captured in cisterns each with a capacity in the range of 200–1000 m^3. The water from cisterns may be used for municipal purposes or irrigation. Wadis receive a considerable proportion of the runoff (*ca.* 4×10^6 m^3 yr^{-1}; Pavalov, 1962). The alluvial lands on the floors of the wadis receive runoff water that is used for cultivation of olives and other fruit trees (Migahid et al., 1971).

Groundwater aquifers in the area are all at shallow depths and charged by precipitation that falls on the coastal plain and on the plateau. There are about 150 active water wells, some of which operate with turbine pumps. Wells are less than 5 m deep in the coastal region and their water is used for municipal and irrigation purposes. Deeper wells (to 50 m depth) occur $\geq$10 km from the coast, and their water is used for municipal purposes only (SUMAMAD, 2003; Migahid et al., 1971).

1.1.3. Biodiversity

The region encompasses sets of interlinked habitats in a relatively small area. These habitats range from marine waters, sandy beaches, coastal calcareous sand dunes, saline and non-saline depressions, inland ridges, limestone plateau, inland siliceous sand formations, and manmade rain-fed farms (Salem, 2003; SUMAMAD, 2003). These habitats support diverse floras and faunas (e.g., habitats of the Omayed region support more than 250 species of flowering plants, 300 invertebrates, 200 birds, 30 herpetofauna and 28 mammals, some of which are endemic and threatened; Shaltout and Al-Sodany, 2002). Floristically, the Mediterranean coastal land of Egypt is one of the nation's richest phytogeographical regions. El-Hadidi and Hosni (2000) indicated that 1060 species or 51% of the total flora of Egypt is in this territory. About 321 species are confined in their distribution to specific habitats found in this territory; two thirds are typical of the Mediterranean chorotype. Four plant species are known to be endemic to this territory; they have not been recorded elsewhere in the country: *Allium mareoticum* Bornm & Gauba, *Echinops taeckholmianus* Ainin, *Fumaria microstachys* Hausskn, and *Helianthemun sphaerocalyx* Gauba & Spach (Boulos, 1995).

2. Material and methods

The present study was based on field studies extending through the northwestern coastal desert of Egypt from Burg El-Arab to El-Salloum (Fig. 2). Eighty-seven stands were selected for deployment of ten transects aligned in a north–south

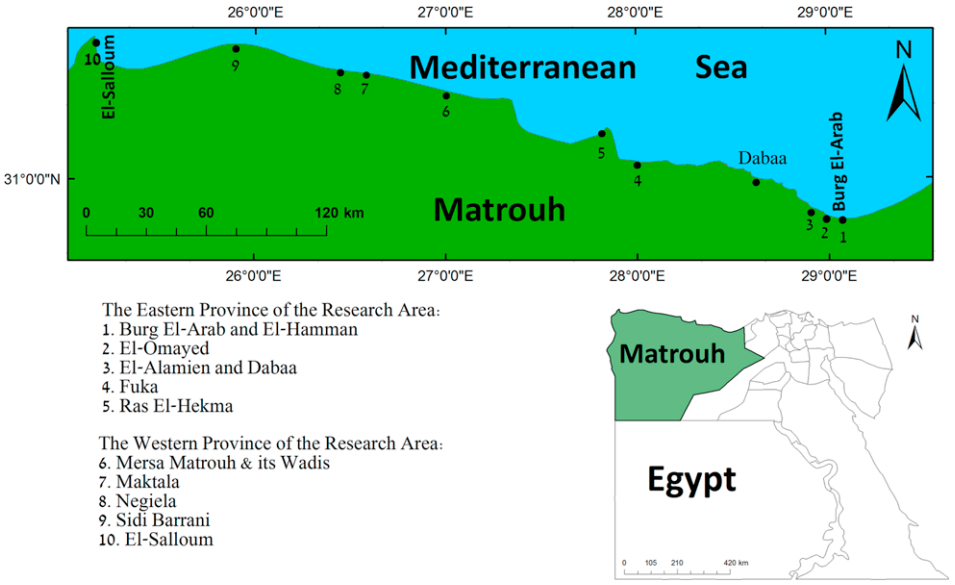

Fig. 2. Map of the northwestern coastal desert of Egypt within the jurisdiction of Matrouh Governorate, showing locations of the ten transects deployed across the study area.

orientation; each stand between Burg El-Arab City and El-Salloum had an area of 100 × 100 m^2. We compiled a detailed description of each stand, including information on topography, geomorphology, geology, and soil. We estimated vegetation cover and the human and/or animal impact on the flora, and compiled a list of the vascular plants present. Plant specimens were collected for pressing on herbarium sheets and later identification of species. Identification and the nomenclature followed Täckholm (1974), Boulos (1995, 2009). The voucher plant material and herbarium specimens of the species recorded have been deposited in Alexandria University Herbarium (ALEX).

We assembled existing knowledge on the services provided by the native plants and their uses through interviews and administered questionnaires in the period January 2005 through June 2006. Data were collected from 76 informants (46 male and 30 female) representative of two age groups (35–50, >50 years old) living in 16 villages incorporated in eight municipalities (ElHamam, Sidi Barani, ElNegilla, Matruh, Ras ElHekma, Dabaa, Alemain, and ElHamam). The informants were selected using the snowball sampling method (Bernard, 2002). We focused on those known to have knowledge or regularly use of plants for medicinal or other purposes. Consent was obtained before conducting interviews, and researchers adhered to the ethical guidelines of the International Society of Ethnobiology (ISE, 2006). Interviews were carried out in local inhabitants' houses, in fields, and in herbalists' shops, where informants were asked to show the researchers the native species used for diverse purposes.

The questionnaire comprised two sections; the first assembled socio-demographic data (gender, age, marital status, education, income, occupation… etc.) and the second compiled information on traditional knowledge that local inhabitants had about the native plant species growing in their surrounding areas: their uses and value to humans, and the dependence of the populace on these plants for economic activities and other traditional uses. We collected the following information: vernacular names of plant species, local folk medicinal uses of plants, plant part(s) used in treatment, methods of preparation, administration procedures, and other local uses. We then analyzed these data to identify the services provided by native plant species.

