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ORIGINAL PAPER

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Land-use Evaluation of Arid Lands for Wildlife Habitats and Recreational Camping Using Soil Information and GIS

Abstract: Management of lands for a variety of uses requires knowledge of sensitive areas so that effective land use strategies can be designed. Soil surveys provide baseline information that can be used for land use evaluation. In this study, the Kuwait soil information system, which is based on a field survey at reconnaissance level (1:100,000 scale), was used to generate suitability information and maps for wildlife habitats and recreational camping areas.

Land use suitability for wildlife habitat and recreational camping areas was determined by interpreting soil property information from the soil survey database against criteria established for Kuwait's conditions. Using a geographic information system, maps were developed, based on interpretation of the soil survey map unit component soils, and used to show the suitable areas.

Results showed that 87% of the land was classified as "well suited" and "suited" for wildlife habitats and that 56% of the land had "severe limitations" for recreational camping. Soil information, when expressed using suitability criteria, can assist with land use evaluation and provides valuable information for screening areas.

Keywords: Arid environment, land suitability, mapping, vegetation, soil.

تقييم إستخدام الأراضي في المناطق القاحلة لبيئات الحيوانات البرية ومخيمات الترفية باستخدام معلومات التربة ونظام المعلومات الجغرافي

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المستخلص: تحتاج إدارة الأراضي إلى معرفة مناطق هامة لغرض تطوير إستراتيجية للإستخدامات المختلفة، وتوفر دراسات مسح التربة، المعلومات اللازمة لتقييم إستخدام الأراضي. في هذه الدراسة تم إستخدام نظام المعلومات الجغرافي للتربة (GIS) الذي تم تطويرة عن طريق المسوحات الحقلية للتربة بمقياس (100000:1) ، لعمل خرائط وتحديد مناطق كمخيمات الترفيه وبيئات للحيوانات البرية. إلى جانب الإستفادة من المعلومات المستقاة من مسوحات التربة مقابل معايير تأخذ بعين الإعتبار طبيعة التربة في الكويت. تم إستخدام تقنية نظم المعلومات الجغرافي ووحدات خرائط التربة لتحديد المناطق. وبينت النتائج بأن 87% من الأراضي في الكويت تعتبر أراض (لها قابلية جيدة لبيئات الحيوانات البرية، 56% من الأراضي لها قابلية "محدودة جداً" لمخيمات الترفيه. ساعدت المعلومات المتعلقة بالتربة والمعايير التي تم تطويرها في الدراسة في تقييم مدى إمكانية إستخدام الأراضي لأغراض محددة.

كلمات مدخلية: مناطق قاحلة، ملائمة الأراضي، خرائط، غطاء نباتي، تربة.

Introduction

In most arid regions, rangelands are traditionally used for livestock grazing, wildlife hunting and recreation. The excessive use of land for these activities has caused land degradation in many parts of the arid regions (Eweg *et al.* 1998; McClure, 2000). The rangeland of Kuwait, which constitutes 75% of the total area, is being used by these human activities during mild seasons. Due to the intensive use of the land, many areas have shown degradation and loss of biota (Al-Dousari *et al.* 2000). Careful evaluation, planning and management of the land are essential to maintain its quality and productivity (Tueller, 1998).

Knowledge of the suitability of the soil for producing various kinds, proportions and amounts of plants is important in developing management alternatives needed to maintain productivity (Stoddart *et al.* 1975; Heady and Child, 1994). In areas having similar climates and topography, differences in the kind and amount of vegetation produced on rangelands are closely related to soil types (Soil Survey Division Staff, 1993). Interpretation of soil properties is useful for land evaluation and for designing land use strategies based on their potential for sustainability and environmental quality.

The geographic information system (GIS) is widely used in natural resource management and land use planning (Brinkman, 1990; Kessel, 1990;

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Al-Kodmany, 2000) as well as land evaluation studies (Machin and Navas, 1995). In some cases, expert land evaluation systems along with a GIS were used to develop computerized spatial data to suggest suitable land management strategies for environment conservation (Machin and Navas, 1995). Manipulated soil databases in GIS allowed the establishment of a sustained land use system in watershed areas (Adinaryana and Krishna, 1995) and rehabilitation planning to be done (Eweg *et al.* 1998).

A soil information system was developed for the State of Kuwait that combined the spatial information management capabilities of a GIS with a database of soil property, soil class and map unit information.

The purpose of this present work is to adopt suitability criteria based on soil properties for evaluating land use potentials for (1) establishing herbaceous desert plants for wildlife habitats; and (2) recreational camping areas. Such information derived from interpretation of the soil data can help prevent soil-related failures in land use and, hence, encourage better management. The results will serve as a guideline for decision-makers to properly manage and plan land use according to its potential and to reduce depletion of natural resources and land degradation.

