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Mapping the vegetation of Kuwait through reconnaissance soil survey

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Previous studies on the vegetation of Kuwait showed dominance of five plant communities; however, due to both natural and human factors, the vegetation has been altered. In the present study, a vegetation map was prepared by integrating soil information and vegetation information in a Geographic Information System (GIS). A reconnaissance field survey was conducted at scale 1:100,000 for the entire state excluding urban, agricultural and restricted areas. Some 8351 observation-points were assessed for vegetation and soils covering an area of 1,670,209 ha. A vegetation map was prepared constituting eight vegetation map units. In comparison with previous studies, this study showed alteration in the distribution of plant communities. Perennial shrubs constitute about 27% of the surveyed area while perennial grass and sedge constitute 67·9%. The current status of vegetation show intensive land degradation. The vegetation units can be managed after considering potential and status of the dominating plant community and soil types.

Keywords: Plant community; land degradation; vegetation surveys; plant ecology; desert ecosystem; dynamics of vegetation; Geographic Information System

Introduction

Mapping of vegetation is one of the most important phases of rangeland inventory (Stoddart *et al.*, 1975). It is helpful in developing rehabilitation programs particularly in degraded areas (De Villiers *et al.*, 1999). Grazing causes vegetation changes. It may influence vegetation composition by acting upon competition and the supply of resources (Heady & Child, 1994). Mapping and analysis of desert ecosystems can be very useful for good management (Tueller, 1998). The vegetation of Kuwait is under severe pressure from over-grazing, uprooting of shrubs, off-road vehicle traffic, recreation and other activities (Taha *et al.*, 1988; Omar & Zaman, 1995, 1998; Shahid *et al.*, 1998*a*; KISR, 1999). These pressures have been further exacerbated by impacts of oil fires, combat disturbance and subsequent military cleanup operations (Zaman &

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AlSdirawi, 1993). Mapping the vegetation of Kuwait is necessary to assess the current status of the rangeland and to suggest rehabilitation measures.

The amount of vegetation in any location is directly related to the amount of precipitation (Omar, 1990; Halwagy & Halwagy, 1974). Landform is particularly important as it influences the distribution of rainwater and surface sediments by directing them toward lower areas. The accumulation of soil material on exposed surfaces provides a favourable site for the growth of annuals and perennials. Flora of Kuwait includes 374 species belonging to 55 families. The majority are annuals, with 83 herbaceous perennials, and 34 shrubs and under-shrub species (Boulos, 1988; Boulos & Al Dosari 1994, Al-Rawi, 1987; Daoud & Al-Rawi, 1987). In the Arabian Gulf region, many publications were issued related to the ecology of the desert and the flora of the Arabian Peninsula (Betanouny, 1981; Migahid & Hammouda, 1974; Miller *et al.*, 1982; Wickens, 1982; Zohary, 1957). Of particular relevance to Kuwait is the *Flora of Eastern Saudi Arabia* by Mandaville (1990).

Dickson (1955) distinguished three plant community types: *Haloxylon salicornicum* (Moq.) Bunge ex Boiss., *Rhanterium epapposum* Oliv. and *Cyperus conglomeratus* Rottb. Kernick (1966) acknowledged these communities and included the community type *Zygophyllum qatarense* Hadidi. Macksad (1969) confirmed the presence of these communities and modified their distribution. The vegetation of Kuwait consists of perennial shrubs and ephemerals (Halwagy & Halwagy, 1974). They recognized five community types: *Haloxylon salicornicum*, *Rhanterium epapposum*, *Cyperus conglomeratus*, *Zygophyllum qatarense* and *Panicum turgidum* Forssk. These communities have developed mechanisms that allow them to exist under severe environmental conditions, including low rainfall, high temperature, dry wind and gypsic and alkaline soils. The Halwagy & Halwagy (1974) paper provides the baseline vegetation map for comparison with the present study.

Rangeland degradation in Kuwait is an increasing problem that should be addressed as a priority by gathering current information on vegetation and related soil types. Soil survey information provides basic knowledge to interpret rangeland status and potential for multiple use (Soil Survey Division Staff, 1993). Mapping of vegetation under the current rangeland status of Kuwait can provide necessary information for monitoring changes in vegetation and for suggesting rehabilitation measures, and therefore, form the focus of the present investigation.

Ecological setting

Physiography

Kuwait (about 17,818 km^2) lies at the north-eastern corner of the Arabian Peninsula and is situated within two main physiographic regions. To the south and south-west, there is a sequence of sedimentary rocks of the Arabian platform overlying the Arabian shield. To the north and north-west of Kuwait, there is the Mesopotamian plain with the Euphrates and Tigris River deltas at the head of the Arabian Gulf. There are four physiographic provinces in Kuwait: (1) Al-Dibdibah gravel plain; (2) southern desert flat; (3) coastal flat; and (4) coastal hills (Al-Sulaimi & El-Rabaa, 1994).