3. Results and discussion

3.1. Floristic composition

The vegetation of the area consisted mainly of xerophytes. We compiled a list of 322 plant species (Table 2) belonging to 218 genera and 58 families. The composites contributed most to the total complement (16.0%), followed by the Gramineae (13%), chenopods (10.0%) and legumes (9%). Most of the species recorded had restricted distributions and are considered to be threatened nationally (Ayyad, 1993). Species richness appeared low compared to previous records by Täckholm (1974) for the western Mediterranean coastal region of Egypt (532 plant species in 66 families). Changes in land use in the area might be responsible in part for the disappearance of some of the species (Salem, 2003; Abd El-Kawy et al., 2011; Halmy, 2012). In her records, Täckholm ranked 191 species as 'very rare', 177 as 'rare', and 164 as common or abundant. Ayyad (1993) has maintained that the rankings by Täckholm (1974) should be viewed with some reservation because of potential inaccuracies. A few species that were recorded as common may now be rare or vice versa. Bidak et al. (2013) reported that

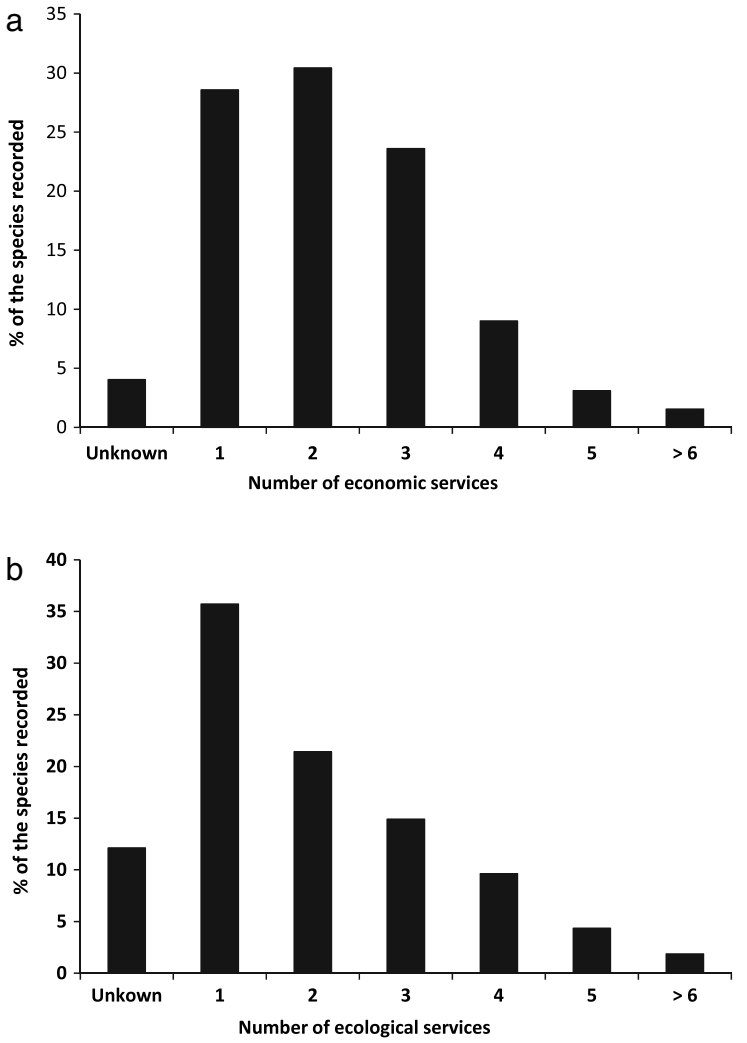

Fig. 3. Proportion (%) of recorded species assigned to classes by number of (a) economic, and (b) ecological services they provide.

62 of the species previously recognized as very common or common by Täckholm are now threatened in this region. For example *Aegilops kotschyi*, *Biscutella didyma*, *Bryonia cretica* and *Gagea fibrosa* are considered to be endangered, and *Prasium majus* is considered as vulnerable. On the other hand, *Colchicum ritchii*, which was previously considered to be rare, is currently listed as common.

Of the eleven habitats we distinguished in the area, the wadis had the highest species richness (171 species; Table 3), followed in rank order by rocky and consolidated dunes, which supported 98 species, and coastal sand dunes that harbored 89 species. El-Sallum plateau had the lowest species richness (22 species); saline habitats that included salt marshes and saline depressions supported 48 species. The wadis bore the largest numbers of unique and the medicinal species (47 and 101 species, respectively).

Species we encountered provided many ecological services and economic uses (Table 2). More than two third of the species compiled had at least one known economic use (Fig. 3); thirteen had none. The main economic uses of the species in the region included grazing fodder, medicines, fuel wood and human food. Other uses included tanning, fencing and windbreak construction, ornamental purposes, handicraft materials, detergent, rope fibers, thatch and shelter materials.

In addition to their economic importance, the native plants in the region play important ecological roles, such as reducing soil erosion, promoting soil formation, and sand fixation. The most influential ecological services provided by the native plants in the region included sand fixation (71% of species provided this service), water storage (13%), refuge (13%), salt tolerance (12%), and contribution to soil fertility (10%). Many species encountered have the ability to tolerate salinity through formation of phytogenic mounds (e.g., *Ammophila arenaria, Artemisia monosperma, Limoniastrum monopetalum* and *Nitraria retusa*), which help in fixation of sand and provide refuge and shelter for many other species.

Below, we consider the most important services provided by native plants in this desert area and the ways in which the livelihoods of the local communities depend upon these plants.

Table 2
Ecological and economic services provided by the species recorded in the study area. Economic services are coded as follows: Gr, grazing; Md, medicinal; Ar, aromatic source; Ed, edible food; Fu, fuel wood; Ta, Tanning; Fe, fencing and windbreaks; Or, ornamental; Han, used in making handicrafts; De, detergent; Ot, others, such as rope making, thatching and shelter materials. Ecological services are coded as follows: Es, esthetic value; Re, refuge; Sf, sand stabilization; Sh, shading; Sr, soil fertility; St, salt tolerance; Wb, windbreak (natural); We, weed; Ws, water storage; Ot, others, such as provision of pollen to bees and bioremediation potential.