Study Area

The State of Kuwait is situated in the northwestern corner of the Arabian Peninsula between latitudes 28° 30′ and 30° 05′ N and longitudes 46° 33′ and 48° 35′ E. The total area is about 17,800 km^2. Similar to other parts of the Arabian shield, Kuwait is characterized by a desert-type environment with low rainfall (113 mm/year) and harsh climatic conditions. Summer is very hot, especially in July and August, with a mean temperature of 37.4°C and maximum mean temperature of 45°C, and the rate of evaporation exceeds precipitation by about 16.6 mm/day. The winds usually blow from the northwest, causing dust storms during summer (Khalaf *et al.* 1984).

Like most arid lands, land use in Kuwait is primarily for livestock grazing (75% of the total area is classified as rangeland). The vegetation of the rangeland consists of grasses, sedges, forbs and shrubs that provide grazing and browsing for domestic animals and habitat for wildlife species. The rangeland is also used for recreational activities such as camping and hunting (mainly birds) (Taha *et al.* 1988; Taha and Omar, 1982). Camping is commonly practiced in the spring and autumn, and is the most popular recreational activity undertaken on non-urban land.

Materials and Methods

A reconnaissance soil survey was conducted in Kuwait at a scale of 1:100,000 by taking one observation for every 200 ha (KISR, 1999). The soils were described as per USDA's fourth order level (Soil Survey Division Staff, 1993) and classified using Keys to Soil Taxonomy (Soil Survey Staff, 1994). The soil survey for the State of Kuwait identified 24 soil families and 75 map units at a scale of 1:100,000 (KISR, 1999). The information on soil was incorporated in a GIS, which is used for the storage, manipulation, analysis and presentation of spatial data.

Different components of data linked to the soil information system developed for the reconnaissance survey include soil class descriptions, soil profile information, laboratory analysis data, soil classification, map unit descriptions, soil maps and interpretive maps. The GIS was used to integrate the soil information generated through the reconnaissance soil survey according to the criteria described herein for wildlife habitats, using suitability for herbaceous desert plants, and recreational camping areas. Each soil class was compared against the criteria and allocated a suitability rating in the database. Each map unit in the GIS was then allocated a suitability rating based on the combination of soils described for the map unit and an interpreted map was generated (Figure 1).

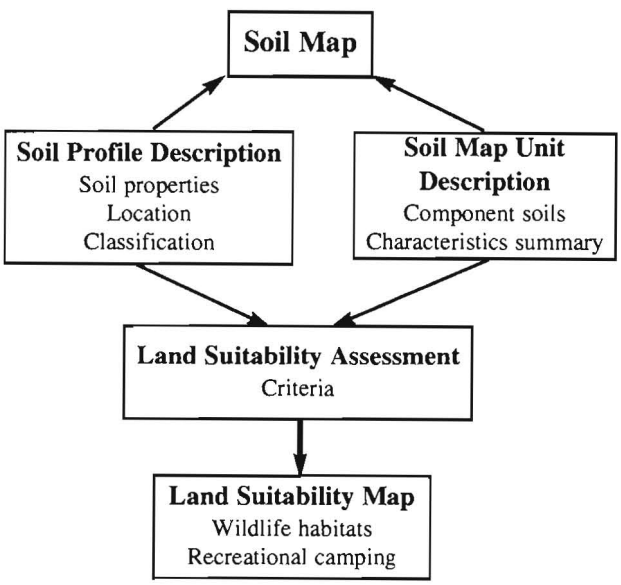

Fig.1. Schematic presentation showing linkages between elements in the GIS to produce suitability maps.

The general distribution of soils in Kuwait, shown at the Great Group level of Keys to Soil Taxonomy (Soil Survey Staff, 1994), is shown in Figure 2; this is a summarized representation of the 75 map units from the reconnaissance scale mapping. Eight soil Great Groups were mapped. The groups and approximate proportion of the area of Kuwait are: Torripsamments 27%, Haplocalcids 8%, Aquisalids 7%, Calcigypsids 6%, Petrocalcids 11%, Petrogypsids 33%, Torriorthents 1% and Haplogypsids 0.5%. Miscellaneous map units comprise 6.5% of the State area and include quarries and dumps (building waste material), urban and industrial areas. The description of soil map units and their associations and complexes are described in detail in the soil survey report (KISR, 1999).