The surface topography is flat to gently-rolling desert plain, broken by occasional low hills, scarps and wadis. Local relief is low, except for the Jal Az-Zor escarpment (about 145 m a.s.l.), Wadi Al-Batin (about 250 m a.s.l.), Al-Ahmadi ridge (about 120 m a.s.l.), and small hills at Wara, Burgan, Umm Qudayr and Wafrah (about 100 m a.s.l.). The average gradient of the north-eastward slope is about 2 m per km (Khalaf & Al-Ajmi, 1993). The landscape slopes gently from about 280 m a.s.l. near Salmi in the extreme south-western corner of the country towards Khor Al-Subiyah in the north-east. The southern part of the country drops across a series of low, discontinuous scarps,

separated by rather wide plateaus and plains towards the Arabian Gulf coast in the east. The continuous northeastern slope in the northern part of Kuwait is interrupted by a very wide shallow inland depression with inland drainage patterns, such as Um Al-Aish and Ar-Rawdatayn, followed by a very gentle dome-shaped elevation acting as a local watershed.

Climatic conditions

Kuwait experiences two main seasons, summer and winter. Spring is short (March–April). The weather during the winter is mild to cool, with average ambient minimum temperatures in January falling to 8°C (1962–1998). The average ambient maximum temperatures (1962–1998) during December, January and February are about 20, 18, and 21°C, respectively. Precipitation is scanty, beginning in October and lasting till May. The average annual precipitation is around 110 mm. It fluctuates annually, ranging from a reported high of 351·7 mm at Al-Ahmadi, in the South, during the season of 1971/1972, to a low of only 20·1 mm at Um Al-Aish, in the north, during the season of 1963/1964. In summer, the temperature during July and August averages 37°C. The average maximum temperature in July is about 45°C. The prevailing winds are from the north-west and, to a lesser extent from the south-east. During the summer, dust storms are rather frequent, particularly in June and July (Khalaf *et al.*, 1984). The average monthly wind speed reaches a maximum of 20·8 km h^{-1} in June and a minimum of 12·1 km h^{-1} in November. The monthly mean of daily pan evaporation is 13 mm in July.

Soils

Generally, the soils of Kuwait are not well developed. They are poor in organic matter and moisture content. Ergun (1969) conducted a reconnaissance survey and compiled a soil map of Kuwait at scale 1:500,000. Ergun's work was followed by a semi-detailed survey conducted by the Societe Centrale pour Le Equipment du Territorie (SCET, 1970) for 40,000 ha selected by Ergun (1969) as being the most suitable for agriculture. Ergun (1969) reported four great groups in the entire State of Kuwait, they are: (1) Desert soils; (2) Desert Regosols Intergrades soils; (3) Lithosols and (4) Alluvial soils. Desert soils and Desert Regosols Intergrades are most frequent and distributed all over Kuwait. Alluvial soils are confined to the Bubyan Island and to the coastal areas. Lithoslos are the least occurring soils. Results of the present reconnaissance soil survey at scale 1:100,000 are briefed in later sections.

Recent sediments

Kuwait's surface is mostly covered by loose mobile sediments. These sediments are continually transported along the surface under the persistent action of wind and are deposited around vegetation, buildings, roads, farms and other structures, resulting in acute environmental problems (Khalaf *et al.*, 1980; Omar *et al.*, 1988; El-Bagouri *et al.*, 1989; Khalaf & Al-Ajmi, 1993). Khalaf *et al.* (1984) concluded that aeolian deposits are the most frequent sediment types in Kuwait.

Foda *et al.* (1983) delineated two sand belts entering the country from Iraq; the larger through Al-Huwaymiliah, and the other through Al-Qashaniyah. The Al-Huwaymiliah belt stretches south-east following the prevailing north-westerly winds, passing through Kabd and Wafrah, and extending to the southern coastal area. The Al-Qashaniyah sand belt crosses Al-Abdali agricultural area towards Al-Subiyah.