Species	Economic services	Ecological services
Achillea santolina L.	Gr, Md, Ar, Fu	Sf, Sh, Es
Adonis dentata Delile	Gr, Md, Ar, Ot	Sf, Es, Sh
Aegilops kotschyi Boiss.	Gr, Md, Fu	Sf
Aeluropus lagopoides (L.) Trin. ex Thwaites	Gr, Ed, Fu	Sf, St
Aeluropus littoralis (Gouan) Parl.	Gr	St
Agathophora alopecuroides (Delile) Fenzl ex Bunge	Gr	
Ajuga iva (L.) Scherb.	Gr, Md, Ar	Sf
Alhagi graecorum Boiss.	Gr, Md, Ed, Fu	Sf, Wb, Sr, Ot
Allium roseum L. var. *tourneuxii* Boiss.	Gr, Md, Ed	Sf
Ammophila arenaria (L.) Link	Gr, Fu	Sf, Sh, Wb
Anabasis articulata (Forssk.) Moq.	Gr, Md, Fu, De, Ot	Sf, Sh, Wb, Re
Anabasis oropediorum Maire	Gr, Md, Fu	Sf, Sh, Wb, Re
Anacyclus monanthos L.	Gr, Fu	Sf, Wb, We
Anagallis arvensis L.	Gr, Md	Es
Anchusa hispida Forssk.	Gr	Sf
Anchusa milleri Willd.	Gr	
Anthemis retusa Delile	Gr, Md, Ar	Sf, Es
Argemone mexicana L.	Md	We
Argyrolobium uniflorum (Decne.) Jaub. & Spach	Gr, Md, Fu	Sf, Sh, Wb, Sr
Arisarum vulgare var. *veslingii*	Gr, Md, Ed	Sf, St
Seriphidium herba-album (Asso) Soják	Gr, Md, Ar, Fu, Ed	Sf, Sh, Wb
Artemisia monosperma Delile	Gr, Md, Fu	Sf, Sh, Wb, Re
Arthrocnemum macrostachyum (Moric.) K. Koch	Gr, Md, Fu, Ot	Sf, Sh, Wb, Re, St, Ws
Asparagus aphyllus L.	Gr, Md, Fu	Sf, Wb, Sh, Es
Asparagus stipularis Forssk.	Gr, Md, Fe, Fu, Ot	Sf, Sh, Wb, Es, Re
Asphodelus aestivus Brot.	Gr, Md, Fu, Or, Ot	Sf, Sh, Wb, Es, Ws
Asphodelus viscidulus Boiss.	Gr, Md, Fu	St
Aster squamatus(Spreng.) Hieron ex Sod	Gr, Md	St, Ot
Asteriscus spinosus (L.) Sch. Bip.		Sf
Asteriscus hierochunticus (Michon) Wiklund	Gr, Md	Sf, Es
Astragalus annularis Forssk.	Gr, Md	Sf, Sr
Astragalus boeticus L.	Gr, Md	Sr
Astragalus caprinus L.	Gr, Md	Sf, Sr
Astragalus mareoticus Delile	Gr	Sf
Astragalus sieberi DC	Gr, Md, Fu	Sf, Sh, Wb, Es, Sr, Re
Astragalus spinosus(Forssk.) Muschl.	Gr, Md, Fu	Sf, Sh, Wb, Es, Sr, Re
Atractylis carduus (Forssk.) C. Chr.	Gr, Md	Sf, Sr
Atractylis prolifera Boiss.		We
Atriplex halimus L.	Gr, Md, Ed, Fu, Or, Ot	Sf, Sh, Wb, Re
Atriplex leucoclada Boiss.	Gr	St
Atriplex nummularia Lindl.	Gr, Md, Fu	Sf, Sh, Wb, Re
Atriplex prostrata Boucher ex DC.	Gr	St
Atriplex semibaccata R. Br.	Gr, Md	Sf, Sh
Avena barbata Pott ex Link	Gr, Md	Sf, We
Avena fatua L.	Gr	
Bassia indica (Wight) A. J. Scott	Gr, Md, Ed, Fu	Sf, Sh
Bassia muricata L. (Asch.)	Gr, Md, Fu	Sf, Sh, Ws
Beta vulgaris L.	Gr, Ed	St
Biscutella didyma L.	Gr, Md	Sf
Blepharis edulis (Forssk.) Pers.	Gr, Md	Sf, Es
Brachypodium distachyum (L.) P. Beauv.	Gr	We
Brassica tournefortii Gouan	Gr, Md, Ar, Ed, Ot	Sf, Ws
Bromus catharticus Vahl.	Gr, Ed	
Bromus rubens L.	Gr, Md	Sf
Bupleurum semicompositum L.	Gr, Md, Ar, Fu, Ed, Ot	Sf, Es
Cakile maritima Scop.	Gr, Md, Ar, Ot	Sf, Sh, Wb, St
Calendula arvensis L.	Gr, Md	Sf, Es
Calligonum polygonoides L.	Gr, Md, Fu, Ta, Ot	Sf, Sh, Wb, Re
Capparis spinosa.L.	Md, Ar, Fu, Ed	Sf, Sh, Es, Re
Carduncellus eriocephalus Boiss.	Gr, Md	Sf, Sh, Es
Carduus getulus Pomel	Md	We
Carrichtera annua (L.) DC.	Gr, Md	Sf
Carthamus lanatus L.	Gr, Md, Fu	Sf, Sh, Wb, Re

(continued on next page)

Table 2 (*continued*)

Species	Economic services	Ecological services
Centaurea glomerata Vahl.	Gr, Md, Fu	Sf, Sh, We
Centaurea alexandrina Delile	Gr, Md	Sf, Sh, We
Centaurea calcitrapa L.	Gr, Md, Ed	Sf, Sh, Re
Centaurea pumilio L.	Gr, Md	
Centropodia forskaolii (Vahl) Cope	Gr, Md	Sf
Chenopodium album L.	Gr, Ed	
Chenopodium murale. L.	Md, Ar, Ed	Sf
Chenopodium opulifolium Schrad. Ex Koch & Ziz	Ed	
Chiliadenus candicans (Delile) Brullo	Gr, Md	Sf, Es
Cichorium endivia L. subsp.*divaricatum* (Schousb.) P.D. Sell	Md, Ed	
Cistanche phelypaea (L.) Cout.	Md, Ta, Ot	Sf, We
Cistanche tubulosa (Schenk) Hook. f.	Md	We
Citrullus colocynthis (L.) Schard.	Gr, Md, Fu	Sf, Sh, Re
Cleome amblyocarpa Barratte & Murb.	Md, Ar, Fu, Ot	Sf, Sh, Wb
Colchicum ritchii R. Br.	Md	Sf, Es, We
Convolvulus althaeoides L.	Gr, Md	Sf, Es
Convolvulus arvensis L.	Gr, Md, Fu	Sf, Es, Sh, Re
Convolvulus lanatus Vahl	Gr, Md, Fu	Sf, Sh, Wb, Es, Re
Conyza bonariensis (L.) Cronquist	Gr, Md, Fu	Sf
Coronopus squamatus (Forssk.) Asch.		St
Cotula cinerea Delile	Gr, Fu	Sf, Wb
Cressa cretica L.	Md, Fu	Sf
Crucianella aegyptiaca L.		Sf
Crucianella maritima L.	Md	Sf
Cuscuta planifolora Ten.	Md	Sf
Cutandia dichotoma (Forssk.) Trab. in Batt. & Trab.	Gr	Sf
Cutandia memphitica (Spreng.) Benth.	Gr	Sf, Sr
Cynodon dactylon (L.) Pres.	Gr, Md, Fu	Sf, Sh, Re
Cyperus capitatus Vand.	Gr	
Cyperus rotundus L.	Gr, Md	Sf, Re
Dactylis glomerata L.	Gr, Md	Sf, Sh, Re
Datura metel L.	Md, Ar	Sf
Daucus syrticus Murb.	Gr, Md, Ar	Sf
Deverra tortuosa (Desf.) DC.	Gr, Md, Fu, Ar, Ed, Ot	Sf, Wb, Es, Ws, Re
Didesmus aegyptius (L.) Desv.	Gr, Md, Ar, Ed	Es
Diplotaxis simplex	Gr, Md, Ar, Ed	Sf
Ebenus armitgei Schweinf. & Taub.	Gr, Md	Sf, Sh, Wb
Ecballium elaterium (L.) A. Rich.	Md	
Echinops hussonii Boiss.	Gr, Md, Ed	Re, Ws
Echinops spinosus L.	Gr, Md, Fu, Ed	Sf, Wb, Ws, Re
Echiochilon fruticosum Desf.	Gr, Ed, Fu	Sf, Wb, Es, Re
Echium angustifolium Mill	Gr, Md, Fu	Sf, Wb, Es, Re, Ws
Elymus farctus (Viv.) Runemark ex Melderis	Gr	Sf, Wb
Emex spinosa (L.) Campd.	Gr, Md, Ed	Sf
Eminium spiculatum (Blume) Schott	Md	Sf, Ws
Enarthrocarpus strangulatus Boiss.	Gr, Md, Ar	Sf, Es
Ephedra alata Decne.	Md	Sf, Sh, Wb, Es
Erodium cicutarium (L.) L'Hér.	Gr, Md, Or	Sf, We
Erodium crassifolium L'Hér.	Gr, Ed, Or	St
Erodium laciniatum (Cav.) Willd.	Gr, Md	Sf
Erucaria pinnata (Viv.)Täckh. & Boulos	Gr, Md, Ar	Sf
Eryngium campestre L.	Md	Sf, Es
Euphorbia granulata Forssk.	Md	Sf, Es
Euphorbia helioscopia	Md	Sf
Euphorbia hierosolymitana Boiss.	Md	Sf
Euphorbia paralias L.	Md	Sf
Euphorbia peplis L.	Md	Sf
Euphorbia peplus L.	Md	Sf
Euphorbia retusa Forssk.		Sf
Eurca sativa Mill.	Gr, Md, Ed	
Fagonia arabica L.	Gr, Ed, Fu	Sf
Farsetia aegyptia Turra	Gr, Md	Sf
Farsetia longisiliqua Decne.	Gr	Sf
Filago desertorum Pomel1	Gr, Md, Ar, Ot	Es
Foeniculum vulgare Mill.	Gr, Md, Ar	Sf, Wb, Es
Frankenia pulverulenta L.	Gr	St
Frankenia revoluta Forssk.	Gr, Md, Ed, Fu	Sf, Wb, Ws
Fumana thymifolia (L.) Spach ex Webb	Md	Sf
Fumaria densiflora DC.	Gr	