1. Criteria for selecting wildlife habitats

Landscape, climate, soil, vegetation, hydrology, and time determine the management, reestablishment, or introduction of native herbaceous desert species to provide a diverse vegetation community that meets wildlife requirements. A limitation in any of these factors can influence the survival, growth, and vigor of the herbaceous species. Herbaceous desert plants are predominantly xerophytic species, naturally or artificially established and adapted to an arid or semiarid environment. Assessment of the restrictions for herbaceous desert plants was made against the criteria specified in Part 620, Tables 620-51, of the *National Soil Survey Handbook* (Soil Survey Staff Soil Conservation Service, 1993). The criteria address only the factors that relate primarily to the soil. They were modified for the Soil Survey for the State of Kuwait database fields, converted to metric units (KISR, 1999) and employed to develop limitation ratings and restrictive features for a range of soil properties (see Table 1).

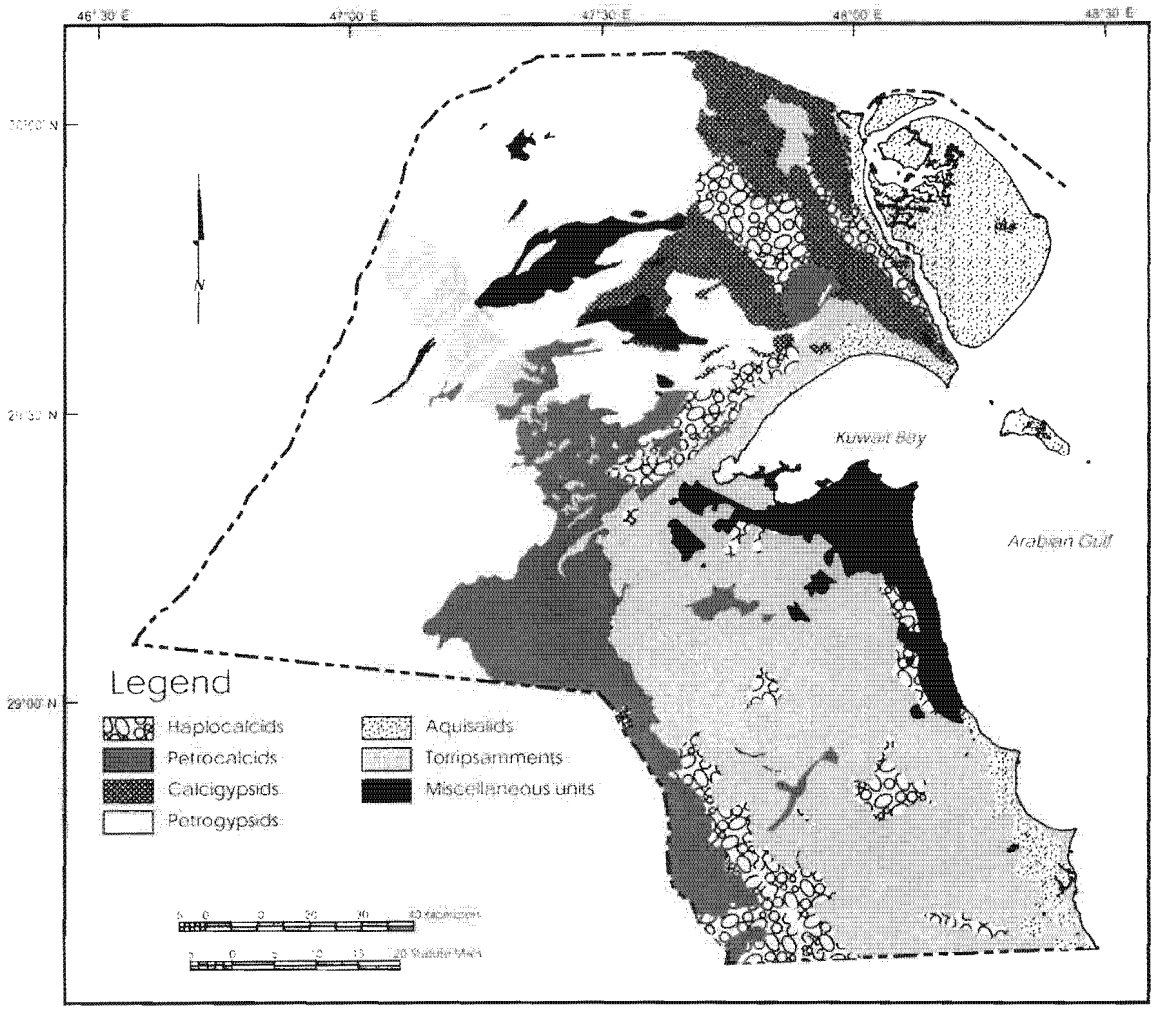

Figure 2. General distribution of major soil Great Groups in Kuwait (modified after KISR 1999). Due to map scale limitations Haplogypsid and Torriorthent map units are not shown.