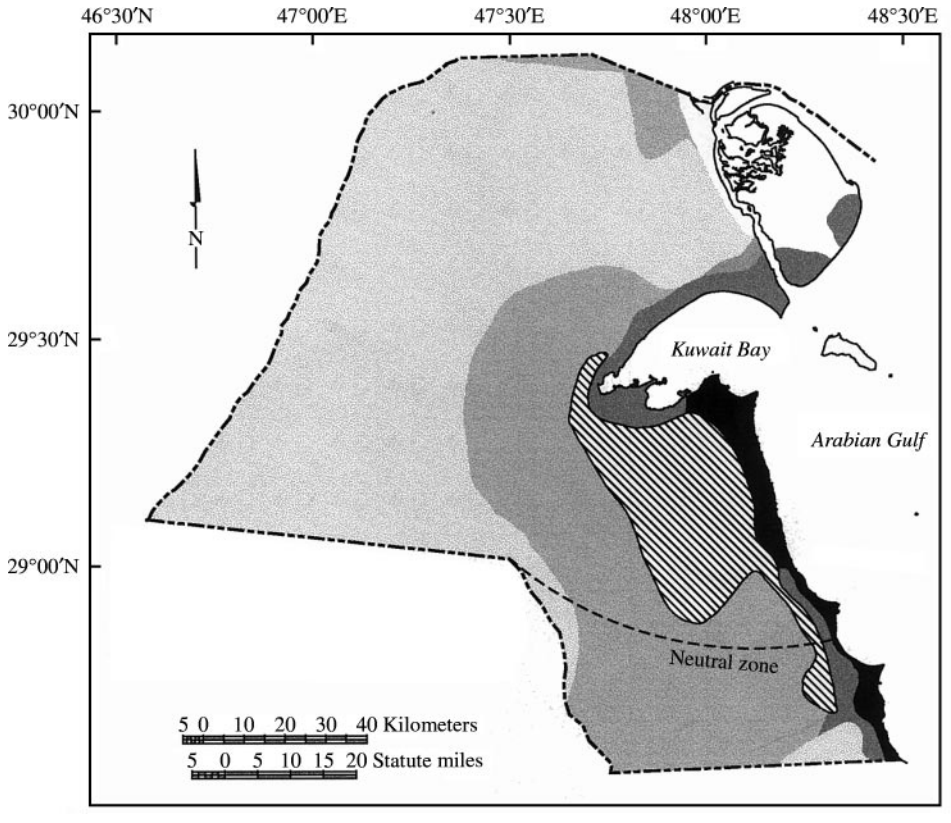

Figure 1. Vegetative map of Kuwait (after Halwagy & Halwagy 1974). *Haloxylon salicornicum* (▭) *Cyperus conglomeratus* (▩) *Rhanterium epapposum* (■) *Zygophyllum qaterence* (and other haplophytes) (▨) Urban area (■).

Vegetation

Four broad vegetation ecosystems are recognized in Kuwait. These are: sand dunes and sand sheets; salt marshes and saline depressions; desert plains; and desiccated hilly terrain. A further five plant communities were recorded: *Haloxylon salicornicum*; *Rhanterium epapposum*; *Cyperus conglomeratus*; *Panicum turgidum*; and *Zygophyllum qatarense*. *Rhanterium epapposum* was commonly found in the sand sheet terrain in middle and southern parts of Kuwait. *Zygophyllum qatarense* communities were restricted to the coastal areas. The other communities dominated the inland desert areas. Their natural distribution is shown in Fig. 1. The environmental conditions which determine the distribution of the *Haloxylon, Rhanterium* and *Cyperus* communities are not well known. The general edaphic relationships described by Halwagy *et al.* (1982) are: *Cyperus* associated with deep loose sandy soils; *Rhanterium* on shallow to moderately deep soil overlying gypsic or calcic layers; and *Haloxylon* commonly on shallow soils overlying a hardpan.

Methods

Vegetation map units are defined as areas where vegetation is relatively homogenous (Soil Survey Division Staff, 1993). A map unit is identified and named according to

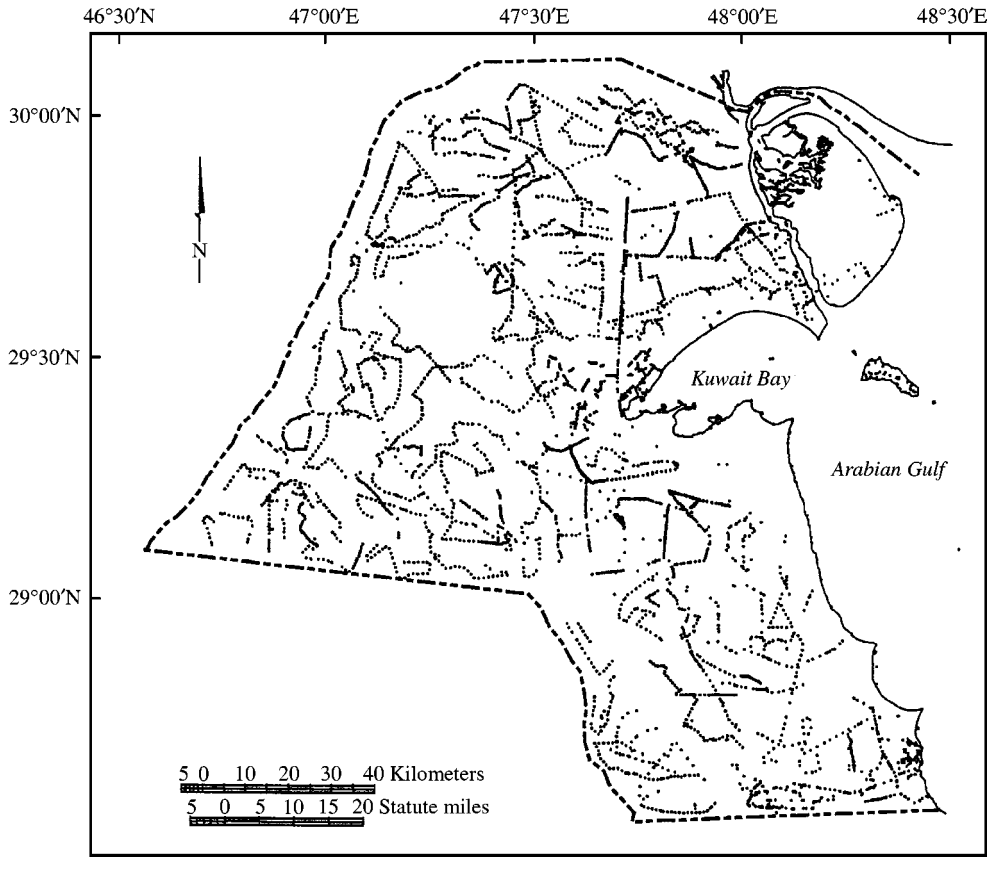

Figure 2. Site location for vegetation and soil studies in the State of Kuwait. Examination site (geographically located using GPS) (◆).

the taxonomic classification of the dominant community. Occurrence of other plant communities on the same map units indicates their association to the dominating community or to a similar physical environment. Composite map units, which include a set of integrated physical and ecological data (landform, soil and plants), are delineated. In this way, it is possible to evaluate rangeland status and suggest a proper management plan (Soil Survey Division Staff, 1993).