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Table 2 (*continued*)

Species	Economic services	Ecological services
Fumaria parviflora Lam.	Gr, Md	Sf
Gagea fibrosa (Desf.) Schult. & Schult. f.	Gr, Md, Fu	Sf, Es
Glebionis coronaria (L.) Tzevlev	Md, Ar, Or	Sf, Wb, We, Ot
Globularia arabica Jaub. & Spach.	Gr, Md, Fu	Sf, Sh, Wb, Ws, Re
Gymnarrhena micrantha Desf.	Gr	Sf, Ot
Gymnocarpos decanderus Forssk.	Gr, Md, Fu	Sf, Sh, Wb, Ws, Re
Halocnemum strobilaceum (Pallas) M. Bieb.	Gr, Md, Ot	Sf, Wb, Re
Haloxylon salicornicum (Moq.) Bunge ex Boiss.	Gr, Fu, Or, Ot	St
Haloxylon scoparium Pomel	Md, Ot	
Haplophyllum tuberculatum (Forssk.) Juss.	Md, Ar, Fu, Ed, Ot	Sf, Wb, Es
Helianthemum kahirikum Delile	Gr, Md, Fu	Sf, Wb, Es
Helianthemum lippii (L.) Dum. Cours.	Gr, Md, Fu	Sf, Wb, Es
Helianthimum stipulatum (Forssk.) C. Chr.	Gr, Md, Fu	Sf, Wb, Es
Herniaria hemistemon	Gr, Md	Es
Herniaria hirsuta L.	Md	We
Hippocrepis areolata Desv.	Gr, Md	Sf, Sr
Hippocrepis cyclocarpa Murb	Gr, Md	Sf, Sr
Hordeum marinum Huds.	Md	
Hordeum murinum L. subsp. *leporinum* (Link.) Arcang.	Gr, Md	Sf
Hordium murinum L.	Gr, Md	Sf
Hyoscyamus muticus L.	Md, Ar	Sf, Wb, Ws
Hyoseris radiata L.	Gr, Md	Sf, Ws, We
Hyoseris scarba. L.	Gr, Md, Ot	Sf, Es
Ifloga spicata (Forssk.) Sch. Bip.	Gr, Md, Ot	Es
Imperata cylindrica (L.) Raeusch.	Gr, Md, Han	Sf, Wb
Juncus acutus L.	Gr, Han, Ot	Sf, Wb, St
Juncus rigidus Desf.	Gr, Ot	Wb, St, Re, Ot
Kickxia aegyptiaca (L.) Nábelek	Gr, Md, Fu	Wb, Es
Lactuca serriola L.	Gr, Md	Sf
Lathyrus gorgonei Parl. var *lineatus* (Post) C. C. Towns.	Gr, Md	Sf, Sr
Launaea capitata (Spreng.) Dandy	Gr, Ed	Sf
Launaea nudicaulis (L.) Hook. F.	Gr, Md	Sf, Es
Launaea fragilis (Asso) Pau subsp. Fragilis	Gr, Md	Sf, Wb
Launaea mucronata (Forssk.) Muschl.	Gr, Md	Sf
Leontodon hispidulus (Delile) Boiss.	Gr, Md	Sf
Leontodon tuberosus L.	Gr	
Limbarda crithmoides (L.) Duormt.	Ed	St, Ot
Limoniastrum monopetalum (L.) Boiss.	Md, Fu	Sf, Wb, Ws, Re, St
Limonium pruinosum (L.) Chaz	Md	
Limonium tubiflorum (Delile) Kuntze	Gr, Md, Fu	Sf, Wb, Es
Linaria albifrons (Sm.) Spreng.	Gr	Sf, Es
Linaria micrantha (Cav.) Hoffmanns. & Link		
Lobularia arabica (Boiss.) Muschl.	Gr, Md	Sf
Lobularia maritima (L.) Desv.	Gr, Md	Sf
Lolium multiflorum Lam.	Gr, Md	
Lolium perenne L.	Gr, Md, Fu	Sf
Lolium temulentum L.	Gr, Md, Fu	
Lotus arabicus L.	Gr	Sr
Lotus creticus L.	Gr, Md	Sf, Sr
Lotus glaber Mill.	Gr, Md	Sf, Es, Sr
Lotus halophilus Boiss. & Spruner	Gr, Md	Sf, Sr
Lotus polyphyllos E. D. Clarke	Gr, Md	Sf, Wb, Sr
Lycium europaeum L.	Gr, Md, Fe, Fu, Ed, Ot	Sf, Sh, Wb, Sr, Ws, Re
Lycium shawii Roem. & Schult.	Gr, Md, Fu, Ed	Sf, Sh, Wb, Ws, Re
Lygeum spartum Loefl. ex L.	Gr, Md, Han, Ot	Sf, Wb, Ws
Malva parviflora L.	Gr, Md, Ed	Sf
Malva sylvestris L.	Gr, Md, Ed	Sf
Marrubium vulgare L.	Gr, Md, Ar, Fu	Sf, Wb
Matthiola longipetala (Vent.) DC. *subsp. livida* (Delile) DC.	Gr, Md	Sf
Matthiola longipetala (Vent.) DC. subsp. *longipetala*	Gr, Md	Sf, Sr
Medicago coronata (L.) Bartal.	Gr	Sr
Medicago littoralis Rohde ex Loisel.	Gr, Md	Sf, Sr
Medicago polymorpha L.	Gr, Md	Sf, Sr
Medicago rigidula (L.) All.	Gr, Md	Sf, Wb, Sr
Medicago sativa L.	Gr	Sr
Melilotus indicus (L.) All.	Gr, Md	Sf
Mesembryanthemum crystallinum L.	Md, Ed, Or	Ot
Mesembryanthemum nodiflorum L.	Ed	Ot

(continued on next page)

Table 2 (*continued*)