Table 1. Criteria for rating herbaceous desert plants for suitability as wildlife habitat in Kuwait*.

Rating Criteria	Well Suited	Suited	Poorly Suited	Restrictive Feature
Texture (surface layer)	loamy sand loamy fine sand loamy very fine sand fine sand very fine sand	coarse sand	—	Too sandy
Texture (surface layer)	all other textures	silty clay loam clay, sandy clay	—	Too clayey
Available Water Capacity (average 0-100 cm)	> 0.05 cm/cm (> 5.0 cm)	< 0.05 cm/cm (< 5.0 cm)	—	Dry
Salinity (0-50 cm)	< 4 dS/cm	4-8 dS/m	> 8 dS/m	Excess salt
Sodium Adsorption Ratio (SAR) (0-50 cm)	< 13	13-30	> 30	Excess sodium
Soil Reaction (pH) (0-50 cm)	< 8.4	8.4-9.0	> 9.0	Too alkaline
Soil Moisture Regime	Aridic	Xeric, Ustic	Udic	Too moist
Depth to High Water Table (perched or apparent)	> 90 cm	45-90 cm	< 45 cm	Wetness
Weight Percent >2mm (surface layer restriction fraction with highest %)	< 50%	50-75%	> 75%	Too gravelly Too cobbly Too stony

*Adapted from Tables 620-51, Soil Survey Staff Soil Conservation Service (1993).

The criteria, (Table 1), are intended to provide minimum soil restriction guidelines for the selection of sites for growing and managing herbaceous desert plants and not to reflect commercial or livestock grazing values. This is then integrated into the map units developed by the Soil Survey of Kuwait (KISR, 1999).

The following factors were considered in developing the criteria for selecting herbaceous desert plant areas (Table 1):

- Sandy surface layers are soft and loose, dry and low in inherent soil fertility. They may adversely affect seedling emergence and survival.
- Clayey surface layers are slippery and sticky when wet. They are slow to dry, and when dry, are usually hard. Hard surfaces affect seedling establishment and survival.
- Low available water capacity means that the ability of the soil to provide continual moisture to herbaceous desert plants is lower than is necessary for the plants to establish or survive.
- Excess water-soluble salts restrict the growth of most plants. This condition reduces species diversity and favors those species that are more tolerant of salts. Salts also reduce seed germination and seedling survival.
- High concentrations of exchangeable sodium cause poor physical soil conditions that restrict plant growth. Crusting and blocked pores reduce soil permeability and prolong soil wetness.
- Soils that are too alkaline restrict plant growth and species composition. Alkaline soils have low amounts of phosphorus, iron, manganese, boron and zinc available to plants.
- A seasonal high water table can affect the establishment, growth and survival of herbaceous desert vegetation. It results in poorly aerated soils.
- A high concentration of rock fragments affects seedbed preparation.

Soil characteristics not addressed in this guide include aspect, carbonates and cation exchange capacity. The ability of individual species to adapt to these conditions is generally too site-specific to be considered. The selection of herbaceous desert species based upon the rating criteria is more adequately addressed at a more detailed level of assessment. Additionally, the frequency and duration of flooding or ponding are not considered as criteria.

2. Criteria for selecting recreational camping areas

Soil interpretations for recreational development can be used to identify and evaluate the suitability of the soil for specific recreational purposes. However, due to the relatively low intensity of the 1:100,000 scale mapping, only general observations on site suitability may be made here.

The assessment undertaken for recreational suitability does not take into consideration site location factors such as proximity to urban development or restricted areas; accessibility, size, shape and scenic quality; the ability of the soil to support vegetation; access to water; or the capacity of the soil to absorb septic tank effluent. These features are extremely important in evaluating a site and making final site selection. They can be incorporated in the future for making decisions in selecting specific camp locations.

Assessment of the restrictions for camp areas was made using the criteria specified in Part 620, Tables 620-12, of the *National Soil Survey Handbook* (Soil Survey Staff Soil Conservation Service, 1993). These criteria were modified for the Soil Survey for the State of Kuwait (KISR, 1999) database fields and converted to metric units. Suitability ratings and restrictive features to a range of soil properties in Kuwait were assigned (Table 2). The ratings are based on the soil properties and site features, which influence the ease of developing camping areas and their performance after development. Camping areas are tracts of land used intensively as sites for tents, trailers and the accompanying activities of outdoor living (see, table 2).