A reconnaissance survey (covering some 1,670,209 ha) was carried out from 1996 to 1998 to delineate soil and vegetation map units. The survey was conducted at scale 1:100,000 (about one observation point per 200 ha) for the entire country, excluding urban, agricultural and restricted areas. Some 8351 observation points were geographically positioned and assessed for soil and vegetation (Fig. 2). Site selection was made using a free technique (site selected by surveyor) and transect technique (sites placed at regular intervals along a road or compass bearing) (Gunn *et al.*, 1988). Soils were described (Soil Survey Division Staff, 1993) and classified according to the Keys to Soil Taxonomy (Soil Survey Staff, 1994). All site information relating to soil profiles and vegetation was recorded on field site cards and later keyed into the soil information system database. Plant species were identified by using references such as Al-Rawi (1987), Daoud & Al-Rawi (1987) and Mandaville (1990).

Delineation of vegetation and soil map units was digitized and stored on the Geographical Information System (GIS) for further analysis. An Integraph GIS with

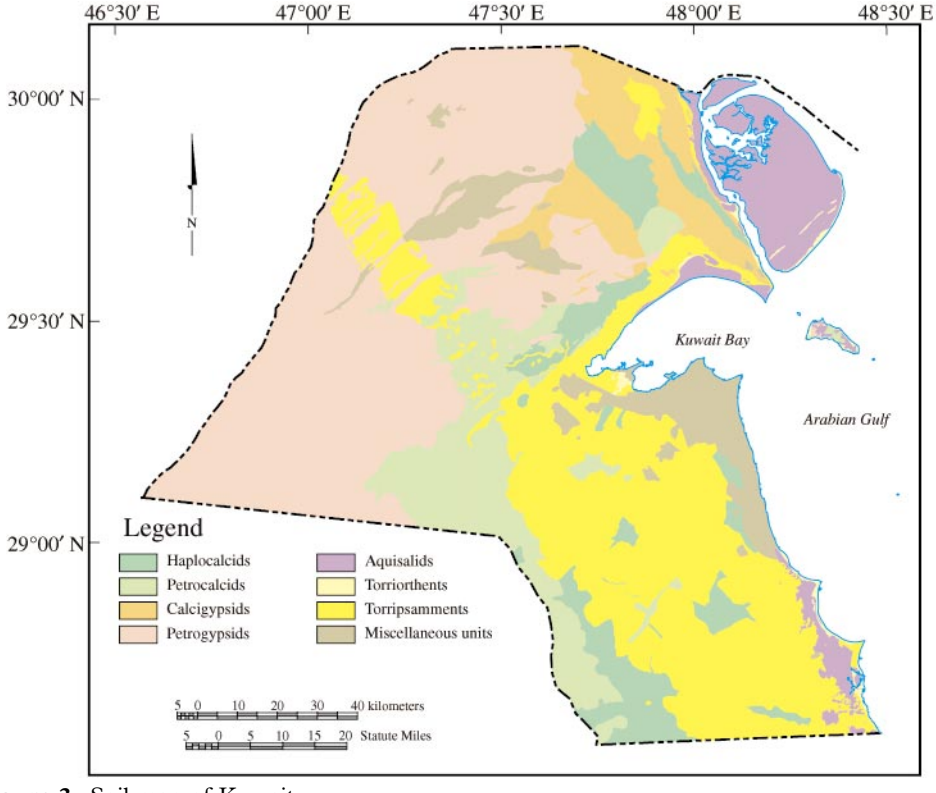

Figure 3. Soil map of Kuwait.