Species	Economic services	Ecological services
Moltkiopsis ciliata (Forssk.) I. M. Johnst.	Gr, Md, Fu	Sf, Wb, Es
Moraea sisyrinchium (L.) Ker Gawl.	Md	Sf, Ws, Ot
Moricandia nitens (Viv.) Durand & Barratte	Gr, Md, Fu	Sf, Sh
Muscari neglectum Guss.	Md	Wb, Ws
Narcissus tazetta L.	Gr, Md, Ar	Sf, Wb, Es
Neurada procumbens L.	Ed	
Nicotiana glauca R. C. Graham	Md	Sf
Nitraria retusa (Forssk.) Asch.	Gr, Fu	Ot
Noaea mucronata (Forssk.) Asch. & Schweinf.	Gr, Fu, Ed	Sf, Wb, Re
Onobrychis crista-galli (L.) Lam.	Gr, Md	Sf, Wb, Sr
Ononis serrata Forssk.	Gr, Md	Sf
Ononis vaginalis Vah	Gr, Md, Fu	Sf, Sh, Wb, Es, Sr, Re
Onopordum alexandrinum Boiss.	Gr, Md	Sf, Wb
Ornithogalum trichophyllum Bioss. & Heldr.	Gr, Md, Ar	Sf, Es
Orobanche ramosa L.		We
Oryzopsis miliacea (L.) Asch. & schweinf.	Gr	Sf
Osteospermum vaillantii (Decne.) Norl.	Gr, Md	Sf, Es
Otanthus maritimus (L.) Hoffmanns. & Link	Gr, Md	Sf, Wb, Es
Pancratium maritimum L.	Md, Or	Sf, Es
Pancratium sickenbergeri Asch. & Schweinf.	Md	Sf, Es
Panicum turgidum Forssk.	Gr, Md, Ed, Fe Ot	Sf, Sr
Papaver rhoeas L.	Md	Sf, Es
Parapholis marginata Runemark	Gr	St
Paronychia arabica (L.) DC. var. *longiseta* Asch.	Gr, Md, Ed	Sf
Paronychia argentea Lam.	Gr, Md, Ed	Sf, Es
Paronychia capitata (L.) Lam.	Gr, Md	Sf
Peganum harmala L.	Md, Ar, Ot	Sf, Wb, Es, Ws
Periploca angustifolia Labill.	Md	
Phagalon rupestre (L.) DC.3	Md	
Phagnalon schweinfurthii Sch. Bip. ex Schweinf.	Gr, Md	Sf, Es
Phalaris minor Retz.	Gr	Sf
Phalaris paradoxa L.	Gr	
Phlomis floccosa L.	Gr, Md, Fu	Sf, Wb, Es
Phoenix dactylifera L.	Md, Ed, Fe, Or, Han, Ta, Ot	Sh, Ot
Phragmites australis (Cav.) Trin. ex Steud.	Gr, Md, Fu, Ed, Fe, Ot	Sf, Wb, Re, Ws, Ot
Picris altissima Delile	Gr	
Plantago albicans. L.	Gr, Md	Sf, Ws
Plantago crassifolia Forssk.	Gr	St
Plantago crypsoides Boiss.	Gr, Md	Sf
Plantago lanceolata L.	Md	
Plantago major L.	Gr, Md	Sf, Es
Plantago ovata Forssk.	Gr, Md, Ar,	Sf
Polygonum equisetiforme Sibth. & Sm.	Gr, Md, Ar, Ed	Sf, Es, Ws
Polygonum maritimum L.	Gr, Md	Sf
Polypogon monspeliensis (L.) Desf.	Gr	
Polypogon viridis (Gouan) Breistr.	Gr	
Posidonia oceanica (L.) Del.	Md	
Prasium majus L.	Gr, Md, Ar, Fu	Sf, Wb, Re
Pseudorlaya pumila (L.) Grande	Gr	Sf
Pulicaria arabica (L.) Cass.	Md	
Ranunculus bulbosus L.	Md	Sf
Reaumuria hirtella Jaub. & Spach	Md	Sf, Wb, Ws
Reichardia tingitana (L.) Roth	Gr, Md, Or	Sf, Es, Sr, Ot
Reseda alba L.	Gr	
Reseda decursiva Forssk.	Gr, Md	Sf
Retama raetam (Forssk.) Webb & Berthel	Gr, Fu, Md	Sf, Sh, Wb, Sr, Re
Rhamnus lycioides subsp. *oleoides* (L.) Jahand. & Maire	Gr	
Rostraria cristata (L.) Tzvelev	Gr	Sf
Rumex dentatus L.	Ed, Gr	
Rumex pictus Frossk.	Ed, Gr, Md	Sf, Re, Ws, We, Ot
Rumex vesicarius L.	Ed, Gr, Md	Sf, Ws
Saccharum spontaneum L.	Md	
Salicomia fruticosa L.		Sf, Wb, Ws, St
Salsola kali L.	Ed, Md, Ot	Re
Salsola longifolia Forssk.	Gr, Md	Sf, Wb, Ws, St
Salsola tetragona Delile1	Ed, Gr, Fu, Md	Sf, Wb, Ws, St, Ot
Salsola tetrandra Forssk.	Gr, Md	Sf, Wb, Ws, St
Salsola villosa Schult.	Gr	St

(continued on next page)

Table 2 (*continued*)