Camp areas may require such site preparation as shaping the areas used for tents and vehicle parking, stabilizing access tracks and intensively used areas, and installing sanitary facilities. Camp areas are subject to heavy foot and some vehicular traffic. Slope, stoniness, and depth to bedrock or cemented pan are the main concerns in developing camp areas. Soil properties that influence traffic ability and promote the growth of vegetation after heavy use are also taken into consideration.

Soil properties that influence traffic ability such as texture of the surface layer, wetness, permeability, and presence of large stones are also considered. While the suitability of slow permeability and clayey surface texture are not severe in dry regions like the Kuwaiti desert, silty soils can be dusty. Areas that are subject to flooding are particularly hazardous for camping areas because of the danger to life and property. On-site assessment of the duration and frequency of flooding is essential in planning recreational facilities.

Results and Discussion

1. Distribution of herbaceous desert plant areas for wildlife habitats

The results of the assessment of herbaceous desert plants for wildlife habitats are presented in Figure 3. The suitability ratings are expressed as the areas being "well suited", "suited", or "poorly suited" for herbaceous desert plants (Table 1). Comparison of the map on herbaceous desert plants for wildlife habitats (Figure 3) with the generalized soil Great Group map (Figure 2) shows, as expected, correlation of suitability classes with soil types in Kuwait.

Soils that are rated "well suited" for herbaceous desert plants have no restrictions for use and are favorable for herbaceous desert species that can be used as wildlife habitat. It is apparent that the area in the "well suited" class for herbaceous plants is related to Haplocalcids and Calcigypsids. Haplocalcids are soils that have a sandy to loam texture with an accumulation of carbonate. They were mapped in the northeast and south of Kuwait. The Calcigypsids soils are generally sandy and have well-developed calcic and gypsic horizons. Calcigypsids occurred in the northeast of Kuwait. Areas that were rated as "well suited" covered about 14% of Kuwait.

A "suited" rating implies that the site is suitable for the establishment and growth of climatically adapted herbaceous desert species and that some restrictive features limit the full potential of plant growth. The soils rated as "suited" for herbaceous desert plants covered approximately 72% of Kuwait. The main soil types are loose sandy soils (Torripsamments), cemented gypsic horizon (Petrogypsid) and cemented calcic horizon (Petrocalcids).

Table 2. Criteria for rating camping areas in Kuwait.

Rating Criteria	Slight Limitation	Moderate Limitation	Severe Limitation	Restrictive Feature
Texture Modifier (surface)	—	35-60% stones 35-60% boulders 0-35% cobbles 0-3 % flagstones	>60% stones >60% boulders >35% cobbles; >35% flagstones	Large stones
Texture (surface layer) Aridic Suborders Great Groups and Subgroups	—	Silty clay clay	—	Too clayey
Texture (surface layer)	loamy fine soil loamy sand when finer material <50 cm	loamy coarse sand very fine sand loamy fine sand loamy sand	coarse sand fine sand	Too sandy
Texture (surface layer) Aridic Great Groups and Subgroups	—	silt loam, silt, very fine sandy loam loam	—	Dusty
Flooding	None	—	rare, occasional, frequent	Flooding
Slope	< 8%	8-15%	> 15%	Slope
Ponding	—	—	yes	Ponding
Depth to High Water Table	> 75 cm	45-75 cm	< 45 cm	Wetness
Stoniness Class	stony	very stony	extremely stony rubbly, rockiness	Too stoney
Weight percent 2-75 mm (surface layer)	< 25%	25-50%	> 50%	Small stones
Permeability (0-100cm) Aridic Suborders Great Groups and Subgroups	≥ 1.5 mm/h	< 1.5 mm/h		Percs slowly
Unified Soil Classification System (surface)	—	—	Peat	Excess humus
Depth to Bedrock			<50 cm	Depth to rock
Depth to Cemented Pan			<50 cm	Cemented pan
Sodium Adsorption Ratio			>13	Excess sodium
Salinity (surface layer)	<4 dS/m	4-8 dS/m	>8 dS/m	Excess salt
Soil Reaction (pH)	—	—	<3.5	Too acid

*Adapted from Tables 620-12, Soil Survey Staff Soil Conservation Staff (1993).