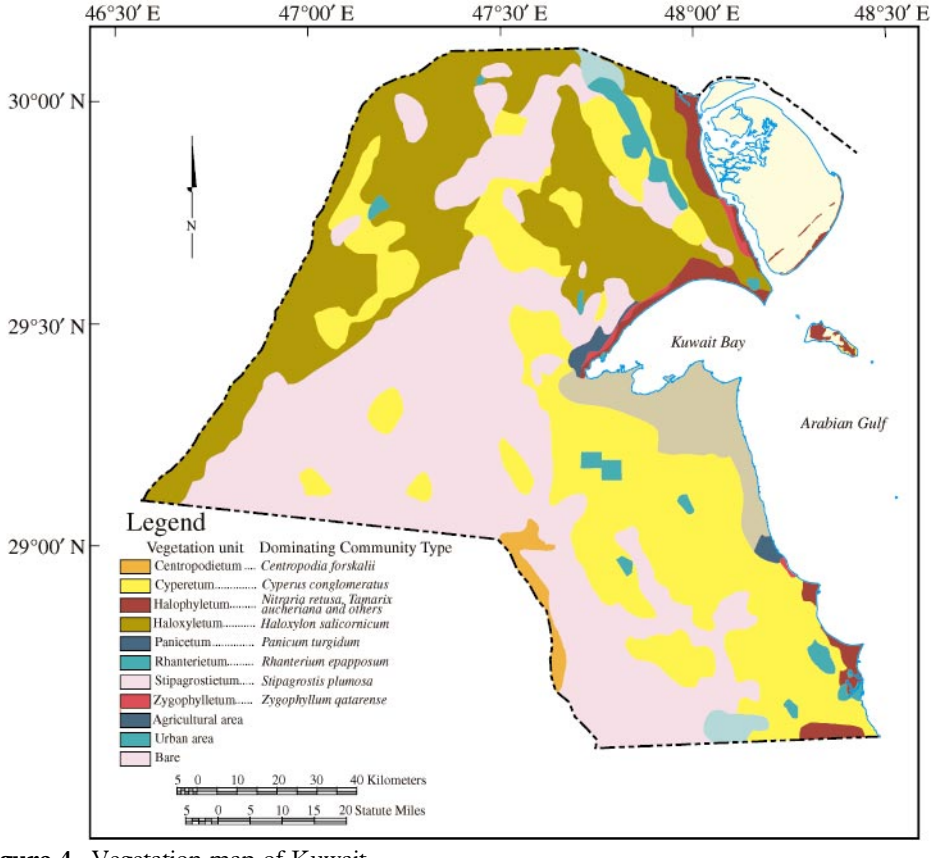

Figure 4. Vegetation map of Kuwait.

Table 1. *Description and area of soil map units in Kuwait*

Map unit*	Area (%)	Description†
Torripsamments	27	Well to somewhat excessively drained, deep or very deep sandy soils
Petrocalcids	11	Well drained or moderately drained, shallow or moderately deep, sandy to loamy soils overlying a calcic hardpan. When upper soil is truncated, it may appear at surface
Haplocalcids	8	Well drained, deep or very deep, sandy to loamy soils, which have a layer of carbonate masses and nodules in the profile
Haplogypsids‡	<1	Well drained, deep or very deep, sandy to loamy soils, which have a layer of gypsum crystals in the profile
Aquisalids	7	Poorly or somewhat poorly drained, deep or very deep, sandy to clayey soils. Within the soil there is a layer of salt accumulation that usually occurs near the surface
Calcigypsids	6	Well drained, deep or very deep, sandy to loamy soils containing a layer of carbonate masses and nodules and a layer of gypsum crystals within the profile
Petrogypsids	33	Well drained, shallow or moderately deep, sandy to loamy soils overlying a gypsic hardpan. Hardpan may be exposed at surface, when upper soil is truncated
Torriorthents	1	Excessively drained to well drained, moderately deep or very deep, sandy soils. Within the soil profile there is a high content of shell fragments and some gypsum accumulations

*Not including 'Miscellaneous' map unit, which comprises about 6% of the surveyed area.
† Shahid *et al.*, (1998b); Soil Survey Staff (1999); KISR (1999).
‡Due to map scale limitations, Haplogypsids were not shown in Fig. 3.

Microstation and MGE suite of software was used to process the mapped data and conduct map overlay analysis. Vegetation boundaries represent the prevailing plant community that has broad spatial amplitude. Vegetation map units were delineated on a map at scale 1:250,000. On the vegetation map urban and agricultural developments were excluded and given special color codes. Layers of topographic lines, drainage channels and roads were included in the map information. The map was further reduced and presented in this study. Cross tabulation was conducted to show how the vegetation distribution has changed with time between the two vegetation maps.

Soil mapping was done on the bases of interpretation of: the Landsat 5 Thematic Mapper (March 1995); aerial photography at scale 1:29,000 taken in 1991/1992; and a Map of Kuwait at scale 1:250,000 by the Ministry of Defense, as well as a ground truthing assessment. The soil map units described in this study are a summary of the detailed information collected for the reconnaissance soil map of Kuwait. All soil data and related information are separately reported in KISR (1999).

The accuracy of the vegetation map was determined by comparing the site classification with the map unit classification in which the site occurred. Map unit purity was assessed as the proportion of sites within a map unit, which contained the expected vegetation class and associated vegetation classes. Overall purity of the vegetation map is estimated as the sum of individual map purity multiplied by their respective proportional areas.

Results and Discussion

Eight great soil groups are identified and grouped into eight map units; they characterize the soils of Kuwait (Fig. 3). The map units are associations and complexes, and therefore, contain other soil types in minor quantities. The general characteristic of each map unit is described in Table 1. Results show that the dominating soil types of Kuwait are Petrogypsids and Torripsamments. Petrogyspsids soils generally occur on a level to gently undulating plain formed on the sand and gravel deposits of the Dibdibah Formation. The Torripsamments soils generally occur on an extensive sand sheet in central and southeast direction. They also occur at the base of escarpments where fall dunes have formed, along the coast on dunes and in the north-west on isolated barchan dunes and sand ridges (Fig. 3). Calcigypsids and Haplogypsids occur in the northern part of Kuwait, Haplocalcids occur in the north, south and central part of Kuwait; while Aquisalids are confined to Bubyan and Failaka Islands and the coastal areas. Torriorthents are the least occurring soils.