Species	Economic services	Ecological services
Salsola volkensii Schweinf. & Asch.	Gr, Md	Sf, St, Ws, We
Salvia aegyptiaca L.	Ar, Fu, Gr, Md	Sf, Wb, Es
Salvia lanigera Poir.	Gr, Md, Ar, Ot	Sf, Wb, Es
Sarcocornia fruticosa (L.) A.J. Scott.	Gr, Fu, Md	Sf, Wb, Ws, St, Sr, Ot
Scabiosa arenaria Forssk.	Gr	We
Schismus barbatus Nees	Gr, Md	Sf
Scorpiurus muricatus L.	Gr	
Scorzonera undulata Vahl	Ed, Gr, Md	Sf, Es, Ws, Ot
Senecio glaucus subsp. coronopifoliusMaire C. Alexander.	Ed	We
Senecio vulgaris L.	Gr, Md	Sf, We
Silene rubella L.	Gr	St
Silene succulenta Forssk.	Md, Or	
Silene villosa Forssk.	Md, Ot	Sf
Silene vivianii Steud.		We
Silybum marianum (L.) Gaertn	Ed, Gr, Md	Sf, Wb, Ws, Re
Sinapis arvensis L.	Gr	
Sisymbrium irio L.	Gr	
Solanum nigrum L.	Ed, Md	Sf
Sonchus oleraceus L.	Ed, Md	Ws, We
Spergula fallax (Lowe) E. H. L. Krause	Gr	St, We
Spergularia diandra (Guss.) Boiss.		St, We, Ws
Spergularia marina (L.) Griseb.	Gr	Ws
Sphenopus divaricatus (Gouan) Rchb.	Or, Ot	St
Stipa capensis Thunb.	Gr	Sf
Stipa plumosa (L.) Munro ex T. Anderson	Md	
Stipagrostis ciliata (Desf.) De Winter	Gr	Sf
Stipagrostis scoparia (Trin. & Rupr.) de Winter	Gr, Md	Sf, Sr
Suaeda pruinosa Lange	Gr, Fu, Md, Ot	Sf, Wb, Ws
Suaeda vera Forssk. ex J. F. Gmel	Md, Ot	Sf, Wb, Ws, St
Suaeda vermiculata Forssk. ex J.F. Gmel.	Gr	St
Tamarix aphylla (L.) H. Krast.	Md, Or, Ot	Sh
Tamarix nilotica (Ehrenb.) Bunge	Gr, Fu, Md, Or, Ot	Sf, Sh, Wb, Ws, Re
Terfezia claveryi Chatin	Md	
Teucrium polium L.	Ar, Gr, Md	Sf, St
Thesium humile Vahl		We
Thymelaea hirsuta (L.) Endl.	Gr, Fe, Fu, Han, Md, Ot	Sf, Sh, Wb, Re
Thymus capitatus (L.) Link	Ar, Fu, Ed, Gr, Md	Sf, Wb, Es
Traganum nudatum Del.	Gr	St
Tribulus terrestris L.	Gr, Md	Sf
Trifolium resupinatum L.	Gr	Sr, St
Trigonella stellata Forssk.	Ar, Gr, Md, Ot	Sf, Wb
Typha domingensis (Pers.) Poir ex Steud.	Ed, Fu, Han, Ot	Sf, Wb, St, Ot
Uorospermum picroides (L.) F. W. Schmidt	Gr	Sf
Urginea maritima (L.) Baker	Md	Sf, Sh, Es, Re
Urginea undulata (Desf.) Steinh.	Md, Ot	Sf, Ws
Urtica urens L.		Sf
Vaccaria hispanica (Mill.) Rauschert.	Gr	Sf
Valantia hispida L.		Sf
Verbascum letoumeurii Asch. & Schweinf.	Gr, Md	Sf, Es
Vicia monantha Retz.	Gr, Fu, Md	Sf
Vicia sativa L.	Gr, Fu, Md	Sr
Xanthium spinosum L.		Sf
Zilla spinosa (L.) Prantl	Gr, Fu, Md	Sf, Sh, Wb
Zygophyllum album L.f.	Md, Ot	Sf, Wb, Ws, St

3.2. Uses of native plants

3.2.1. Medicinal plants

Of the species recorded in the study area, 236 (almost 73% of the total) were used for medicinal purposes (Table 2). Other studies have reported large number of medicinal plants in the same area. For example, Heneidy and Bidak (2004) recorded 230 plant species in the region, of which 206 were found to have medicinal uses. Medicinal herbs from the northwestern coast are a source of income, and collecting these plants is among the major economic activities in the local community. They are used to treat many diseases in both local communities and those in urban areas of Egypt (Table 4). For example, *Seriphidium herba-album* is a commonly used as anthelmintic, while *Herniaria hirsuta* is used for treating sore throats (Mossa et al., 1987; Boulos, 1983). The dried roots of *Centaurea pumili*o are used as a fattening agent. The leave and the green unripe fruits of *Solanum nigrum* are used for treating cervical inflammation, sore throat and as a diuretic (Batanouny, 1999).

Table 3
Species richness, numbers of unique species and numbers of medicinal plants in major habitats within the study area.

Habitat	Total	Unique	Medicinal
Coastal sand dunes	89	12	55
Consolidated and rocky dunes	98	5	70
El-Sallum plateau	22	10	19
Saline habitat	48	6	36
Non-saline depressions	80	8	52
Inland ridges	63	6	48
Inland plateau	56	5	42
Sand formations	63	6	44
Roadsides	56	7	40
Wadis	171	47	101
Cultivated lands	66	8	44

Table 4
Wild medicinal plants used for folk medicine in the western Mediterranean region (after Batanouny, 1999).

Plant species	Parts used	Some uses in folk medicine
Adonis dentata	Above-ground fruiting and flowering portions	Preserving strength and youth
Anchusa hispida	Leaves	Refreshing drink, rheumatism
Centaurea pumilio	Dried roots	Slices of roots added to other ingredients as a fattening agent
Colchicum ritchii	Seeds and corms	Rheumatism, gout and abdominal colic
Cyperus rotundus	Rhizome, in the form of ellipsoid tubers	Tubers are aromatic, stomachic, sedative and analgesic
Peganum harmala	Dried ripe seeds	Kidney stones
Posidonia oceanica	Flower and root	Headache, heart tonic, and root for coughs and colds
Rumex vesicarius	Entire plant	Hepatic diseases and bad digestion
Solanum nigrum	Leaves and green unripened fruits	Diuretic, cervical inflammation, sore throat
Thymus capitatus	Green and dried parts	Used as refreshing drink, for stomach diseases and cough
Teucrium polium	Stems and flowering tops	Hot infusion for intestinal troubles, steam bath for cold and fever
Tribulus terrestris	Dried aerial parts	Flower for leprosy, stem for scabrous skin diseases and psoriasis; seed for anemia and coughs
Urtica urens	Aerial parts and leaves	Rheumatism, eczema and diuretic

3.2.2. Fuel wood

About 75 species in the region, mostly woody perennials, were harvested by local communities for use as a fuel wood (Table 2). Some species were preferred over others and commonly harvested, including *Gymnocarpos decanderus*, *Lycium europaeum*, *Artemisia monosperma*, *Anabasis articulata*, *Echiochilon fruticosum*, *Noaea mucronata* and *Thymelaea hirsute* (El-Kady, 1980). These preferences put these species under the pressure (Bidak et al., 2013).

3.2.3. Human food

We found that 59 species in this region were eaten by local inhabitants (Table 2). For example, the fruits of *Lycium europaeum* and *Nitraria retusa* were collected and eaten locally. *Cichorium endivia*, *Sonchus oleraceus* and *Deverra tortuosa* were eaten as greens and added to salads. *Terfezia claveryi* is an edible fungus with high economic value. It is gathered and sold by collectors for US$ 10.50/kg to the retailers, who in turn sell it for more than double this price (Table 5). The collection of this species requires skill as it grows underground.

3.2.4. Other uses

Many species have other traditional uses, such tanning (e.g., *Calligonum polygonoides*, *Cistanche phelypaea*), detergent making (e.g., *Anabasis articulata*), rope making, handicraft supplies (e.g., *Juncus acutus*, *Juncus rigidus*, *Lygeum sparntum*, *Phoenix dactylifera*, *Typha domingensis*, *Thymelaea hirsuta*) and in the making of thatches and shelters.

3.3. Economic activities and traditional knowledge

The northwestern coastal desert lies in the jurisdiction of the Matrouh Governorate, which comprises eight districts, and 56 villages. Seven of these districts extend along the western Mediterranean coast. The total population is about 231,000, with a maximum concentration in Mersa Matrouh District and a minimum in El-Sallum. In general, societies located in

Table 5
Quantities collected, numbers of collectors, wholesale and retail prices of three important medicinal plants (*Ecballium elaterium, Terfezia claveryi*, and *Seriphidium herba-album*) in different districts of the study area.