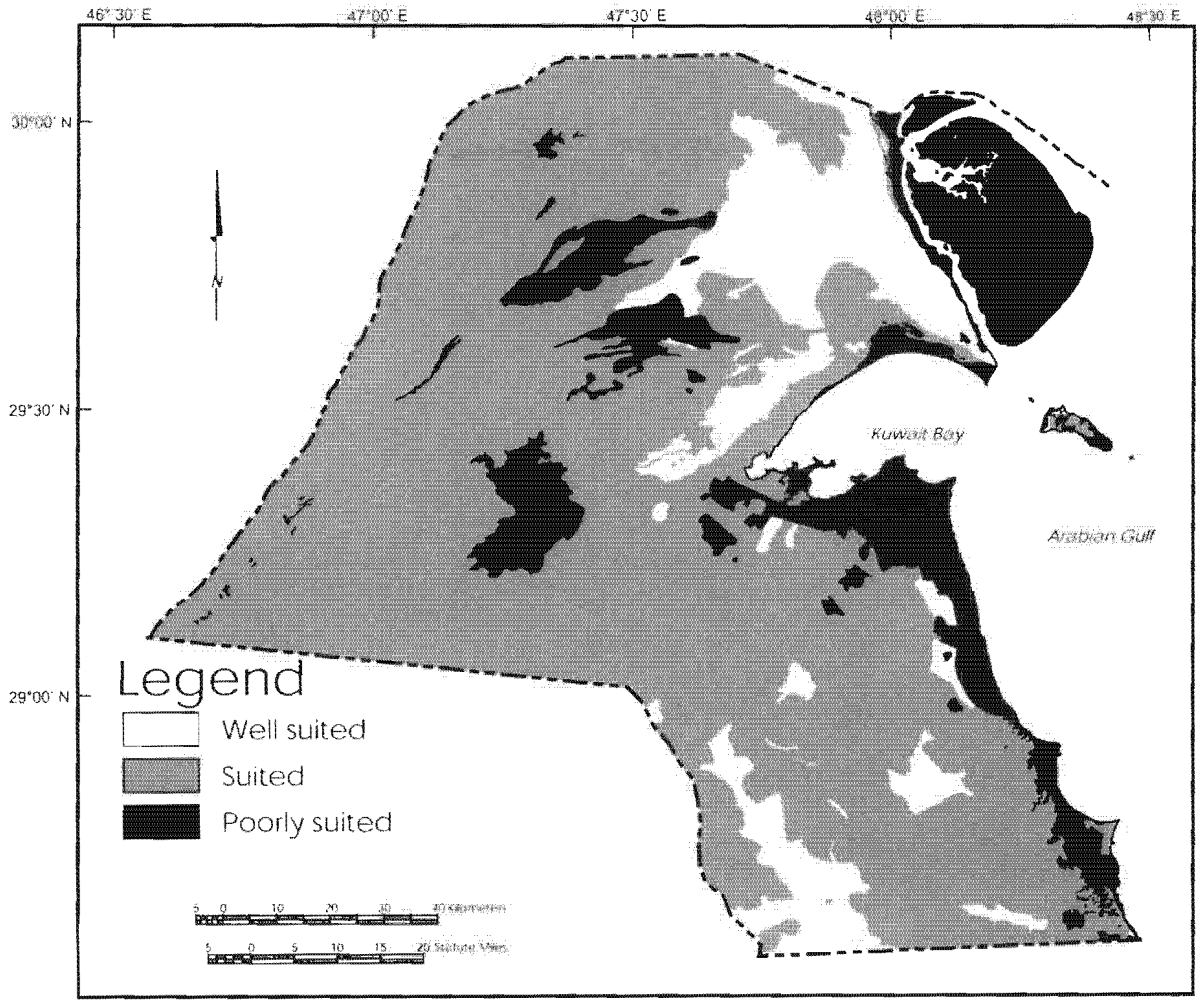

Figure 3. Suitability of areas for growing herbaceous desert plants for wildlife habitats.

A "poorly suited" rating indicates that the soil characteristics are such that they may limit establishment, growth, maintenance, or performance, and, thus, affect the establishment of the herbaceous desert vegetation to be used as wildlife habitats. The soil types rated "poorly suited" were those that belonged to high salinity areas and were mapped as Aquisalids and Torriorthents. Other "poorly suited" areas were mapped as miscellaneous units that include urban areas, quarries, dumps, and a small portion of Petrogypsids in the central west. The soils rated as "poorly suited" occupied approximately 14% of Kuwait. (see Fig. 3 and 4.)

2. Distribution of recreational camping areas

The results of the assessment for camping areas are presented in Figure 4. In this figure, suitability ratings are presented as soil limitations to development. Suitability ratings are expressed as "slight", "moderate", or "severe". Soils with "slight" suitability require no additional measures other than the normal local procedures used in site development and maintenance. Comparison of the map on suitability for camp areas (Figure 4) with the generalized soil Great Group map (Figure 2) indicates that only limited areas of Haplocalcids are in this category (about 1% of Kuwait).