The surveys showed that species such as *Cyperus conglomeratus*, *Stipagrostis plumosa* (L.) Munro ex T. Anders., *Haloxylon salicornicum*, *Zygophyllum qatarense*, *Panicum turgidum* and *Centropodia forsskalii* (Vahl) Cope are widely distributed. Other perennial species such as *Convolvulus oxyphyllus* Boiss, *Gynandriris sisyrinchium* (L.) Parl, *Lycium shawii* Roem. & Schult., *Ochradenus baccatus* Delile., and *Pennisetum divisum* (J.F. Gmel) Henrard showed narrow ecological amplitude and are correlated to particular site physical characteristics. The *Rhanterium epapposum* community was confined to protected areas. Halophytic communities such as *Tamarix aucheriana* Decne, *Nitraria retusa* (Forssk.) Asch., *Halocnemum strobilaceum* (Pall.) M. Beib., and *Siedlitzia rosmarinus* Bunge ex Boiss. were presented in one map unit (Halophyletum). Some areas were totally barren or void of vegetation due to natural conditions, such as the extremely high soil salinity in Bubyan Island or due to intensive land use. In some areas such as the southwest only annual plants occurred, indicating their ability to easily colonize open or disturbed habitats. Communities that have a short life span and dominate immediately after a disturbance, such as *Cornulaca aucheri* Moq., *Salsola imbricata* Forssk. and *Stipa capensis* Thunb., are excluded from vegetation mapping because they deviate from the adopted vegetation map unit approach. Eight vegetation map units were recognized, these were (1) Haloxyletum; (2) Rhanterietum; (3) Cyperetum; (4) Panicetum; (5) Stipagrostietum; (6) Zygophylletum; (7) Centropodietum; and (8) Halophyletum. The spatial distribution of each map unit is portrayed in Fig. 4 and the percent of area constituted by each map unit is shown in Table 2.

Vegetation map units

Haloxyletum

This map unit is dominated by the species *Haloxylon salicornicum*, a low shrub that grows up to 60 cm in height in summer. It is associated with other shrub species of less spatial distribution such as *Astragalus spinosus* (Forssk.) Muschl, and *Chrozophora* spp. The map unit covers 22·7% of the total area distributed in the north-east, north-west and west of Kuwait. Soils in these areas are mostly Petrogypsids, Haplocalcids and Calcigypsids. Landform is level, forming a gently undulating plain. The *Haloxylon salicornicum* community is under severe pressure from grazing, uprooting, quarrying, spring camping, off-road traffic, urban expansion and military activities. Management of disturbed sites, particular in the northeast, may improve the status of the community and its associated species. Under severe disturbance such as the case in the north-west, however, the *Haloxylon salicornicum* community will regress, allowing annual grass species such as *Stipa capensis* to dominate. When the disturbing factor is removed, such as controlling rangeland grazing, the annual grass will proceed through a perennial grass stage to a point of near stability. In this case, the dominating grass will be *Stipagrostis plumosa.*

Table 2. *Percent area and total area of vegetation map units in Kuwait*

Map Unit*	Area	
	ha	%
Haloxyletum	369,557	22·7
Rhanterietum	33,755	2·1
Cyperetum	438,157	26·9
Stipagrostietum	640,713	39·3
Zygophylletum	4140	0·3
Centropodietum	16,018	1·0
Panicetum	11,391	0·7
Halophyletum	30,297	1·9
Agricultural area	16,413	1·0
Urban area	68,572	4·2
Grand total	1,629,013	100

*Not including bare areas.

Rhantereitum

This vegetation unit is dominated by the species *Rhanterium epapposum* in association with *Convolvulus oxyphyllus* and *Moltkiopsis ciliata*. The dominating plant species *R. epapposum* is highly susceptible to grazing. When mature, it can reach 80 cm in height, forming fibrous stems and roots that are often used as fuel by bedouins. In comparison with previous studies, the community has significantly receded in its geographic distribution showing 2·1% area. It was more abundant in the south of Kuwait (Halwagy & Halwagy, 1974), but now it is confined to protected areas.

Other plant species that are associated with the community favor specific site characteristics such as soil type and relief. These are: *Gynandriris sisyrinchium* in shallow depressions; *Cornulaca aucheri* in disturbed mobile sandy areas; and *Anthemis deserti* Boiss., *Schimpera arabica* Hochst & Steud ex. Boiss., *Arnebia decumbens* Vent. Coss & Kralik., and *Arnebia tinctoria* Forssk. in stable and well developed soils. *Salsola imbricata* Forssk. may become a weed in any of these habitats, particularly when they are disturbed. Soils associated with community types are Calcigypsids in the north, and Torripsamments and Petrocalcids in the south. Landform in the north is typically gently undulating plains with gentle slopes and flats that have many shallow drainage depressions. In the south, the landform is a gently undulating sand plain and level undulating plain. Under severe grazing pressure, the community will regress into sedge (*Cyperus conglomeratus*), particularly in areas with Torripsamment soil type.

Cypertum

The map unit is dominated by the species *C. conglomeratus* that colonizes mainly on sandy areas with Torripsamment soil type. The plant is about 60 cm tall, forming a dense cluster at the base. It is an excellent sand stabilizer as hummocks of fine sand are accumulated on the leeward side of the plant. Generally, these hummocks (maximum 2 m length) stretch in a NW-SE direction, i.e. parallel to the prevailing winds. The plant is usually associated with annual species such as *Astragulas annularis* Forssk., *Brassica tournefortii* Gouan. and *Plantago boissieri* Hausskn. & Bornm. When heavily grazed, a temporary community type of annual shrub, *Cornulaca aucheri* dominates. This case is particularly recorded along several stretches in the southern part of Kuwait. The map unit showed 26·9% distribution.