District	Number of collectors	Quantity collected (kg)			Wholesale price (US$)			Retail price (US$)		
		E. elaterium	*T. claveryi*	*S. herba-album*	*E. elaterium*	*T. claveryi*	*S. herba-album*	*E. elaterium*	*T. claveryi*	*S. herba-album*
Matrouh	4		10	400		105	70		523	348
Hammam	3			300			52			261
Dabaa	2	200	20	200	244	209	35	3485	523	174
Barrani	3		50	300		523	52		1307	261
El-Sallum	2		50	200		523	35		1307	174
Total	14	200	130	1400	244	1359	244	3485	3659	1220

deserts suffer from low income and high unemployment due to limited natural resources. Accordingly, local inhabitants engage in a range of activities simultaneously to secure a living. The traditional activities practiced by the communities include rain-fed farming, herding grazers, raising livestock, collection of herbs and medicinal plants, and folk medicine (Ayyad and Le Floćh, 1983). Recently, other forms of activities have been developed in the region, such as the establishment of tourist resorts, real-estate businesses, intensive agriculture, and quarrying (Salem, 2003; Abd El-Kawy et al., 2011; Halmy, 2012). Women participate in the economic activities and generate revenue through involvement in raising livestock, herding grazers, and the production and marketing of wool handicrafts. We found that native plants supported a number of the economic activities practiced by local communities, as follows.

Grazing

Grazing herds in the region feed mainly on the natural vegetation supplemented with fodder. About 240 species (*ca.* 75%) in the area are used as grazing plants. They support both domestic and wild animals. Some plants in this area were found to be highly palatable and preferentially consumed by grazing animals, including *Echiochilon fruticosum*, *Plantago albicans*, *Deverra tortuosa*, *Helianthemum lippii*, *Seriphidium herba-album*, *Malva parviflora* and *Gymnocarpos decanderus* (Table 2). Field observations and information collected from the local community about grazing plants and their palatability were congruent with observations of El-Kady (1980), Heneidy (2003), Heneidy and Bidak (2004), and Heneidy (2012). We also found that most of the highly palatable species are now suffering from overgrazing as herd sizes have increased with human population growth in the study area.

Animal husbandry, especially sheep and goat breeding, is a basic Bedouin economic activity (Abu Zeid, 1991). We found that a considerable number of the local inhabitants in the study area still practiced livestock grazing, which provided food for home consumption and income. Also, raising herds of grazers is considered a prestigious activity. The local communities practice grazing on the coastal area after the rainy season. When the vegetation dries out, and depending on the length of the grazing season, they begin southward herding trips (Heneidy and Waseem, 2007) to oases or other locations where natural vegetation is better supported by underground water (e.g., Moghra Oasis; Salem and Waseem, 2006). The herders are able to live in small houses or tents in the southern locations for 3 months or more, and in many cases all family members, including women, join the herders.

Collecting medicinal plants

Medicinal herbs growing in the northwestern coastal desert are source of income and one of the major economic activities supporting local communities (Batanouny, 1999). Local community members collect medicinal plants to sell them to herb dealers and druggists. Collectors were usually in the 35–50 year age range and sufficiently experienced to know plant names, locations and methods of collection during their herding trips. Collecting medicinal plants is not a main economic activity; it is practiced along with other activities, such as farming, herding and trading. Of the large number of the medicinal plants growing naturally in Egypt, about 39 species were reported by Batanouny (1999) to be the main species used in folk medicine in Egypt. They are collected and gathered to be sold in "Attarin" or herb-seller stores, which retail to consumers in urban areas. Twenty-one of these species occurred in our study area. The most important plants, which are usually in high demand, included *Colchicum ritchii*, *Ecballium elaterium*, *Deverra tortuosa*, *Seriphidium herba-album*, *Urginea maritima*, and *Atractylis carduus*. Wild-gathered plants are prepared for retail sale. Some dealers sell either green or dried specimens. Dried plants are separated from dust by rinsing with water, followed by drying in the sun on a piece of cloth for 2 days, with subsequent packaging for sale.

According to the collectors we interviewed, each of them usually gathers on average about 200 kg of Shih (*Seriphidium herba-album*), 130 kg of Terfas or desert Truffles (*Terfezia claveryi*) and 100 kg of Torbage (*Ecballium elaterium*). The collector's return from selling 200 kg of Shih is US$ 35.00, while the dealer's is US$ 175.00 (Table 5). Dealers apply a markup on the prices they pay to the collectors (Table 6). For example, collectors in Matrouh sell 1.0 kg of *Deverra tortuosa* to herbalists for US$ 0.30; herbalists sell a 50 g package of this plant for US$ 0.90. Nevertheless, collectors are able to obtain a reasonable income from the sale of medicinal plants.

Prices of the medicinal plants fluctuated seasonally depending on supply and demand, and spatially among districts. Table 5 presents examples of price variations across districts. For example 1.0 kg of *Terfezia claveryi* is sold for US$ 10.50 in

Table 6
Values of some important traditional medicinal plants (*Urginea maritime, Deverra tortuosa, Terfezia claveryi*, and *Ecballium elaterium*) in the study area.

Latin name	Vernacular name	Price to herbalist (in US$/kg)	Price to consumer (in US$)
U. maritima	Basal pharoon	0.52	0.9 (per bulb)
D. tortuosa	Gozzah	0.3	0.9 (50 g package)
T. claveryi	Terfas	52.3	11.3 (10 g package mixed with other herbs)
E. elaterium	Torbage, Wedn El-Homar	1.2	8.7 (50 g package)

Table 7
Economic value of areas supporting the growth of *Urginea maritima* and *Ecballium elaterium*.

Details of location/habitat	*U. maritima*	*E. elaterium*
Location	Maktala	Matrouh
Area (ha)	105	0.035
Latitude (N)	31° 30′ 48.00″	31° 03′ 24.54″
Longitude (E)	26° 12′ 06.66″	28° 07′ 21.84″
Elevation (m)	45.8	40.3
Habitat type	Sand flats	Wadi bed
Uses and value		
Parts used	Bulbs	Roots, fruits
Uses	Skin diseases	Analgesic, treat hemorrhoids, treat jaundice, nocturia, lumbago, otalgia
Density (individual/m^2)	3	0.34
Price	US$ 0.87/specimen	US$ 24.22/kg
Value (US$/ha)	25,829.94	26,1369.58

Matrouh to the dealers, who retail it for US$ 52.30. *Seriphidium herba-album* is sold for US$ 0.18 in Matrouh to the herbalists, who retail it for US$ 0.87. The wholesale price in Hamam is US$ 0.17.

Our estimates of average annual values at two sites in Matrouh area, where two important medicinal plants are growing at densities of 3/m^2 (*Urginea maritime* in sand flat habitat) and 0.34/m^2 (*Ecballium elaterium* in a wadi bed habitat), are US$ 25,830/ha and US$ 26,1370 respectively (Table 7).