Soils with "moderate" suitability require application of corresponding conservation practices to overcome the limitations. Major portions of area occupied by Haplocalcids, Calcigypsids, Petrogypsdis and Petrocalcids in the north and south are rated as "moderate", covering about 43 percent of Kuwait. "Severe" suitability soils are found where soil properties are unfavorable, and such limitations can be offset only by costly soil reclamation, special design, intensive maintenance, limited use, or a combination of these measures. "Severe" suitability is related to loose sandy soils (Torripsamments), Aquisalids, Torriorthents, urban and industrial areas, quarries and dumps areas, and a part of Petrogypsids. "Severe" areas cover about 56% of Kuwait.

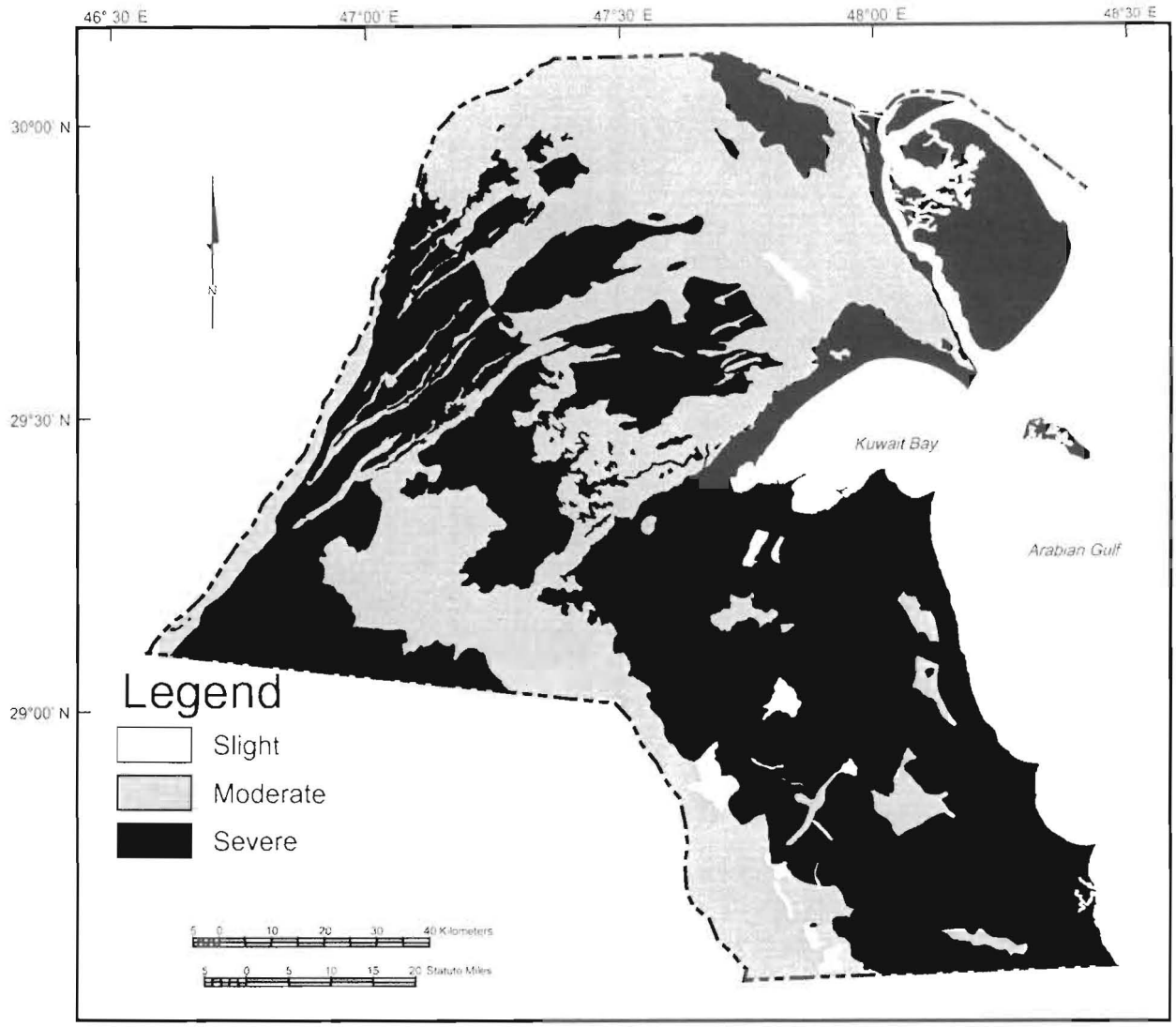

Figure 4. Suitability of areas for recreational camping.