Stipagrostietum

This is dominated by *St. plumosa*. The community is expanding in areas that have been heavily used or disturbed. It extends in the west and southwest of Kuwait with few clusters in the north and north-west covering 39·3% of total area. The associated species are *M. ciliata*, *Plantago boisieri* and *S. capensis*. It traverses a range of soil types, including Petrocalcids, Haplocalcids and Petrogypsids on level to gently undulating plains. Under sever conditions, the community will disappear, allowing the dominance of annuals such as *P. boissieri* and *S. capensis*. Under proper management and protection measures, the community will develop into either *R. epapposum* on Petrocalcids soils or *H. salicornicum* on Petrogypsids soils.

Zygophylletum

The map unit is dominated by *Zygophyllum qatarense*, a medium-sized shrub commonly found in coastal areas and depressions with 0·3% distribution. The community is associated with salt-tolerant annuals and perennials such as *Salsola imbricata*, *Cressa critica* L., and *Aizoan hispanicum* L. The soil is Aquisalid that is characterized by high salinity. These areas have a shallow water table (50–200 cm) and are often inundated during the rainy season.

Centropodietum

This map unit is dominated by the species *Centropodia forsskalii*, a perennial grass that has recently become abundant in the south-west of Kuwait with 1·0% distribution. The community is usually associated with *St. plumosa*. The soil type in this area is Petrocalcids on a gently undulating plain.

Panicetum

This unit is dominated by *Panicum turgidum*, a perennial desert grass forming tangled bushes up to 1 m tall. Sandy hillocks (up to 1·2-m height) usually accumulate around this plant. The community is intensively grazed by sheep and goats, allowing it only to survive in the north-west of Kuwait Bay and along the south-eastern coast with 0·7% distribution. The soil types in these areas are Torripsamments and Aquisalids, located on level coastal plains covered by uneven sand sheets or isolated hummocks. Associated species are *Aeluropus lagopoides* (L.) Trin. Ex. Thwaites., and *Pennisetum divisum*.

Halophyletum

Many halophytic plant communities, such as *Tamarix aucheriana*, *Nitraria retusa*., *Halocnemum strobilaceum*, and *Siedlitzia rosmarinus*, dominate this map unit with 1·9% distribution. High water table and occasional flooding from surface runoff characterize the map unit. *Tamarix* favors saline flats, such as those found along the coast in the Sulaibikhat/Doha area, west of Kuwait City. It is a large shrub, about 3 m high, with scale-like leaves. *Nitraria retusa* also occurs with *Tamarix*; the plant is a stiff-branched shrub, 1–2 m high. It forms hummocks, with gray woody twigs. The habitat where *Nitraria retusa* grows best is sabkha near the coastal areas in the south. The plant forms the basis for a typical example of nebkha, which are anchored dunes accumulated around shrubs. The *Nitraria retusa* nebkhas have an elongated domal shape with an average height of 102 cm and an average length of 18 m (Khalaf *et al.*, 1995). Other

community types in this map unit include *Halocnemum strobilaceum*, which is found in the northern and southern coastal zones. The plant is usually submerged by seawater at high tides and may grow in large areas on sandy saline soils. Soils in this map unit are Aquisalids.

Comparison of the current vegetation map with previous studies

Eight vegetation map units were recognized compared to five plant communities as reported by Halwagy & Halwagy (1974). The percentage distribution of area constituted by urban development and plant communities in the vegetation map of Halwagy & Halwagy (1974) was 3·0, 10·1, 52·2, 30·6, and 4·2% for urban areas, *C. conglomeratus*, *H. salicornicum*, *R. epapposum*, and *Z. qatarense* respectively (Table 3). These were compared to the percentage distribution of the new map units, which scored 4·2, 26·9, 22·7, 2·1 and 0·3% for urban areas, Cyperetum, Haloxyletum, Rhanterietum, and Zygophylletum respectively (Table 3). The comparison showed that some plant communities retreated in distribution whereas others expanded. For example, *C. conglomeratus* community in the previous vegetation map covered 10·1% of the total area compared to 26·9% in the current map indicating its potential to expand in time. This map unit extended over areas that were previously dominated by *R. epapposum*, *H. salicornicum* and *Z. qatarense* communities by 9·9%, 7·8% and 1·0% of areas respectively, 7·8% of the area remained unchanged (Table 3).

On the other hand, the percentage distribution of the *R. epapposum* community was considerably altered from 30·6% in the previous vegetation map to 2·1% in the current vegetation map. Only 0·6% of the area remained unchanged (Table 3). This indicates that this community has considerably retreated from the rangelands of Kuwait and that the community is more susceptible to grazing than *C. conglomeratus*. Presently, it is confined to protected areas such as the Sulaybia Field Station, military air bases, military camps and some restricted oil fields.

Haloxylon salicornicum and *Z. qatarense* also decreased in percentage distribution from 52·2 and 4·2% in the previous vegetation map to 22·7 and 0·3% in the new vegetation map respectively. Only 0·4% of the *H. salicorniccum* area and 0·2% of the *Z. qatarense* area remained unchanged (Table 3). The *H. salicornicum* community in the south of Kuwait reported by Halwagy & Halwagy (1974), is presently non-existent due to changes in the borderline with Saudi Arabia and Kuwait. The Haloxyletum map unit showed that the *H. salicornicum* has retreated from the west and north-west of Kuwait. Both communities are under pressure from overgrazing.