Folk medicine

Folk medicine is among the traditional activities in the study area (Khutb, 1981; Evans, 1998). We found that folk medicine is still the most important procedure for medication and therapy (along with other approaches, such as Hegama, takhzem and tagbeer). In the Bedouin societies, the differentiation between family and household is not clear. The Arabic word "Aila", which is used to refer to a sub-tribe, translates literally to "family". The word "bait", used to refer to an extended family that may or may not live in a single household, translates literally to "house". On average, each household comprises 14–17 people, including children and adults, women and men. Each "family" in a tribe included at least one or two persons who practiced folk medicine. We found about 65 healers in the study area, and interviewed 10 of them. Their activity depended upon traditional knowledge of medicinal herbs, plant types, locations, and remedial usefulness. Skills required were acquired through herding trips to numerous locations, and by inheriting knowledge of the traditional treatment of diseases from the elders. Traditional knowledge of medicinal plants and folk medicine has elevated the standard of living in some families by creating a source of income, thereby contributing to the economic well-being of the community. Other communities have also benefited, as many herb dealers and druggists from outside the study area depended on medicinal plants collected by local communities of the northwestern coast. The income of herbalists improved in summer with increasing numbers of visitors arriving to spend their summer vacations in the resorts along the coast.

3.4. Threats to ecological services

Egyptian deserts provide a good example of the manner in which anthropogenically-induced disturbances have resulted in habitat loss and fragmentation, leading to reduction in biodiversity and degradation of ecosystems (Ayyad and Le Floćh, 1983). Traditionally, local inhabitants had a nomadic lifestyle, moving from place to place in search for water and pasture. Recently, they started settling down, and their numbers are increasing (Abu Zeid, 1991). This in turn has led to overconsumption of natural resources, reduction in water supplies, overgrazing and increased uprooting of indigenous vegetation. The western coastal desert of Egypt has attracted large numbers of development projects in the last three decades, especially urban projects and agricultural intensification. Increasing the pressure on natural resources of the region may affect the provisioning of goods and services by the native ecosystems (SUMAMAD, 2003). Here, we highlight the main stresses and threats that may influence the provision of ecosystem services and goods, particularly those directly influencing native plants and vegetation cover as follows:

Overharvesting: An increase in the human population in the area has elevated the demand for fuel woods. Collectors usually target larger woody perennials and species that develop woody branches and roots (e.g., *Gymnocarpos decanderus*). Individual plants are obviously threatened; their removal also increases soil erosion and overall habitat degradation.

Overgrazing: Historically sparse nomadic population had small grazing herds with limited impacts on the scarce resources in the desert region (Heneidy, 1992, 2002a,b). Current increases in the human population coupled with excessively large herd sizes and stocking rates in some areas has resulted in the dominance of unpalatable perennials, such as *Thymelaea hirusta* and *Artemisia monosperma*. Annual species that are heavily browsed are disappearing and so are the palatable perennials (Heneidy and Waseem, 2007; Heneidy and Halmy, 2009). Motorized trucking now allows local inhabitants to transport their herds from one grazing site to another, thereby rapidly depleting vegetation in previously inaccessible areas. Adoption of modern techniques, availability of transportation, and supplementary feed and water allow the locals to maintain larger herds and to take them to previously unreachable areas, where they graze marginal habitats at rates far exceeding ecosystem resilience capabilities (Heneidy, 2000, 2012). These new practices threaten future human food production.

Urban development: Urban development is proceeding along the northwestern coast at an alarming rate. Many summer resorts and settlements have been established over the last two decades (Abd El-Kawy et al., 2011; Halmy, 2012). Development involves clearing native plants and the cover they provide. In consequence, some plant species have disappeared especially in coastal dune habitats (Salem, 2003). Plant cover minimizes soil erosion through surface run-off and reduces the removal of surface soil by wind scour. Removal of vegetation cover in some places in our study area has resulted in loss of surface soil and formation of a compact gravely surface layer and un-stabilized soil accumulations.

New intensive agriculture practices: One of the most serious threats to native plants in the region is the complete and irreversible destruction of habitats by modern agricultural activities. Rain-fed agriculture was practiced traditionally by the local inhabitants of the northwestern coast in small areas where they grew winter cereals, olives and fig trees (Kassas, 1972; SUMAMAD, 2003). As the local inhabitants began to settle down, they started to practice modern intensive agriculture over larger areas. The establishment of new irrigation canals in the coastal area has made these intensive agricultural practices possible, especially in the coastal zone where agriculture accounts for up to 70% of gross income. It is estimated that over the last two decades the terrain used for this type intensive agriculture have tripled in area at the expense of rangelands and shrub lands (Abd El-Kawy et al., 2011; Halmy, 2012). The fragile desert ecosystem is unable to support these types of intensive, unsustainable agricultural practices, which remove all the natural vegetation that previously provided refuge and shelter to wildlife, thereby causing depletion of soil nutrients, soil erosion, and reduce rangeland resources (SUMAMAD, 2003). In consequence, grazing pressure is increasing dramatically in all remaining patches of natural habitats and in marginal areas not suited for cultivation, leading to further degradation of naturally vegetated areas.

Invasive species: The new agricultural practices include introductions of non-indigenous species, such as the Australian taxa *Casuarina* sp. and *Acacia saligna*, which are used as windbreaks to protect the new agricultural areas from sand encroachments (SUMAMAD, 2003). Weeds and alien plants from the new cultivation sites have started to invade surrounding natural areas (Shaltout and Al-Sodany, 2002), threatening native plants and animals in the region.

Other threats: Quarrying, solid waste disposal and pollution generated by the dwellers in the new settlements and resorts are all threats to the desert ecosystems. They have resulted in unmistakable signs of environmental deterioration over the last few decades. Another threat worthy of mention is the decline in the number of local inhabitants holding traditional knowledge on the uses of the native plants in medicine and in other traditional uses. The new generation of the local inhabitants is no longer interested in gaining this knowledge and prefers to work in the developmental projects in the area. An action should be directed toward documentation of this traditional knowledge in order to preserve it for future generations as part of a social heritage and as a component of biodiversity preservation.

4. Conclusions and recommendations

We found a range of economic activities supported by the native plants in our study area, including food production, fuel collection, livestock herding, and medicine. Thousands of local tourists already visit the area annually for recreational purposes. In addition, to natural ecosystem benefits, the region offers educational and scientific research services. The use of rational principles for land management underpins the conservation of desert ecosystems and their services. Management should be based on a thorough understanding of the diverse potential in these ecosystems and their inherent limits. The economic value of maintaining natural vegetation that supports the provisioning of many ecological and economic services has not been adequately documented. It should be quantified and then compared with the revenue generated from new development activities. Such comparisons will promote adoption of rational land management practices and may help in maintaining the traditional knowledge and cultural heritage of the local inhabitants in the area, which are important and integral parts of the desert ecosystem. Medicinal plants generated substantial economic income for community members, thereby improving the living standard of many families within the study area. It is therefore essential to plan for sustainable plant collection to conserve the desert vegetation. Since the trade in medicinal plants represents an important source of economic income in the northwestern coastal region, we recommend a management program that incorporates the following suggestions:

- Training the collectors to be less invasive in their forays, thereby minimizing and reducing the destruction of plants. For example, harvesting should be restricted to the plant parts needed, and uprooting of the whole plant should be avoided when possible. Collectors should avoid focusing on only one location.
- Managing the relationships between collectors of medicinal plants and sellers, which might be coordinated under the umbrella of selected NGOs.

- Involving the local community in any management plan that aims at sustainable use of medicinal plants; planners should make use of their considerable experience in this field.

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