Conclusions

Land use management can be interpreted from soil information by applying criteria and using a GIS to manage and manipulate the data. This allows users to plan and identify alternatives for site selection that best meet land use objectives.

A generalized assessment of soil attributes based on interpretation of soil data from the soil survey for the State of Kuwait (KISR, 1999) was used in this study for identifying areas for recreational camping and wildlife habitats. The general locations of areas suitable for herbaceous desert plant establishment as wildlife habitats were delineated; about 87% of Kuwait was classified as "well suited" and "suited". Delineation of recreational camping areas showed that most areas in Kuwait have "severe" suitability (about 56% of total area).

Effective management is based on the relationship between the soil, vegetation and water, as well as grazing pressure. Thus, more information is needed at more detailed scales to manage the rangelands for particular uses and to reduce land degradation. As this information becomes available, the flexibility of the database and GIS can be used to provide updated maps for the same or modified criteria. Soil information, when expressed using suitability criteria, can assist with land use evaluation and provides valuable information for screening areas to determine suitable wildlife habitats and recreational camping in Kuwait.

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References

Adinarayana, J., Krishna and **N. Rama** (1995) An approach to land-use planning in a hilly watershed using geographical information systems. *Land Degradation & Rehabilitation* **6**: 171-178.

Al-Dousari, A.M., Misak, R. and **Shahid, S.** (2000) Soil compaction and sealing in Al Salmi area, western Kuwait. *Land Degradation & Development* **11**(5): 401-418.

Al-Kodmany, K. (2000) GIS in the urban landscape: reconfiguring neighborhood planning and design processes. *Landscape Research* **25**(1): 5-28.

Brinkman, R.P. (1990) Advance forest planning in the Otways. *Australia Forestry* **53**: 290-294.

Eweg, H.P.A., Van Lammeren, R., Deurloo, H. and **Woldu, Z.** (1998) Analyzing degradation and rehabilitation for sustainable land management in the highlands of Ethiopia. *Land Degradation & Development* **9**(6): 529-542.

Heady, H. and **Child, R.D.** (1994) *Rangeland Ecology and Management.* Westview Press, San Francisco, California, USA.

Kessel (1990) An Australian geographical information modeling system for natural area management. *International Journal of Geographical Information Systems* **4**: 333-362.

Khalaf, F.I., Gharib, J.M. and **Al-Hashash, M.Z.** (1984) Types and characteristics of the recent surface deposits of Kuwait, Arabian Gulf. *Journal of Arid Environments* **7**: 9-33.

KISR (1999) *Soil Survey for the State of Kuwait, Volume II. Reconnaissance Survey.* Kuwait Institute for Scientific Research: AACM International, Adelaide Australia.

Machin, J. and **Navas, A.** (1995) Land evaluation and conservation of semiarid agrosystems in Zaragoza (NE Spain) using an expert evaluation system and GIS. *Land Degradation & Rehabilitation* **6:** 203-214.

McClure, B.C. (2000) Policies related to combating desertification in the United States of America. *Land Degradation & Development* **9**(5): 383-392.

Soil Survey Division Staff (1993) *Soil Survey Manual.* United States Department of Agriculture, Handbook No. 18. Government Printing Office: Washington D.C., USA.

Soil Survey Staff, Soil Conservation Service (1993) *National Soil Survey Handbook.* United States Department of Agriculture. US Government Printing Office: Washington, D.C., USA.

Soil Survey Staff (1994) *Keys to Soil Taxonomy.* 6th Edition, US Government Printing Office: Washington, D.C., USA.

Stoddart, L.A., Smith, A. and **Box T.W.** (1975) *Range Management.* McGraw-Hill Book Company: London, UK.

Taha, F.K. and **Omar, S.A.** (1982) *Selection and criteria for national parks/nature reserves in Kuwait desert.* Kuwait Institute for Scientific Research, Report No. KISR729, Kuwait.

Taha, F.K., Omar, S.A., Hegab, A.E., Zaman, S. and **Nassef, A.A.** (1988) *Assessment of rangelands in Kuwait and improvement for forage animal production and de-desertification:* Volume 1. Introduction, vegetation survey and fodder production. Kuwait Institute for Scientific Research, Report No. KISR2762, Kuwait.

Tueller, P.T. (1998) Rangeland change and desertification—A remote sensing viewpoint. *In:* **Omar SA, Misak R, Al-Ajmi D** and **Al-Awadhi N. (eds).** *Sustainable Development in Arid Zones.* Vol.2. *Management and Improvement of Desert Resources.* Balkema, Netherlands, pp.383-403.

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