The *St. plumosa* map unit was not recorded in the previous vegetation map. Presently, it is occuring in the south and in the south-western areas. The unit has spread over areas previously dominated by *R. epapposum* and *H. salicornicum* communities by 16·6% and 22·3% of areas respectively (Table 3).

Halwagy & Halwagy (1974) indicated that Panicum turgidum has retreated considerably and may soon disappear. In this study, Panicetum map unit percentage distribution was 0·7% (Table 2). It was found dominating in the south-eastern coastal strip between Shuaiba and Umm Al-Hayman. The community in this area, however, is under severe pressure from grazing and urban expansion.

Both Centropodietum and Halophyletum map units were not reported in Halwagy and Halwagy (1974). Both map units showed low percentage distribution and expanding in areas which were dominated by *R. epapposum* and *H. salicornicum*. Halophyletum also expanded in areas that were dominated by *Z. qatarense*. The new map showed expansion in urban area distribution from 3·0% to 4·2% and agricultural area showed 1·0% distribution.

The species *Cornulaca aucheri* may form a temporary community type during favorable conditions, particularly when late spring rainfall is abundant and thick sand

Table 3. *A comparison matrix showing changes in percentage distribution of community types and urban area from previous to new vegetation maps*

		Community types from previous vegetation map* and percent distribution				
		Cyperus conglomeratus	*Haloxylon salicornicum*	*Rhanterium epapposum*	*Zygophyllum qatarense*	Urban area
Map units From new map	% total	10·1	52·2	30·6	4·2	3·0
Haloxyletum	22·7	0·0	0·4	0·1	1·0	0·4
Rhanterietum	2·1	0·3	0·7	0·6	0·3	0·1
Cyperetum	26·9	7·8	7·8	9·9	1·0	0·4
Stipagrostietum	39·3	0·3	22·3	16·6	0·1	0·0
Zygophylletum	0·3	0·0	0·0	0·1	0·2	0·0
Centropodietum	1·0	0·0	0·7	0·3	0·0	0·0
Panicetum	0·7	0·3	0·0	0·1	0·2	0·1
Halophyletum	1·9	0·0	0·4	0·1	1·0	0·4
Agricultural area	1·0	0·0	0·2	0·8	0·0	0·0
Urban area	4·2	1·3	0·0	0·0	1·9	1·0

*Halwagy & Halwagy (1974).

accumulation exist (> 30 cm thick). The community started to dominate in the Cyperetum map unit between 1993 and 1996 in the south. Currently, many new seedlings have been established in the central and northern parts of Kuwait while the recently established community in the south has receded. A new community type of Convolvulus oxyphyllus was found near Um Al-Jethatheel playa in the central part of Kuwait (29°06′ 43″N; 47°29′58″E) and in the north-west of Kuwait along with *Ziziphus nummularia* (Burm. f.) Wight & Arn. (30°04′28″N; 47°18′93″E). The later species was first recorded in this study. Also, a community type of *Astragalus spinosus* was found in the northwestern portion of Kuwait near Umm Al-Madafae (29°39′02″N; 47°26′50″E). These communities form clusters of less than 5 km^2. Due to map scale limitations, these two community types were not delineated.

The vegetation map accuracy was calculated as 70%, which is high for a reconnaissance scale map such as this. The value is high because the three dominant map units had high individual map unit purities (Cyperetum 77%, Haloxyletum 84%, Stipagrostietum 72%), and they contributed 68% to the map purity.

Conclusions

The current study adopted a new approach for mapping the vegetation of Kuwait by using the Geographic Information System (GIS). The application of GIS technology helped in mapping and evaluating soil and vegetation. It is a primary tool for range managers who wish to manage and monitor rangeland status and use. New information from field studies can be entered into the GIS database and then compared with existing data sets for monitoring and to determine what change has occurred.

The vegetation of Kuwait has been altered due to intensive deterioration of rangeland productivity. Past attempts to classify vegetation showed dominance of five communities, most of which were shrubby species. The current status of vegetation, however, has shown intensive land degradation and retrogression of shrubby species, in particular *Rhanterium epapposum*. Perennial shrubs constitute about 27% of the surveyed area while perennial grass and sedge constitute 67·9%. Weedy shrubs such as *Cornulaca aucheri* are invading the rangelands, forming temporary communities.

Improvement of deteriorated vegetation units is vital to the future stability of Kuwait rangelands. Natural revegetation is the most economically sound approach for regeneration of depleted rangelands. Natural revegetation is based on eliminating the factors that have caused retrogression, and allowing autogenic succession to take place. Good range management and rehabilitation practices in Kuwait are essential to promoting land recovery and improving vegetation. Rehabilitation of degraded rangelands by using native plants that have wide spatial distribution is more appropriate than using species growing in confined specific habitats. It is, thus, recommended to include native species such as *C. conglomeratus*, *H. salicornicum*, *R. epapposum*, and *St. plumosa* in re-vegetating soil map units classified as Torripsammints and Petrogypsids, that contribute to 60% of total surveyed area.

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